A WORLD BANK STUDY

Concentrating Solar Power in Developing Countries

REGULATORY AND FINANCIAL INCENTIVES FOR SCALING UP

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Foreword

Concentrating solar thermal (CST) technologies have a clear potential for scaling up renewable energy at the utility level, thereby diversifying the generation portfolio mix, powering development, and mitigating climate change. A recent surge in demand for solar thermal power generation projects in several World Bank Group (WBG) partner countries shows that CST could indeed become an important renewable energy technology that would be able to provide an alternative to conventional thermal power generation based on the central utility model.

The WBG is supporting the development of the technology in several partner countries. In the Middle East and North Africa, the World Bank, the International Finance Corporation (IFC), and the Clean Technology Fund (CTF) are working with Algeria, the Arab Republic of Egypt, Jordan, Morocco, and Tunisia to assist them on the financing of the construction of a series of CST facilities. South Africa's government has sought funding support from the CTF and technical advice from the World Bank for a 100 MW power tower CST plant in the Kalahari Desert. In addition the WBG is assisting India on a CST program that supports the Jawaharlal Nehru National Solar Mission (JNNSM).

To assist our partner countries better, there is a need to analyze the experience of developed and developing countries in designing and implementing regulatory frameworks supporting the deployment of this technology and to draw relevant lessons for emerging markets. We expect that this report will provide insights for policy makers, stakeholders, private financiers, and donors in meeting the challenges of scaling up the deployment of renewable energy—and CST in particular.

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Acronyms and Abbreviations

AET	average electricity tariff
AfDB	African Development Bank
BUB	back-up boiler
CAPEX	capital expenditure
CCGT	combined cycle gas turbine
CDM	Clean Development Mechanism
CERC	Central Electricity Regulatory Commission
CHP	combined heat and power
CIF	climate investment funds
CLFR	Compact Linear Fresnel Reflector
CoC	cost of capital
CPV	concentrating photovoltaic (subset of CSP)
CREB	Clean Renewable Energy Bond
CSP	concentrating solar power (includes CST and CPV)
CST	concentrating solar thermal (subset of CSP)
CTF	Clean Technology Fund
DISCO	distribution company
DNI	direct normal irradiation
DSCR	debt service coverage ratio
DSG	direct steam generation
EBIT	earnings before interest and taxes
ENPV	economic net present value
EPC	engineering, procurement, and construction
ERR	economic rate of return
ESTELA	European Solar Thermal Electricity Association
EIB	European Investment Bank
FiT	feed-in tariff
GDP	gross domestic product
GEF	Global Environment Facility
GW	gigawatt
GWh	gigawatt-hour
HTF	heat transfer fluid
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
IPP	independent power producer
ISCC	integrated solar combined cycle
ISCCS	integrated solar combined cycle system
JNNSM	Jawaharlal Nehru National Solar Mission
KfW	Kreditanstalt für Wiederaufbau
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of electricity
MASEN	Moroccan Agency for Solar Energy
MAT	minimum alternative tax
MDB	Multilateral Development Bank
MENA	Middle East and North Africa
MW	megawatt

MWh	megawatt-hour
NERSA	National Energy Regulator of South Africa
NREL	National Renewable Energy Laboratory
NTPC	National Thermal Power Corporation Ltd.
O&M	operation and maintenance
OBA	output-based approach
OPEX	operational expenditure
PCU	power conversion unit
PPA	power purchase agreement
PPP	public-private partnership
PSA	Plataforma Solar de Almería
R&D	research and development
RAM	reverse auction mechanism
REC	Renewable Energy Certificate
REFIT	renewable energy feed-in tariff
RFI	Request for Information
RFP	Request for Proposal
RPO	Renewable Purchase Obligation
RPS	Renewable Purchase Standard
RSA	Republic of South Africa
SEGS	solar energy generating system
SWOT	strengths, weaknesses, opportunities, and threats
TES	thermal electric storage
TSP	Tunisian Solar Plan
USDA	United States Department of Agriculture
WACC	weighted average cost of capital
WTP	willingness-to-pay
ZAR	South African rand

Executive Summary

Concentrating solar thermal power (CST) has a tremendous potential for scaling up renewable energy at the utility level, diversifying the generation portfolio mix, powering development, and mitigating climate change. A recent surge in demand for solar thermal power generation projects using different CST technologies in various countries shows that CST could become an important renewable energy technology that would provide an alternative to conventional thermal power generation based on the central utility model.

At present, different CST technologies have reached varying degrees of commercial availability. This emerging nature of CST means that there are market and technical impediments to accelerating its acceptance, including cost competitiveness, an understanding of technology capability and limitations, intermittency, and benefits of electricity storage. Many developed and some developing countries are currently working to address these barriers in order to scale up CST-based power generation.

Given the considerable growth of CST development in several World Bank Group (WBG) partner countries, there is a need to assess the recent experience of developed countries in designing and implementing regulatory frameworks and draw lesson that could facilitate the deployment of CST technologies in developing countries. Merely replicating developed countries' schemes in the context of a developing country may not generate the desired outcomes.

Against this background, this report (a) analyzes and draws lessons from the efforts of some developed countries and adapts them to the characteristics of developing economies; (b) assesses the cost reduction potential and economic and financial affordability of various technologies in emerging markets; (c) evaluates the potential for cost reduction and associated economic benefits derived from local manufacturing; and (d) suggests ways to tailor bidding models and practices, bid selection criteria, and structures for power purchase agreements (PPAs) for CST projects in developing market conditions.

Regulatory Frameworks

Based on an assessment of the experiences of regulatory frameworks that are in place in developed markets and an assessment of regulatory incentives proposed and employed in developing markets to incentivize the development of CSP, the following general conclusions can be drawn:

1. In nearly all cases analyzed in this report, including in India, Morocco, and South Africa, the levelized cost of electricity (LCOE) for parabolic trough and power tower projects is still too high in relation to the tariffs available for CST-generated electricity to allow for full cost recovery and to meet financing constraints.
2. Further modifications of regulatory frameworks that are currently in place in emerging markets should be considered to at least partly mitigate these constraints and thereby ensure large-scale CST deployment and the creation of local manufacturing and service capacities.

3. A feed-in tariff (FiT) seems to be the most appropriate instrument if large-scale CST deployment and the maximization of local inputs are the main drivers behind the establishment of the incentive framework *and* if cost considerations are not pivotal. This is because of the demonstrated ability of FiTs to trigger large-scale investments in a relatively short timeframe. If properly designed, FiTs are the most straightforward way to provide investors with the security necessary to overcome otherwise prohibitive development risks and ensure adequate financial returns.
4. Any FiT scheme could benefit from several recent lessons learned regarding its design to reduce high societal costs. A FiT scheme should entail at the minimum (a) an annual and overall capacity cap based on a realistic and affordable policy goal, and (b) predetermined tariff revisions for new capacities and ultimately a phase-out schedule to keep tariffs in line with decreasing capital and investment costs. While preserving the main benefits of a FiT for developers—its simplicity and predictability—these measures can help keep societal costs under control and minimize them.
5. An alternative scheme involves a combination of a FiT with a reverse auctioning mechanism. Such mechanisms could have the following minimal features: (a) an annual and overall capacity cap based on a realistic and affordable policy goal, (b) the possibility for developers to bid on the eligible capacity within a given timeframe and offer the delivery of the electricity at a fixed tariff level below the original FiT, and (c) a mechanism assuring the technical and financial feasibility of the submitted bids. While offering similar benefits as a FiT for developers, this approach could lower societal costs.
6. A Renewable Portfolio Standard (RPS) scheme that combines a variety of other regulatory and financial incentives could also be a viable option. An RPS scheme could be successful in triggering investments in CST if it is combined with (a) sovereign guarantees for PPAs signed with utilities or a single buyer to ensure bankable sources of revenue; and (b) significant amounts of concessional financing, which tend to be the most cost-efficient way of incentivizing CST investments.
7. The recent experience on RPS schemes and/or FiT frameworks shows that both developers and commercial banks assign a higher overall risk profile to projects with cash flows based on a typical PPA arrangement under an RPS scheme instead of a FiT. This might be different if PPAs reflect competitive tariffs and are signed with single buyers or utilities under explicit or implicit sovereign backing. RPS schemes currently seem to be preferable to FiTs only if (a) societal cost considerations are the prevailing issue for policy makers; (b) there are no fixed targets for CST capacity to be installed; and (c) building local capacity for component manufacturing and service delivery is somewhat less of a priority.
8. Incentive frameworks should be tailored to the specific circumstances to allow developers to use the respective CST capacity in the most efficient way possible. This could includes avoiding capacity limits on *individual* plants, because of the considerable economies of scale for individual plants that can be achieved, and limits on the use of storage. The latter is particularly important, since an optimal amount of storage decreases the LCOEs of individual plants and therefore the cost of CST-generated electricity on a per-kilowatt-hour basis.

In addition to these general conclusions, the report provides a review and detailed analyses and recommendations on the incentive schemes for CST currently in place in some of the major emerging markets as described below.

Middle East and North Africa Region

In the context of MENA, the current support schemes are centered on either public sector projects or public-private partnership (PPP) models. Experience to date shows that (a) the region is not quite ready to embrace FiTs or RPSs, although efforts to champion the introduction of such schemes are ongoing; (b) independent power producer and power purchase agreement (IPP/PPA) schemes have not worked well in the past, as illustrated in projects supported by the Global Environment Facility (GEF), which had to be restructured into public projects; and (c) a new PPP scheme is being tried out for an individual, large-scale projects (Morocco), and it seems to have a better chance of success than the earlier attempts to engage the private sector through a pure IPP concept.

The approach currently taken to scale up CST deployment in MENA with the support of the Clean Technology Fund (CTF) assumes that guaranteed source of subsidies will help address, to a certain degree, issues related to both high capital costs and uncertainties regarding the policy and regulatory frameworks. The expectation is that, with more clarity in the policy framework for CST development in the MENA countries in the midterm, the need for subsidies will be reduced. Over the longer term, and in order to achieve transformational effects and replicability goals, these investments need to be accompanied by appropriate national policies, such as FiTs and/or RPS quotas combined with other regulatory and financial incentives in the respective jurisdictions.

India

The Government of India has made a strategic choice to promote grid-connected solar power and put in place the needed incentive packages. The Government of India's policy on CST is designed to be largely private sector–driven, with the government creating an enabling environment for investors. Despite criticisms on the FiT guidelines, private developers are active participants in the early bidding stages to strategically position themselves in India's emerging CST market. This could explain the oversubscription of the first bidding round for CST projects under Phase 1 of the JNNSM. Over the long term, the regulatory framework could benefit from improving the consistency among instruments (the current process mixes RPS and FiT elements), and the coordination between state-level and central government–level incentives.

Given the great degree of uncertainty about the required (or justified) level of capital costs for CST projects in developing countries in general, and in India in particular, an approach involving competitive procurement of specified amounts of CST capacity may be a good choice. A combined RPS/FiT scheme with a built-in reverse auction mechanism may not be as aggressive a strategy as a pure FiT in securing a massive expansion of solar power capacity. However, it facilitates the price discovery process better than a pure FiT system. This may result in substantial cost savings both for the public sector and for the rate payer. By contrast, doubts remain as to whether the tariffs offered by winning bidders are not undervalued. The overall effectiveness of the incentives framework for solar power development is still to be demonstrated by financial closures for the concluded PPAs.

South Africa

The proposed framework of the renewable energy feed-in tariff (REFIT) is not yet operational in South Africa. One can only speculate as to how successful it will be in encouraging investments in both CST and other renewable energy technologies. There are concerns over the lack of a defined structure of the REFIT, uncertainty over what the final tariffs will be, and how they could attract or deter potential IPPs. However, many of these concerns could be addressed once the National Energy Regulator of South Africa (NERSA) and the national utility (Eskom), as a single buyer, finalize the process for arranging the PPAs. This will happen once tariff levels are decided and the role of the single buyer (Eskom or an independent party) is better defined.

It is conceivable that the REFIT may encourage more investment for certain technologies than for others. In the same way that an RPS scheme induces investments predominantly in the cheapest technology, the REFIT may only promote significant investments in more established and less risky technologies, such as wind power, rather than CST. The fact that the vast majority of applications received by Eskom so far have been for wind projects indicates the disparity of the effectiveness of the policy across different technologies.

The combination of a CTF-funded, large-scale CST project, a planned solar park project, and the introduction of a FiT system may well succeed in mobilizing private sector investments in CST technology in South Africa. However, the process is still ongoing and various steps need to be completed before electricity generated from renewable technologies will be sold at the prescribed tariff.

Cost Reduction Potential and Sustainability Assessment

Different CST technologies have, at present, reached varying degrees of commercial availability. While parabolic trough and, to a slightly lesser degree, power tower are basically close to full commercial state, clear commercial cost data have yet to be established for the Linear Fresnel and Dish Stirling technologies. A detailed LCOE analysis based on the existing incentive schemes and various assumptions regarding country specific natural and economic characteristics was conducted for some of the major emerging markets for CST—India, Morocco, and South Africa—comparing parabolic trough and power tower technologies (as the most mature technologies).

The report also presents a review of typical cost structures for parabolic trough and power tower plants, which was derived from projects developed or under preparation in Spain and the United States specifically for this report, and an in-depth assessment of the respective cost drivers. Based on these analyses, the report provides (a) technology-specific LCOE reduction potentials and (b) an assessment of effects on public sector resources from different regulatory and financial incentives used to lower the LCOEs in various emerging market conditions.

Component-, Technical-, and Scale-Related Cost Reduction Potential

Detailed analyses of potential for component-specific cost reductions are given in the report. This was based on a detailed assessment of the respective cost drivers for each component and the underlying development in the respective industries producing these components. Among parabolic trough components, the most potential for cost reduction in the timeframe until 2020 is demonstrated for reflectors (18–22 percent), reflector mounting structures (25–30 percent), receivers (15–20 percent), heat transfer systems (15–25 percent), and molten salt systems (20 percent). Power tower system components showing the most cost reduction potential are reflector mounting structures (17–20 percent), heat transfer systems (15–25 percent), and molten salts as heat transfer fluids (20 percent). Components for Linear Fresnel systems showing the most cost reduction potential include reflector mounting structures (25–35 percent) and receivers (15–25 percent), while for the Stirling Dish engine system, it is the reflectors (35–40 percent) and reflector mounting structures (25–28 percent).

The overall cost reduction potential for each CST technology was derived by modeling reference plants based on the assumed component specific cost reduction potentials. For these reference plants, the individual cost reduction potentials of components were deducted from the component specific cost data available from developed markets for CST. The latter were chosen, since they were seen to be more established than the component specific cost data available from emerging markets for CST.

Sustainability Analysis of Financial and Regulatory Incentives

A basic sustainability analysis was conducted for a variety of regulatory and financial incentives granted in three of the major emerging markets for CST—India, Morocco, and South Africa—based on the incentives' impact on the LCOEs of 100 MW reference plants in these markets. The primary aim was to estimate the impacts of specific regulatory and financial incentives on CST generation cost and the societal cost expressed in financial terms. The analysis was carried out to

Determine the financial cost-effectiveness of different regulatory incentives and approaches in terms of their ***impact on LCOEs*** *and hence their ability to facilitate investments* ***per dollar spent.***

The tested incentives ranged from tax holidays to favorable depreciation schemes and the use of concessional financing schemes, such as through the International Bank for Reconstruction and Development (IBRD), CTF, and GEF. The following observations can be derived:

1. The accuracy of solar resource assessment in measuring site-specific levels of direct normal irradiation (DNI) is essential as the robustness of the financial analysis for a CST plant is heavily dependent on the quality of the DNI data. Given the inverse relationship between the DNI and LCOE for CST plants, data measured on the ground at the actual site of the project over the course of at least a full year are required to provide sufficient grounding for a solid financial model.
2. For all technologies in all three scenarios considered, the LCOEs for standalone projects are most likely currently too high to allow for cost recovery and meeting financing constraints. This is especially the case when the LCOEs are compared to the FiTs available for CST-generated electricity in Phase 1 of the JNNSM in India and the FiTs that have been proposed for Phase 2 of the REFIT scheme in South Africa.
3. LCOE calculations based on balance sheet financing might be considerably lower than estimates based on nonrecourse (off–balance sheet) financing assumptions, such as the ones made for this analysis. However, balance sheet financing increases the risk profile of a company's investments and might

require cross-subsidization among projects within the company's portfolio, since the financial viability of a stand-alone project is no longer guaranteed.

4. Financial and regulatory incentives, as well as concessional financing schemes, can significantly lower LCOEs. Within the range of considered financial and regulatory incentives, simple tax reductions and exemptions tend to have the lowest impact and are likely to be the least cost-effective incentives in financial terms (not considering economic opportunity cost). By contrast, concessional financing schemes tend to have the highest impact and are likely to be the most cost-effective incentives in terms of their impact on LCOE on a per-dollar-spent basis.

With regard to the other incentives considered, accelerated depreciation, especially when compared to simple tax reductions or exemptions, seems to be the superior option. Although far from cheap, it might be worth considering in cases where—as seen in the case of South Africa—the existing regulatory incentive framework just needs to be moderately adjusted to lower LCOEs to the threshold where stand-alone projects become financially viable.

Economic Analysis of Reference CST Plants

The report provides an economic analysis based on current investment costs for reference 100 MW CST plants—both parabolic trough and power tower—in the three respective countries considered in the report—India, Morocco, and South Africa. Sensitivity analyses are provided for higher investment costs, project delays, lower load factors, and a higher value of the power generated. The following important observations can be made across all three countries:

1. In none of the countries does the economic rate of return (ERR) achieve a rate required for infrastructure projects of more than 10 percent. Excluding carbon and other environmental benefits, the ERR ranges from –0.65 percent to 4.8 percent for the power tower and from –2.55 percent to 3.8 percent for the parabolic trough. Including the economic benefit of reducing carbon emissions, the ERR ranges from 2.1 percent to 8.8 percent for the power tower and from 1.1 percent to 7.4 percent for the parabolic trough reference plants.
2. The carbon values that are needed to make projects achieve an ERR are implausibly large in India and Morocco. In South Africa they are also quite high, but one could argue that carbon reduction projects with costs in that range (US$80–100/ton CO_2) have been undertaken in other sectors.

The sensitivity analysis shows approximately a 1 percent reduction in the ERR for a 10 percent higher project cost and a further 1 percent reduction for an additional 10 percent higher project cost. A reduction in the load factor by 20 percent has a bigger impact—reducing the ERR by 2.5 percent to 3 percent.

In the case of **India**, the results show that parabolic trough has a higher return than power tower, and that a five-year delay increases the ERR by nearly 3 percent. In the case of **Morocco**, the delay is not as effective in increasing the ERR (possible because the increases in power value are more modest). Even with carbon and local pollutant benefits, the ERR is well below a test rate. In Morocco, power tower appears to exhibit slightly better economics than parabolic trough. For the **South African** case, because of the higher value of power and carbon benefits, a 12 percent ERR can be exceeded with both technologies, although the power tower has a higher return by 1–2 percent. Including the benefits of reduced local pollutants would increase the ERR further—potentially by up to 1 percent.

The analysis indicates that while power tower technology has a slightly higher return than parabolic trough, and the use of wet cooling can slightly improve the ERR, CST projects at current investment costs have low ERRs that would be unable to meet commercial infrastructure investment requirements. However, investment costs are projected to decrease considerably over the coming years—a development that is expected to largely alter the economics of CST technologies. Therefore, the decision to uptake CST technology might not necessarily be based on economic considerations alone, but might include other aspirations, such as gaining market leadership and experience through technology development or targeting the building-up of a local manufacturing industry. Potential ways also exist for improving the economics of CST, even under current investment cost assumptions through, for example, hybridization and the large-scale application of storage—areas that, however, are outside the scope of this report.

Potential for Cost Reduction through Local Manufacturing

To realize the cost reduction trajectories projected in this report, a major scale-up of CST developments would be necessary, both in the already-established markets, as well as in emerging markets in the MENA region, India, and South Africa. A major increase in CST capacity in emerging markets, however, is likely only when the countries concerned benefit from the technology for their economic development in general. One of the primary means to foster development could be the establishment of local manufacturing and assembly capacities. Local manufacturing might have the added benefit of reducing the cost of local projects in the near term and bringing down the cost for a variety of components and CST-related services in the mid- to long term. By looking at local manufacturing capabilities in several emerging markets for CST, including the MENA region and South Africa, several general conclusions on incentivizing and supporting the buildup of local capacities to manufacture components and provide CST-related services can be made:

1. The implementation of a stable and sustainable regulatory framework is the key precondition for the development of a market for CST projects that is needed to create investment conditions for local manufacturing and service capacities in emerging markets.
2. In the medium to long term, the annually installed capacity should be on the highest scale possible in order to incentivize the development of production lines, particularly in the case of mirrors and receivers.
3. Regulatory incentive frameworks must be in line with general national strategies for industrial development, and national energy policies should be well coordinated and involve clear targets for the market diffusion of CST, substantial research and development (R&D) efforts, strategy funds for industrial development of CST industry sectors, and—in most cases—a stronger regional integration of policies.
4. The provision of low-interest loans and grants specifically designed for local manufacturing of renewable energy components might help local companies

raise funds for R&D to support product innovation or provide risk capital for new start-up companies.

5. The buildup of local industries could further be facilitated by introducing local content clauses within CST bids and other support instruments. Local content requirements, however, need to be set at realistic levels while being allowed to increase over time, according to the speed at which local industries can be developed.
6. Business models should build on the comparative advantages of particular sectors in the respective country and should involve international cooperation agreements, for example, in the form of joint ventures and licensing. In the case of receivers, for example, subsidiaries of foreign companies will most likely be relevant business models in the beginning. Furthermore, obvious areas for local manufacturing capacity development include investments in new, highly automated production lines for the mounting structure and glass production, as well as the adaptation of techniques for coating and bending mirrors. With regard to CST-related services, the local assembly of plants and involvement of local EPC contractors are important initial steps to maximize the local value contribution.
7. Establishing local manufacturing capacity will have to involve comprehensive education and training programs for the industrial workforce in relevant sectors. Universities and technical schools should be encouraged to teach CST technology–based courses to educate the potential workforce, particularly engineers and other technical graduates.
8. Ultimately, to ensure regional and international quality requirements and to strengthen the competitiveness of future local CST industries, implementing quality assurance standards for CST components should be considered.

Specific assessments of the local capabilities were conducted for two of the major emerging markets for CST—the MENA region and South Africa. Based on an in-depth assessment of the local CST value chain, the report provides component-specific projections for local manufacturing, draws roadmaps and action plans in order to maximize local content generation in the industry, and estimates the immediate economic benefits of local manufacturing, especially with regard to employment generation.

For the **MENA region,** an important finding concerning the status quo and future perspectives of local manufacturing is that, while 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, a further scale-up of local manufacturing capabilities in certain sectors—especially mirrors—has significant potential. For this potential to be reached, however, the countries would have to aggressively build on the know-how gained from the successful construction of the integrated solar combined cycle (ISCC) projects, while at the same time encouraging the involvement of international companies to build up local production facilities. A certain specialization in each country would be beneficial because local demand will probably be relatively low in the short to medium term.

In **South Africa** the currently possible proportion of local manufacturing for CST power plant projects is expected to be up to 60 percent, depending on whether specific CST components, such as receiver tubes, heat transfer fluid (HTF) pumps, and swivel joints, can be developed and manufactured locally. Depending on the uptake of the CST industry, however, this share can be considerably lower for construction and components or can increase further. Local mirror and receiver production are seen as starting as early as 2015 in the accelerated scenario, which also projects the local production of other specialized, high-precision steel accessories for CST applications. Beyond 2020, the share of local manufacturing would increase even more as a result of further technology transfer and knowledge sharing through the realization of more CST plants in South Africa, since the learning effect is expected to play out fully around this time. This would also lead to a drop in the cost of locally manufactured CST components because of technological advancements, economies of scale, and competition in the CST component manufacturing sector.

Roadmaps for the Development of Local Manufacturing of CST Components

The report identifies potential routes for the development of local manufacturing capacities for different components for both MENA countries and South Africa, and sets out the main milestones required for the establishment of both local and export markets. The approach is to define a set of actions to be implemented among stakeholders who may bring about an activation of CST component manufacturing in the respective jurisdictions.

Potential Economic Benefits of Developing a CST Industry in MENA and South Africa

The economic and employment benefits of developing a CST industry estimated in the report are gross estimates and therefore do not consider the potential cost of scaling down or not strengthening other industries providing other technologies that could supply the same amount of energy. In general, the economic benefits are strongly related to the market size of CST. For the **MENA region**, an accelerated scenario—assuming 5 GW of installed capacity by 2025—would create a local economic impact of US$14.3 billion, roughly half of which would be from indirect impacts of the CST value chain (excluding component exports), compared to only US$2.2 billion in a business-as-usual scenario, assuming no replication effects from the uptake of 1 GW of capacity as envisaged by the CTF Investment Plan for region. The impact on labor generation would be a permanent workforce of 4,500–6,000 local employees regionally by 2020 under a business-as-usual scenario based on the CTF Investment Plan. In contrast, in the accelerated scenario in 2025, the number of permanent local jobs could rise to between 65,000 and 79,000 (46,000–60,000 jobs in the construction and manufacturing sector plus 19,000 jobs in operation and maintenance). Additional impacts on job creation and growth of gross domestic product (GDP) could come from export opportunities for CST components. Exporting the same components that are manufactured for local markets to the European Union, United States, 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 CST industries.

For **South Africa** the accelerated scenario creates a local economic impact of US$25.9 billion compared with US$4.1 billion in the same business-as-usual scenario as described for the MENA region. In terms of employment generation, the impact would be 66,800–83,100 permanent jobs for local employees by 2020 under the accelerated scenario and 11,000–14,800 permanent jobs under the business-as-usual scenario based on the CTF Investment Plan. Exporting components could lead to additional revenues of more than US$3.6 billion by 2030.

Assessment of Procurement Practices

The report concludes by describing and analyzing various bidding models, practices, and the bid selection criteria typically used for CST projects based on information available from the developers and utilities in developed markets. The report then provides recommendations on tailoring these practices, criteria, and PPA structuring for developing country markets to help facilitate business transactions for CST projects. Recommendations are provided for primary elements of each subtopic.

Bidding Criteria

The report provides guidance on the best-practice structuring of bidding criteria—from both a regulator's point of view under, for example, a FiT scheme, and a utility's or single buyer's point of view under an RPS scheme. In addition, it provides recommendations on how to design PPAs under an RPS scheme. With regard to bidding selection criteria, the report suggests a weighted bid matrix for CST projects, as shown in table ES.1. The weighted bid matrix provides a set of recommended bid selection criteria. The weights associated with each criterion should be assessed by individual respective entities responsible for bid criteria design based on the relative importance placed on each factor.

Table ES.1: Recommended bid selection criteria for CST in developing countries

Cost-Based
• Level of concessional financing necessary
Feasibility-Based
• Company and team experience • Company financial stability • Technology maturity • Interconnection feasibility • Site control • Environmental approvals • Ability to raise financing • Levelized cost of electricity (LCOE)
Policy-Based
• Speed of implementation (schedule)
Value-Based (Optional)

Source: NOVI Energy 2011.

Elements of Power Purchase Agreements

Ultimately, the report provides recommendations on components that should be included in an optimally balanced PPA for CST projects to adequately reflect the interests of both the developer and the utility (or a single buyer). When selecting the recommended PPA elements, considerations should include characteristics of solar technologies, as well as aspects that may be applicable to projects in emerging markets for CST, such as per-

Box ES.1: Recommended PPA elements for CST projects in developing countries

- Fixed dispatch with sharing of curtailment risk
- Energy payment using **PPI/CPI/exchange rate/LIBOR**
- **Time of delivery factors** for energy payments
- Renewable energy credits bundled with energy (if applicable)
- **Seller development security** (refunded at commercial operations)
- **Seller performance security** (throughout the term of the PPA)
- **Buyer payment security** (throughout the term of the PPA)
- **Opportunities to rectify default before contract termination**
- **Seller re-pricing and exit on incentive cancellation**
- "Political" force majeure provisions

Source: NOVI Energy 2011.

ceived risks over the reliability of transmission and distribution systems, off taker credit strength, and the sustainability of a respective government policy, particular in regard the executed contracts and promised government incentives. The recommended elements were selected to help reduce the risk perception and thus to improve the attractiveness of PPAs for investors and financiers, while meeting the needs of buyers (see box ES.1).

PART I
Introduction and Technology Brief

CHAPTER 1

Context, Relevance, and Audience

Concentrating solar power (CSP) refers to several different technologies that use mirrors to focus, or concentrate, the sun's rays to generate electricity. The two subcategories of CSP are (a) concentrating photovoltaic (CPV), which focuses the sun's rays onto photovoltaic panels to generate electricity directly and (b) different Concentrating solar thermal (CST) technologies, all of which—with the exception of Dish Stirling—work on the same principle of focusing solar radiation to generate heat, which is then used to drive an engine or turbine to generate electricity.

CST technologies have tremendous potential for scaling up renewable energy at the utility level, diversifying the generation portfolio mix, powering development, and mitigating climate change. A recent surge in demand for solar thermal power generation projects using different CST technologies in Spain, the United States, and a handful of other countries shows that CST could become a key renewable energy technology that is able to provide an alternative to conventional thermal power generation based on the central utility model.

With respect to World Bank Group (WBG) partner countries, several countries in the Middle East and North Africa (MENA)—Algeria, the Arab Republic of Egypt, Jordan, Morocco, and Tunisia—are pursuing regional CST investment projects to be financed by the World Bank, IFC, and Clean Technology Fund (CTF). The plan for these installations is to supply power across the region and potentially to Europe. The South African government has sought funding support from the CTF and technical advice from the World Bank for a 100 MW power tower CST plant in the Kalahari Desert. The WBG is also providing technical assistance to the Government of India on certain aspects of the implementation of the Jawaharlal Nehru National Solar Mission (JNNSM).

At present, the different CST technologies have reached varying degrees of commercial maturity. This emerging nature of CST means that there are market impediments that need to be overcome to accelerate its acceptance, including cost competitiveness, awareness of technology capabilities and limitations, intermittency, and the need for electricity storage.

Given the considerable pace of CST development in several WBG partner countries, there is a need to review the recent experience in developed countries in designing and implementing regulatory frameworks to draw relevant lessons for emerging markets. Adaption of these lessons to specific developing country circumstances will be necessary, since the mere replication of developed countries' schemes may not generate the desired outcomes.

After providing a brief overview of the current state of CST technologies (Chapter 2), the report evaluates recent experiences with regard to regulatory frameworks in some of the developed countries, as well as those developing countries that have started establishing regulatory frameworks targeted at CST deployment (Chapters 3 and 4); assesses the cost reduction potential and economic and financial affordability of various technologies in emerging markets (Chapter 5); evaluates the potential for cost reduction resulting from local manufacturing and associated economic benefits (Chapter 6); and ultimately suggests ways of tailoring bidding models and practices, bid selection criteria, and power purchase agreement (PPA) structuring to specifics of CST projects (Chapter 7).

CHAPTER 2

Overview of Concentrating Solar Thermal Technologies

Applications of solar thermal technologies are best suited for regions that experience high levels of direct normal irradiation (DNI). These regions are typically located in dry areas such as deserts, which also have the advantage of plentiful land unsuitable for agricultural or industrial purposes.

According to a recent report,[1] among the various solar technologies, the CST is primarily suited for larger scale installations, while PV-based technologies are better matched for smaller-scale or distributed generation applications (figure 2.1). Photovoltaic panel theoretically has wider geographical applications, even if a certain level of diffuse radiation is needed in order to make the electricity generation economically viable. Solar thermal technologies have geographical limitations, and can potentially be economically viable only in regions that possess high DNI to ensure high energy yields.

The main advantages of CST applications include less intermittency because of the system thermal inertia, and the option to integrate thermal storage, thus making power generation possible during extended hours (when the sun doesn't shine) and to use CST in utility scale operations.

The following factors are typically cited as drawbacks of the current application of CST technologies:

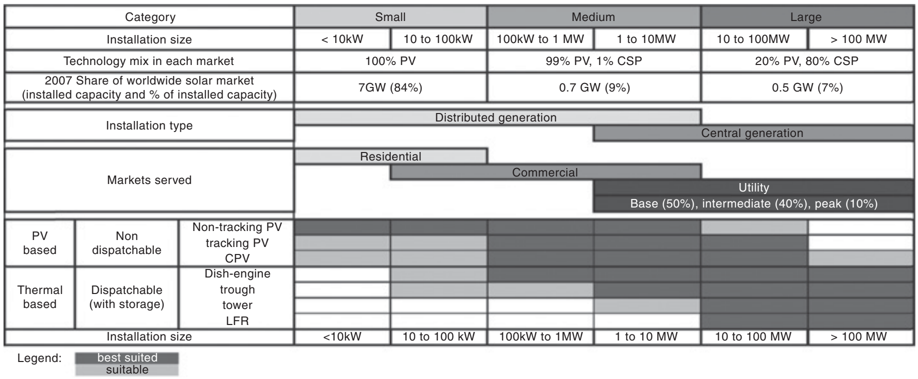
- CST-based plants are presently characterized by high upfront investment resulting in increased electricity generation costs, which could be decreased by further technological innovations and economies of scale, including volume production and larger-sized units.
- Locations with irradiations of more than 2,000 kWh/m^2/year are suitable to make solar thermal performance economically justifiable (Viebahn and others 2008).

The primary CST technologies include

- Parabolic trough
- Power tower (central receiver)
- Linear Fresnel
- Parabolic Dish (Dish Stirling)

The Parabolic Dish technology differs significantly from the other three in both technical and economic terms. The parabolic trough, power tower, and Linear Fresnel technologies, although based on the same technical principals, vary with regard to their reliability, maturity and operational experience in utility scale conditions. Relevant design features of each technology are discussed in more detail in Appendix A, along with a summary of the maturity status of each technology. Every technology has advantages and disadvan-

Figure 2.1: Markets and applications for solar power



Source: Adapted from Grama, Wayman, and Bradford 2008.

tages, and the suitability of each one should be assessed carefully depending on the needs and requirements of every site and project. The summary results of the technical and commercial assessments of the technologies, as per literature and operational experience reviews, are summarized in tables B.1 and B.2 in Appendix B.

Regarding operational experience and technological maturity, parabolic trough and, to a lesser extent, power tower are closest to commercial maturity state. Fresnel and Dish Stirling technologies are still at earlier development levels. Therefore, the technological risk is considered to be the lowest for parabolic through and again to a slightly lesser degree for power tower plants. Investment and operating and management costs (O&M) costs are also better known for these two technologies thus reducing the related financing risks. Tables B.3–B.6 in Appendix B include lists of projects developed for each technology.

Storage has allowed CTS technologies to considerably increase their capacity factors and meet the dispatchability requirements demanded by utilities and regulators. Hybridization, independent of whether it is combined with storage or fuels (such as natural gas, diesel, and biomass), can increase the reliability and the capacity factor of CST plants in general at a potentially lower capital investment cost than storage.

Note

1. Grama, Wayman, and Bradford 2008: A guide to the impact CSP technologies will have on the solar and broader renewable energy markets through 2020.

PART II
Financial and Regulatory Schemes—The Current Situation

CHAPTER 3

Policy Instruments Used to Promote CST in Developed Countries

Several countries—principally in the OECD area—have established dedicated regulatory frameworks and incentives to encourage CST deployment. There are a wide range of regulatory measures and financial incentives that can be used to encourage development in the renewable energy sector (table 3.1). This chapter reviews the experience of the prevailing regulatory and financial approaches for CST in the two largest markets —Spain and the southwestern United States. Both the Spanish FiT regime and the regimes combining Renewable Portfolio Standards (RPSs) with a variety of other instruments, which are in use in the southwestern United States, were hence evaluated against a set of four indicators: (a) the overall investment trends in the renewable energy sector; (b) the total CST capacity installed as a consequence of the introduction of a particular framework or combination of incentives; (c) a share of CST generation in the overall electricity supply mix; and (d) a structure of financial arrangements and the amount of private sector investments leveraged into the respective projects by the applied framework or a combination of incentives.

Regulatory Framework and Financial Incentive Options

The two principal options for the promotion of renewable energy are schemes centered on the FiT and RPS. An RPS is typically combined with several other incentives listed in table 3.2. The actual design, however, usually varies from jurisdiction to jurisdiction.

A review[1] of the literature suggests that the ability of a particular regulatory regime or instrument to trigger investments into the particular technology at the lowest possible societal cost depends on the set policy objectives. If the stated policy objective is to increase the share of energy generated from renewable sources and to facilitate the development of respective industries, FiT schemes have been the most successful instrument employed by policy makers so far. In Europe in particular, the FiT regimes of Denmark, Germany, and Spain (see box 3.1) have won high praise, especially with regard to wind and solar photovoltaic power expansion. Meanwhile, quota systems applied in other European countries (such as Belgium, Italy, Sweden, and the United Kingdom) are largely considered by experts to have failed to bring about the desired levels of capacity growth in the renewable energy sector.

This might lead to an assumption that FiTs are the best policy option available to date. However, recent modifications of FiTs available for solar photovoltaics in Europe suggest that this might not always be the case. Different regulatory experiences in the United States where the RPS scheme prevails as the framework of choice also support

Table 3.1: Policy instruments, characteristics, advantages, and disadvantages in implementation

Policy instruments	Objectives and characteristics	Advantages	Disadvantages
Subsidy/tax incentive	Fiscal instrument to reduce costs for renewable energy consumers or producers	Easy to understand and implement. Use of government funds to meet particular policy objectives	High administrative costs. May not be cost effective. Needs effective monitoring mechanisms to minimize risks. No guarantee of meeting quantitative targets.
Renewable energy fund	Financial instrument to support renewable energy, either in R&D, fund transfer, or in market-based applications.	Increase efficiency and reduce management cost through professional fund management.	Lack of experiences in fund management. How to combine public and private interest/benefit through effective management.
Voluntary green electricity scheme	Mobilize consumers' interest and support. Provide flexibility.	Generate additional funds from consumers, less use of government resources, a tool for engaging public and private sector participation.	Effectiveness depends on electricity prices and consumers' access to information and awareness. Not cost-effective. No guarantee for meeting quantitative target. High administrative costs.
RPS/Green certificate scheme	Combines obligation for producers/consumers to use green electricity with certification of green production.	Encourages competition and cost effectiveness. Relies on market mechanism for resource utilization and (within green) technology choice.	May not do much for high-cost technologies. Transaction costs can be high. Transparency and verification systems needed.
Sovereign Loan Guarantees	Government shares some of financial risk of projects that otherwise would not yet be supported in the commercial marketplace.	Can substantially lower financing costs for a particular project and tip the bankability of a stand-alone project.	High administrative costs. Amount of guarantees provided might be limited.
Feed-in tariffs	Financial scheme ensuring a premium payment to eligible electricity production.	Can ensure long-term return for investors, and is relatively simple to implement and flexible (for example, different technologies can be provided with different tariffs and contract lengths)	May not ensure a long-term target. Requires good monitoring mechanism. Transparency needed. Not necessarily cost-effective.

Source: Adapted from Gan et al. 2007.

this argument. FiT schemes generally are not favorites of U.S. policy makers, who have instead often opted for RPSs coupled with various investment and production tax incentives, grants, and loan guarantees. Indeed, 36 U.S. states and the District of Columbia now have RPSs enacted, while only a handful of U.S. state jurisdictions are implementing FiTs—with none of them currently considering a FiT tailored for CST (U.S. DOE 2011).

Regarding the specific incentives for CST, the European and the U.S. experience are both very relevant and must be taken into account. This chapter will review the regulatory incentive frameworks of Spain and several western and southwestern U.S. states (see table 3.3), in which CST penetration has been most significant (see tables B3.3–B.6 in Appendix B).

Table 3.2: FiTs versus RPS schemes

FiTs	FiT regimes usually guarantee a payment to suppliers for energy generated from a specified source (such as renewable energy) at a defined rate over an extended period. Quite often the FiT regime also provides preferential access to the grid. Tariff levels are usually set at a predefined level or as a premium above the market price. FiT can further be tailored to the cost specifics of a particular technology, as well as to different sites and characteristics of the energy resource (such as reflecting the level of intermittency or seasonal resource availability). Ideally, tariff levels are sufficiently high to mitigate the risk of high up-front investment cost and potential regulatory changes. The period, for which FiT payments are guaranteed, is also long enough to provide developers with adequate incentives to overcome otherwise prohibitive development risks—such as the cost of research, land leases, permitting, construction, guarantees, and warrantees. In most cases, utilities are required to off take all output generated at the respective technology-specific tariff level, but are also usually allowed to pass the cost difference on to final consumers. FiTs can theoretically lead to societal gains in terms of reduced market prices, reduced levels of GHG emissions, and a decrease in fossil fuel consumption and/or imports. By contrast, FiTs also come at a societal cost, since they usually lead to an increase in the overall price of electricity per customer or to an increase in government's subsidies.
RPSs	The prevailing regulatory framework in the United States and several other OECD countries (Belgium, Sweden, and the United Kingdom) is based on a quota system, generally referred to as an RPS combined with a variety of investment and production tax incentives, loan guarantees, financing from renewable energy funds, and voluntary purchases of renewable power by utilities. RPSs are designed to maintain or increase the contribution of renewables to the overall supply mix by obliging retail suppliers to reserve a specified amount or percentage of renewable energy to their individual supply mix. These obligations generally increase over time with suppliers being required to demonstrate compliance on a year-to-year basis. To fulfill their obligations, utilities usually have to rely, at least partly, on generation from their own facilities while being able to make up for shortfalls by purchasing renewable power from independent power producers (IPPs). In some jurisdictions, utilities are also allowed to meet at least a part of their obligations by trading in so-called Green Certificates (GCs), which are created when a unit of energy is generated from a renewable source and which work much like tradable emission permits.

Source: Authors' data.

Box 3.1: Germany's recent FiT reform

Germany introduced FiTs for a variety of renewable energies through its Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act) in 2000. The law guaranteed renewable power generators priority access to the grid and required utilities to off take any electricity produced by renewable sources at predefined tariffs. The latter, and the period they were guaranteed for, were tailored to the respective capital and investment costs of each individual technology, with actual tariff levels decreasing at a certain percentage rate per year to set an incentive for cost reduction. Utilities were allowed to pass the additional cost above the nonrenewable AET through to final consumers. In addition, FiTs were combined with a variety of incentives like subsidized investment loans and tax credits to aggressively increase the share of renewable energy in the overall power portfolio to 30 percent by 2020. The law jump-started markets for renewable energies—especially for wind and solar PV—causing the share of renewable energies in final electricity consumption to increase from 6.3 percent in 2000 to 15.1 percent in 2008, with wind supplying more than 40,000 GWh and PV supplying around 4,000 GWh in 2008. According to Germany's government, the FiT-based approach reaped considerable societal benefits of approximately EUR 9.3 billion in 2006 from decreased spot-market prices because of the merit-order effect (del Rio and Gual 2007), avoided GHG emissions, and decreased fossil fuel imports, as well as adding around 280,000 new "green" jobs (BMU 2009). By contrast, the overall cost for final consumers rose to EUR 4.5 billion in 2008 (equivalent to EUR 1.1cent/kWh, or 5 percent of the average retail price), and is projected to have peaked at EUR 8.5 billion in 2010 and to decrease after until reaching zero by 2020. The recent spike in consumers' cost has partly been caused by a larger-than-expected number of installations using renewable technologies, namely rooftop solar PV. According to the Association of Consumer Protection Agencies, rooftop PV capacity installed in 2009 will most likely cost final consumers EUR 10 billion over the course of their lifetime as opposed to the planned EUR 2.4 billion (VZB 2010). As a reaction to this development, the government recently decided to decrease FiTs for new PV-based capacity by up to 16 percent, with the stated aim of bringing tariffs in line with decreased investment and production costs and limiting the impact on consumers.

Table 3.3: Currently installed CST capacity (MW)

Regulatory scheme	Main features	Total operating	Total under construction	Total planned
FiT—Spain	• EUR 26.9375 cents/kWh over whole life cycle or premium over market wholesale price up to EUR 34.3976 cents/kWh • Guaranteed grid access/off take	382.48	1,540	497
RPS—U.S. total	*Federal incentives:* • Accelerated depreciation • Investment tax credit or renewable energy grants • Federal loan guarantees • Rural energy grants • Clean renewable energy bonds • Manufacturing investment tax credits • Production incentive payments	432.46	1,077	9,912
California	RPS 33% by 2020 + *Federal incentives* + • Property tax exemption	363.8	718	6,896.8
Nevada	RPS 25% by 2025 + *Federal incentives* + • Property tax abatement	64	0	2,184
Arizona	RPS 15% by 2025 + *Federal incentives* + • Corporate tax credit • Property tax reductions • Business tax incentives	2.6	280	1,010
Florida	*Federal incentives* + • Corporate tax credit • Renewable energy technology grants	10	75	0

Source: Adapted from CSP Today 2010. Database of State Incentive for Renewables & Efficiency.

Spanish Feed-in Tariffs

The Spanish FiT for renewable energy is widely considered the most successful—at least until recently—and as such is certainly the most studied example. In 1998, the Royal Decree on the Special Regime (RD 2818/1998) gave renewable energy generators two options: (a) a fixed premium on top of the electricity market price or (b) a fixed total price (fixed feed-in) (del Rio and Gual 2007). The amended Royal Decree 436/2004 allowed renewable energy producers to sell their electricity to distributors or directly to the market. In both cases, support was tied to the AET.[2] The 2007 modification, reflected in Royal Decree 661/2007, ultimately decoupled renewable energy support from the AET, tied it to the Consumer Price Index (CPI), and instituted a cap-and-floor system for the premium on top of the electricity market price.

Solar thermal electricity was first identified for the FiT support in the RD 436/2004 with the stated aim of developing a local CST industry. The 2007 reform increased the fixed FiT rate to EUR 26.9375 cents/kWh, and set a price range for the premium above the AET between 25.4038 and EUR 34.3976 cents/kWh for electricity generated by plants with up to 50 MW capacity. Either the fixed rate or the premium is guaranteed for 25 years for all electricity supplied to the grid under the scheme until 2013, adjusted annually according to the changed CPI minus 1 percent, and dropping uniformly to

EUR 21.5 cents/kWh after 25 years of operation. Renewable energy projects including CST are also granted priority access to the grid. In theory, the consumer pays the incremental price increase, since utilities are allowed to pass on the cost difference to final consumers. However, this mechanism has not been applied. Only part of the cost difference is passed through, resulting in a situation when the government must partially reimburse utilities for the additional cost related to the FiT.

The first Spanish CST installation—Solucar PS-10, a tower system of 11 MW capacity—was connected to the grid in 2006. Ten more installations have since come online, bringing the total CST generation capacity in Spain close to 383 MW. Fifty-one installations are now under construction or planned. When completed, they will add more than 2,037 MW of CST generation capacity to the grid (CSP Today 2010). This tremendous increase in capacity and the need to reimburse utilities for the cost difference prompted the government to implement some modifications of the FiT scheme starting in 2009. The primary motivation behind these changes—besides the need to deflate the investment bubble—was most likely to limit the societal cost of the FiT, especially in terms of restricting fiscal reimbursements to utilities. The government's Royal Decree 6/2009 established a preassignment register, for which developers need to sign up to be granted approval for their individual projects. A 500 MW annual cap for capacity eligible for the FiT was introduced. This translated into a 2.5 GW cap until 2013 based on the first-come-first-served principle (Boletín Oficial del Estado 283/2009). No plant is subsequently allowed to choose the fixed premium variant of the FiT during its first year of operation.

While these steps will contribute to controlling societal costs, they most likely will not be sufficient to deflate the investment bubble, since FiTs remain relatively generous for capacity coming online until 2013. At the same time, there is a considerable degree of insecurity in the market since the current framework only extends to 2013.

Some modifications, such as annual capacity caps, could further help deflate the investment bubble and avoid unnecessarily high societal costs. The most crucial modification could be to align the FiTs with actual capital and investment costs. A reverse auctioning mechanism (as outlined in box 3.2) for a set amount of capacity eligible for

Box 3.2: The renewable energy reverse auction mechanism

A potential way to assure maximum cost efficiency of the CST capacity installed under a RPS scheme could be in the application of so called Renewable Energy Reverse Auction Mechanisms (RAMs). Already being used for wind power under RPS schemes in New England and proposed for solar PV by the California Public Utilities Commission under the Californian RPS (CPUC 2009), RAM would require developers to bid the lowest possible price per kilowatt-hour, under which they would still be willing to develop a CST project, with utilities accepting the lowest-cost projects up to the total capacity cap. While setting a long-term investment signal, this approach has the benefit of securing the most cost-efficient investment while avoiding any potential windfalls to developers at the expense of ratepayers. However, RAMs would require setting up a standardized procurement system under which utilities would be able to rank individual bids, including their cost-efficiency characteristics. The least-cost projects would then be offered to sign PPAs with utilities for up to the general capacity cap or the target established under the RPS. RAMs would thereby secure preapproved utility cost recovery, cost certainty, and a minimum cost impact for consumers while still presenting regulatory certainty for developers (Kubert and Sinclair 2010).

the FiT in a given year could be a potential solution in this regard. The experience shows that caps on individual plants' capacity are likely to lead to inefficiencies. The latter is linked to considerable gains to be realized from increasing the scale of individual CST plants, which can be foregone by limiting the maximum amount of capacity of a single plant eligible for the FiT scheme.

Renewable Portfolio Standards and CST in the United States

Of the 36 U.S. states that enacted the RPS scheme by 2010, 16 have provisions requiring a specific level of solar power in the supply mix. These states include Nevada (1.5 percent by 2025), Arizona (4.5 percent by 2025), and New Mexico (4 percent by 2020). Usually the RPSs are combined with a variety of other incentives, such as federal loan guarantees, investment and production tax credits, renewable energy grants, property and sales tax breaks, and Clean Renewable Energy Bonds coming from federal and state governments (see also table 3.3 above).

The major downside of the RPS scheme with regard to CST seems to be its inability to attract nonresource financing terms for project development without the availability of loan guarantees at scale. In most cases, small and mid-scale developers are unable to secure nonrecourse financing. For this very reason, until recently, most plants that received construction permits in the United States were based on balance-sheet financing. This is rather different from the Spanish case where nearly every project was financed on a nonrecourse basis.

This situation has, however, changed with the availability of relative large-scale federal loan guarantees starting in 2009, providing the opportunity to improve the bankability of an individual project. The U.S. Department of Energy (U.S. DOE) is authorized to issue loan guarantees up to the total amount of US$10 billion to projects in the field of renewable energy, energy efficiency, and advanced transmission and distribution. CST is one of the eligible technologies under the current U.S. DOE loan guarantee program. The amount of the provided guarantees varies among individual projects, but the total project value is usually higher than US$25 million. The full repayment is required over a period not exceeding 30 years or 90 percent of the projected useful life of the physical asset.

BrightSource, a California-based company, was one of the first awardees of the federal loan guarantee program that secured a US$1.6 billion loan guarantee for its 383 MW Ivanpah power tower project in California. The Spanish developer Abengoa secured another US$1.45 billion in guarantees for its 250 MW Solana plant in Arizona. In both cases, the respective guarantees covered around 75 percent of the total expected project cost. Currently there are apparently another five–six CST projects in the pipeline being evaluated for receiving a loan guarantee.

Though loan guarantees are apparently crucial for improving the bankability of projects, for smaller and mid-size developers, such an incentive comes at a certain administrative and compliance cost, including obligations on the use of local manufacturing and services and labor and environmental requirements. In addition, as already mentioned, the processes to secure the guarantee can be fairly slow, with no assurance that the current scheme will be extended once the US$10 billion has been allocated (which at the current pace of awarding could happen relatively soon).

By contrast, proponents usually indicate the hands-off character of the loan guarantee program, allowing the market to make decisions as opposed to governments actively picking winners. Another discussed advantage is that fees charged for the guarantees can technically be set at a sufficiently high level to cover expected losses from the guarantee program (depending on the expected rate of default).

Investment Trajectories in Spain and the United States

To assess both regulatory approaches in terms of their ability to provide sufficient incentives for developers to deploy CST, the following trends were analyzed:

Overall Investment Trends in the Renewable Energy Sector

Spain is a significant player in the renewable energy sector with overall investments of US$10.4 billion in 2009, down by approximately 50 percent from 2008 because of the financial crisis. The largest chunk of these investments went to wind (34.2 percent or US$3.5 billion) and solar (60.6 percent or US$6.3 billion) power generation. Total investments have grown at about 80 percent over the last five years with total installed renewable capacity having grown by 9.1 percent in the same period, reaching 22.4 GW or 30.1 percent of total installed electricity capacity (PEW Charitable Trusts 2010). In 2010, wind and solar (both PV and CST) accounted for 23 percent of the total installed capacity and 18 percent of total electricity generation. Total renewable capacity installed was 23 GW. This impressive investment trend is probably the result of the relatively generous terms of the FiT framework.

The United States recently dropped to the second rank globally in terms of overall investments in renewables, losing their leading position to China. The same happened with regard to the technology in review, CST, in which the United States just lost its top rank to Spain. Overall renewable investments in the United States stood at US$18.6 billion in 2009, down by 42 percent from 2008, also because of the financial crisis, but were set to have increased considerably in 2010 when roughly one-third of the clean energy stimulus funding was spent. The largest chunk of the overall investments went to wind (43.1 percent or US$8.0 billion), biofuels (22.1 percent or US$4.1 billion), and solar (17.4 percent or US$3.2 billion, both PV and CST). Total investments have grown by over 100 percent over the previous five years with the total installed renewable capacity having grown by 24.3 percent in the same period, reaching 53.4 GW or 4 percent of total power capacity (PEW Charitable Trusts 2010).

Total CST Capacity Installed as a Consequence of the Framework Installed

With regard to Spain, most of the installed CST generation capacity came online after the landmark Royal Decree 661/2007, even though projects were previously developed because of the tailoring of the FiT to CST applications in 2004. The overall capacity added since the introduction of the FiT has since reached nearly 383 MW with a further 1,540 MW under construction. Regarding the United States, one would have to subtract the nine SEG plants, which came online in the late 1980s and early 1990s from current installed capacity. New capacity coming online since 2006—the year in which the first of the cited RPS frameworks was introduced—has added up to 78.7 MW, with 1,077 MW currently under construction (CSP Today 2010). However, the United States has announced a considerably higher amount of capacity to be developed—9,912 MW compared to 497 MW in Spain.

The Share of CST Generation in the Overall Electricity Supply Mix

Despite the recent considerable increase in plants in operation, the overall share of CST in the electricity supply mix of both the United States and Spain is still relatively small.

The most recent yearly overall electricity generation data available from the International Energy Agency (IEA) for Spain and the United States, for 2008, shows total Spanish electricity supply at 311,130 GWh and total U.S. electricity supply at 4,343,820 GWh (IEA 2010). Assuming a capacity factor for installed generation of around 22–24 percent, the overall CST-based output would be equal to 761.1 GWh in Spain and 860.5 GWh in the United States in 2010. Even compared to the 2008 supply data, this would mean that the share of CST generation in the overall electricity supply mix amounts to approximately 0.25 percent for Spain and 0.02 percent for the United States. Assuming that all capacity currently under construction or in development would come online, the overall share, relative to the 2008 supply data, would increase to 1.6 percent for Spain and 0.52 percent for the United States.

The Structure of Financial Arrangements and the Amount of Private Sector Investments Leveraged into the Respective Projects Using Incentive Mechanisms

With regard to Spain, the tailoring of the FiT to CST in 2004 already triggered the first development proposals, but it was not until modification of the FiT by Royal Decree 661/2007—which considerably increased tariff rates and premiums and decoupled them from market reference prices—that a large number of projects became bankable. Although actual data with regard to financial structures are hard to come by—developers are fairly secretive in this regard in both countries—most, if not all Spanish projects, seem to have triggered limited recourse or nonrecourse financing. Currently, more than 1.5 GW of capacity has received either limited recourse or nonrecourse financing from domestic or international commercial banks. This contrasts with plant developments in the United States, where, until the recent large-scale provision of loan guarantees, apparently only very few projects were based on limited recourse or nonrecourse financing.

Analysis and Conclusions

Both the United States and Spain have seen a rapid uptake of CST technology over the past several years, and the trend is likely to continue, despite minor modifications of the Spanish FiT. Based on the investment trends analyzed above, the following conclusions can be drawn:

1. **FiTs have been the most successful incentive for jump-starting renewables' market penetration and encouraging rapid development of domestic CST companies.**
   Spain is regarded as the leader in the CST field, and it is likely to continue in this role because of the continuing success of the FiT scheme. The Spanish FiT has triggered a considerable number of projects in a relatively short time and enabled rather favorable financing terms compared to the RPS schemes in the United States. Although coming at a considerable fiscal cost, the overall net societal benefits in the form of reduced spot market prices for electricity, lower GHG emissions, a reduced need for fuel imports and net contributions to GDP seem to substantial (APPA 2009).
2. **FiTs have encouraged large, integrated infrastructure companies to enter the CST market, providing better opportunities for large-scale project development.**
   The large, integrated infrastructure companies of Spain were motivated to pursue CST because of the secure cash flow revenue streams guaranteed by

the FiT scheme. In the United States, start-up companies, not large developers, have first brought the technology to construction. However, as the technology matures, it seems that large companies would become involved. The Spanish giant Abengoa, for example, has made its way into the U.S. market by securing a US$1.45 billion in guarantees for its 280 MW Nevada-based Solana project. This incentive scheme is likely to benefit large companies, which are generally in a better position to finance larger installations, and to take advantage of economies of scale—one of the primary assumed drivers for cost reduction for CST technologies.

3. **When coupled with well-designed power purchasing agreements, tax incentives, grants and especially loan guarantees, RPSs can also be an adequate incentive for CST industry growth.**
   The success of RPSs seems to be associated with the provision of simultaneous schemes, such as well-designed PPAs, tax incentives, grants, and especially loan guarantees that make CST projects attractive for developers and commercial banks. More than 80 percent of the cost of a CST installation lies in initial construction and connection costs, making it important for developers to receive assistance in financing the upfront costs associated with large-scale CST development until the technology can reap its high, cost-reduction potential. Loan guarantees can be a powerful complementary instrument under an RPS scheme, as evidenced in the United States. However, this set of policy instruments imposes high administrative costs on developers and on the governments.
4. **The details of any incentive scheme—whether FiT or RPS—are critical to its success, perhaps more critical than the choice of a particular incentive scheme to apply.**
   For example, FiTs that deviate too much from the "market clearing" price are either likely to fail to attract sufficient private sector investment if they are set too low or set for too short a timeframe, or to grant a potential windfall to developers and investors at the expense of consumers and/or taxpayers if they are set too high or guaranteed for too long.

   Potential solutions for these problems include, for example, a reverse auction mechanism, which in theory could result in a tariff reflecting the confidence of a developer to implement the project at the bid price that should be close to the actual technology cost. An additional advantage of a reverse auction would be that FiTs would not necessarily have to be reviewed regularly to align them both to investors' interest and the public interest. If technology-specific tariffs are set by the regulator, periodic tariff reviews would undermine the main advantage of FiTs—their predictability for investment decisions. Under a classic FiT regime, a scheduled phase-out of the granted FiT by a certain amount every year could also be a potential solution. However, if a scheduled phase out is applied; it might be problematic to find a reduction rate for the FiT that brings it in line with the actual technology cost reduction rate. The Spanish experience also shows the importance of introducing a capacity ceiling to control societal costs.

   As with stand-alone RPS schemes, concerns are raised with respect the high administrative cost on developers and that it may not provide sufficient incentives to overcome the high investment costs. It is therefore of utmost importance that RPS schemes not be overly burdensome in terms of administrative compliance cost and that incentives be tailored toward the characteristics of CST. Even if the RPS scheme is appropriately tailored, there might still be the need to provide loan guarantees on a large scale to buy down the real and perceived technology risk. The fact that investments in the technology in the United States only took off after the introduction of a comprehensive and generous loan guarantee program seems to support this conclusion.

5. **Continuity is essential for the success of any policy instrument.**
Developers and investors are more likely to assume the financial risk of a CST project if the support scheme in place is credibly guaranteed for a certain period. This is especially important with regard to the timeframe for FiTs, since they were usually able to trigger nonrecourse, project financing. As the latter are obviously based on consistent cash flow projections, any insecurity with regard to the level or timeframe of a FiT will most likely deteriorate conditions for this type of financing and hence for CST development under the respective framework. This can present a problem, since even when periodic tariff reviews or a scheduled phase-out are enshrined in the FiT framework, a sudden change in government priorities or a reassessment of the respective policy goals might well trigger a modification of the tariff framework. Such a modification—regardless of whether or not it is justified from an economic point of view—might have a negative effect on the overall investment trends in the market.

In the case of RPS schemes, best-practice PPAs should provide for a comparable long-term predictability of cash flows. However, the experience of the developers in the United States suggests that, so far, PPAs alone have not been able to trigger large-scale investment in the technology, let alone nonrecourse financing for CST plants. This highlights the need to ensure predictability for both developers and investors. This could be obtained by establishing off take arrangements that allow for a viable and predictable income stream, which in turn would make these projects bankable (see section 7.3 on PPA Structuring in Chapter 7). However, unless the public sector provides additional reliable incentives to cope with the large upfront investments, PPAs alone are unlikely to provide the necessary cash-flow security.

6. **Particular conditions of a country will determine the best approach.**
Both FiTs and RPS schemes are ultimately funded by consumers—be it in their capacity as taxpayers or rate payers—and, as such, will only be appropriate in jurisdictions with well-established governance and electricity regulatory frameworks. Based on the material reviewed in this evaluation, it seems likely that, given the potentially higher administrative costs associated with a complex array of incentives, such as tax incentives and grants, which usually go along with RPS schemes, a FiT combined with concessional and nonconcessional loans might, in theory, be a preferable option for jump-starting industry development, because of its simplicity and predictability. The relative flexibility of FiTs in targeting different technologies might well prove superior to RPS schemes. By contrast, one must keep in mind that the methodology for designing and structuring technology-specific FiTs is rather a "try and adjust" approach, requiring keeping track of technology developments and evolvement of manufacturing markets to produce CST components locally (see Chapter 6).

The tremendous downside of a FiT from a public policy maker's point of view is certainly its considerable societal cost. Incentives should be aligned with the overall affordability of consumers and taxpayers. This holds true for both developed and developing countries, although in the former the impact is less immediate because of higher income levels of the population. There are potential options to minimize the societal cost in the form of a cap on the overall capacity eligible for a FiT, and conducting periodical tariff reviews to adjust FiTs to changes in the investment and production costs or simply schedule the phase-out of the tariff over a certain timeframe. Nevertheless, in situations where the political economy rules out the use of a FiT, or where it is politically inacceptable to pass the full cost increase on to the end user, a strong RPS combined with a variety of incentives might also be effective in promoting CST development, although potentially at a slower pace. In any case, one can assume that a comprehensive sovereign loan guarantee program would have to be launched in order to trigger desired investments under an RPS scheme, especially in emerging markets where investors still perceive project risk as higher than in the developed markets.

Notes

1. The literature review included the following sources: Durrschmidt 2008; Rowlands 2004; Astrad 2006; Fouquet and Johansson 2008; del Rio and Gual 2007; Nilsson and Sundqvist 2006; Lorenzoni 2003; Nielsen and Jeppesen 2003.
2. Meaning the average between different electricity tariffs that tend to vary for residential, business, and industrial customers, and for any single class depending on the time of day or by the capacity or nature of the supply circuit even within a single region or power district.

CHAPTER 4

Renewable Energy Schemes Supporting CST in Developing Countries

A variety of approaches have been taken in developing countries to incentivize investment in renewable energy in general and CST in particular. This chapter will review and analyze those currently under planning or implementation in the Middle East and North Africa (MENA) region, India, and South Africa.

MENA Incentive Schemes

Algeria

Algeria stands out as a notable example of a country within the region that has taken steps to introduce price incentives for renewable energy. In 2004, the Algerian government issued a decree instituting FiTs. Under the decree, premiums are to be granted for electricity produced from renewable energy resources. The premiums are expressed on the percentage of the average wholesale price set by the market operator based on bids from generators and buyers of electricity, as defined in the law on gas and electricity (GOA 2002). The tariffs are differentiated by technology and do include a tariff for CST.

For plants producing electricity exclusively from solar energy (including both CST and CPV), the premium is 300 percent of the average wholesale price. For hybrid solar-gas power plants with solar energy contributing at least 25 percent of the plant's output, the premium is 200 percent. For smaller proportions of solar energy in the plant output, the premium is set at lower levels—for example, 180 percent if solar generation is between 20 and 25 percent (JORADP 2004). Even though the tariff level can vary over time (because of the connection to the price set by the market operator), the size of the premium in relation to the average system price is guaranteed for the full lifetime of a project (FuturePolicy.org 2010).

While the introduction of a feed-in-tariff (FiT) scheme in Algeria is an encouraging example that holds promise for the future, the price incentives along with the entire structure of the scheme do not seem to be attractive enough for investors in solar energy. The proponents of the Algerian renewable energy projects currently in the pipeline (including CST projects) appear to put more faith into leveraging concessional capital from sources such as the CTF and large European Union–sponsored initiatives, such as Desertec (Fenwick 2011)—the only plant currently under construction is an integrated solar combined cycle (ISCC) plant at Hassi R'Mel with a 25 MW parabolic trough CST component in combination with a 125 MW combined cycle gas turbine, which was financed by Kreditanstalt für Wiederaufbau (KfW)—the German bilateral development bank, and the European Investment Bank (EIB). Part of the reluctance of the private sector to embrace the Algerian FiT scheme may be caused by the lack of protection from the wholesale market price volatility and the influence of domestic fuel subsidies on the whole sale electricity pricing.

Egypt

Egypt has no specific price support mechanism yet in place for renewable energy. However, the need to cover additional costs for renewable energy projects through tariffs has been recognized by the country's Supreme Energy Council, and some other policy measures have been initiated to promote renewables and especially CST. These include (a) an exemption from customs duties on wind and CST equipment; (b) the finalization of the land use policy for wind and CST developers; (c) the acceptance of foreign currency denominated PPAs; (d) the confirmation of central bank guarantees for all build-own-operate (BOO) projects; and (e) the support for developers with respect to environmental, social, and defense permits and clearances (CIF 2010). Despite the lack of specific price support mechanisms, an ISCC plant with a 20 MW CST component is already operating at El-Kureimat, located roughly 100 kilometers south of Cairo. The construction of this plant was financed by JBIC and again supported by a grant from the Global Environment Facility (GEF), for which the World Bank was the executing agency.

Morocco

Morocco does not have price incentives yet in place for renewable energy. Nevertheless, the country is aiming to have 2,000 MW of solar power generation capacity installed by 2020, starting with the ambitious Ouarzazate 500 MW CST project. The project is expected to utilize parabolic trough technology equipped with storage. The legal, regulatory, and institutional framework is being set up with several laws enacted in early 2010, including the renewable energy law, the law creating the dedicated Moroccan Solar Agency (MASEN) to implement the Morocco Solar Plan and the law setting up the Energy Efficiency Agency.

Morocco's recently issued Renewable Energy Law (REL) (Dahir 2010) and the Moroccan Agency for Solar Energy (MASEN) Law (Dahir 2010) are intended to scale up the development of renewable energy with special focus on solar technologies. MASEN is entrusted by the government to develop at least 2,000 MW of grid-connected solar power by 2020, and in particular to conduct technical, economic, and financial studies, as well as to support relevant research and fundraising, to seek utilization of local industrial inputs in each solar project and to establish associated infrastructure. While the generated electricity must be sold in priority to the national electric utility ONE (Office National de l'Electricité) for the domestic market, the law allows MASEN, under conditions specified in the convention signed with the government (described below), to sell electricity to other public or private operators on national or export markets.

An obvious export market would be the European Union. EU Directive 2009/28/EC allows EU member states to import renewable energy–generated electricity from projects in third countries using their respective incentive mechanisms in order to fulfill the respective national targets by 2020 if a variety of conditions are fulfilled. This could be the framework for the establishment of major export markets, which could ensure a viable income stream for a major scale-up of CST in Morocco. In reality, the export option, especially at the desired FiT level, is rather difficult to realize for a variety of reasons, including the following: (a) the directive needs to be transferred into national laws, which has so far experienced delays in most cases; (b) approvals in each respective jurisdiction are required to use the electricity generated in nonmember countries against the country compliance with the RE targets; and (c) the EU Directive itself, which in Article 9 sets up certain time limitations on when renewable energy generated in nonmember countries can count toward domestic renewable energy targets.

Notwithstanding these potential limitations with regard to export markets, the US$9 billion Morocco Solar Plan, launched in November 2009, calls for the commissioning of five solar power generation plants between 2015 and 2020, for a total capacity of 2,000 MW. With this plan, 4,500 GWh annually will be produced from solar energy alone. In October 2010, conventions were signed between MASEN and the government on the one hand, to stipulate state support for the Moroccan Solar Plan, and MASEN and ONE on the other hand, to cover the conditions for connection and operation of solar power plants and for sales of electricity. According to the convention, the state will compensate MASEN for the "gap" between the two PPAs. ONE is already operating an ISCC plant with a 30 MW solar-assisted combined cycle gas turbine (CCGT) at Ain Beni Mathar (northeastern Morocco), which is financed by the African Development Bank (AfDB) and supported by a grant from the Global Environment Facility executed by the World Bank.

Issues Related to Regulatory Frameworks in the MENA Region

Information on the enabling policies for CST in MENA countries remains scarce. Morocco's commitment to attracting private sector participation in CST development on a project-specific PPP basis, and Algeria's decree of 2004 introducing technology-specific premiums for renewable energy are notable exceptions. However, the lack of implementation mechanisms in the case of Algeria and Morocco and the lack of defined incentive policies in the case of other countries to support CST (and other renewables) generate regulatory uncertainty that, if not rectified, may become a serious deterrent to future private investments in the sector. The individual bilateral and multilateral projects to build up solar power capacity in MENA may expedite, but cannot substitute the development of such national policies. This is especially true since the first CST projects in MENA are expected to come on line in 2014–15, and even then export opportunities could be limited, and thus generation would essentially focus on domestic markets.

Given the circumstances, while there is a strong rationale for strengthening mechanisms and institutions to enable investments, certain large-scale investment projects may be justified on a stand-alone basis. Support schemes for these projects are highly customized, but usually involve such common features as (a) a long-term PPA between the power utility, or another form of a single buyer, and the generator; (b) a competitive bidding process for the generators; and (c) commitments from the government and financiers, sometimes including international donors, to support the project.

Under the CTF-supported program to scale up CST in MENA, the PPA model is being utilized for the Ouarzazate project in Morocco, among others. For a large donor-supported project, the project model is innovative, since it relies on the private sector—not as just a supplier of equipment, but as an integral partner in the implementation scheme under a public-private partnership.

The rationale for stand-alone projects (as opposed to policies driving investments in projects) needs to pass a reasonable test of sustainability and replicability. A large stand-alone project may enjoy a high-profile status that allows it to receive an unprecedented level of support from the government and the donors. As a result, the project may create attractive incentives for private sector participation, but such conditions may not be easy to replicate. At the same time, large-scale demonstration projects can be essential for reaching the critical mass of investment in new technology, such as CST.

The success of the Ouarzazate project in Morocco in attracting private sector investor participation in the project on a PPA basis could be a considerable breakthrough, since the PPP model for CST deployment Most of the previous attempts to attract private sector investment in CST have failed not only in MENA, but in India and Mexico as well. In MENA, the ISCC projects in El-Kureimat (Egypt) and Ain Beni Mathar (Morocco) were either designed as public sector projects from the beginning, as in the case of El-Kureimat, or had to be restructured because the original project design based on the IPP concept did not work, as in the case of Ain Beni Mathar.

MENA Incentive Conclusions

There are four or five models (depending on classification details) to be considered for supporting CST in the MENA region. The models given most attention in the developed country markets are the FiT and RPS models. In the MENA context, however, the currently relevant choices are largely between the pure public project model (supported by concessional financing) and the PPP model.

The MENA experience to date shows that

- The region is not quite ready to embrace FiTs or RPS, although efforts to champion the introduction of such schemes are ongoing.
- IPP/PPA schemes have not worked well in the past, as illustrated by the GEF projects that had to be restructured into public sector projects.
- Combined PPA/PPP schemes are being tried out for some individual large projects (Morocco), and they have a better chance of success than the earlier attempts to engage the private sector that used a pure IPP concept.

The CST investments planned in the Middle East and North Africa for the next decade and beyond are, to a large extent, driven by individual projects supported by the European Union, and by multilateral and bilateral sponsors. The policies initiated domestically to attract investment that would serve the domestic markets are few, although Morocco's commitment to test the PPP model and Algeria's FiT scheme launched in 2004 are encouraging examples.

The approach currently taken under the CTF-supported CST scale-up program in MENA assumes that concessional financing will help address the issues of both high capital costs and the existing uncertain policy and regulatory framework. The expectation is that, with more clarity in the policy framework for CST development in the Middle Eastern and North African countries by 2015 or so, the need for concessional financing will be reduced (CIF 2010). However, these investments will require to be followed by appropriate national policies, such as FiTs or RPS/quotas combined with other supporting instruments to achieve a transformational impact in the long term.

India's Incentive Schemes

Over the last few years, India has introduced incentive schemes for solar power, both at the central and state level. Among the states, the most advanced are Gujarat and to a lesser degree Rajasthan, where project developers had concluded PPAs and are preparing to close the deals with financiers.

State-Level Incentives

At the state level, Gujarat has emerged as the frontrunner in attracting private investment in solar power. The Gujarat government has laid out the norms of the Renewable Purchase Obligation (RPO) policy and has set the ambitious target of installing 1,000 MW of solar power capacity by the end of 2012 and 3,000 MW in the following five years. According to the Solar Power Policy issued by Gujarat's government in January 2009, each PPA shall include a specific levelized fixed tariff per kilowatt-hour and is concluded for a period of 25 years as shows in table 4.1.

Table 4.1: Gujarat tariff rates for solar projects

Sr. No.	Date of Commissioning	Tariff for Photovoltaic Projects (INR/kWh)	Tariff for Solar Thermal Projects (INR/kWh)
I	Before December 31, 2010	13.00 for the first 12 years and 3.00 during years 13–25	10.00 for the first 12 years and 3.00 during years 13–25
II	Other projects commissioned before March 31, 2014	12.00 for the first 12 years and 3.00 during years 13–25	9.00 for the first 12 years and 3.00 during years 13–25

Source: Adapted from Government of Gujarat 2009.

Recent reports indicate that the state-owned utility GUVNL has signed PPAs with as many as 54 solar power generation companies for 537 MW. The total solar power installation commitments signed via Memoranda for Understanding with the Government of Gujarat have been reported at 933.5 MW, which is close to the installation target of 1,000 MW by 2012 (Panchabuta 2010a).

Central Government Level Incentives—Jawaharlal Nehru National Solar Mission

The Government of India (GOI) announced the JNNSM in January 2010, which set a target of 20,000 MW of solar power installed by 2022. The target for the first phase (by 2013) is 1,000 MW of grid-connected solar power capacity, of which 500 MW should be solar thermal projects and 500 MW solar PV.[1] An additional 3,000 MW is targeted by the end of the second phase in 2017. It is understood that the ambitious target of 20,000 MW or more by the end of the third phase in 2022 will be dependent on the learning success of the first two phases (MNRE 2009).

Since the central government issued guidelines for switching from state supported schemes to JNNSM (CERC 2009), most of the discussion about incentives for solar energy in India has focused on this new initiative by the central government. The available information on the projects whose developers have chosen to switch ("migrate") from the state-level schemes in both Gujarat and Rajasthan to JNNSM shows that 16 projects with a total capacity of 84 MW have officially "migrated." Of these, only three projects with a total capacity of 30 MW were CST projects.

Renewable purchase obligation

Under the JNNSM, investment in the grid-connected solar power will be supported "through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff." The key driver for promoting solar power will be a renewable purchase obligation (RPO) mandated for power utilities (distribution companies, or DISCOMs) with a specific solar component. This is expected to drive utility scale power generation, both solar PV and solar thermal. The solar-specific RPO will be gradually increased, while the tariff fixed for solar power purchase will decline over time (MNRE 2009). The MNRE guidelines mention a national level solar RPO of 0.25 percent of the total annual electricity purchased by the utilities by the end of the first phase and 3 percent by 2022. The state governments are responsible for setting solar RPOs in their respective states.

Related to the RPO targets are the government procurement quotas used under the NNSM. For the first round of competitive bidding, implemented through the reverse auction mechanism and conducted in 2010 to advance the progress toward the 0.25 percent target, the government solicited bids for 150 MW of PV and 470 MW of CST projects. In conjunction with the RPO targets, the government mandate to procure the solar power capacity is the first and foremost element of the Indian incentive scheme for solar power.

Preferential tariff

The preferential tariff is the second element in the scheme. The Central Electricity Regulatory Commission (CERC) guidelines published in July 2010 (CERC 2010b) specify INR 15.31/kWh (or about US$0.34/kWh, converting at 45 INR/US$) as the levelized total (single-part) wholesale tariff for CST in the first phase of the JNNSM. Provided the capital costs of CST plant construction in India will be consistent with the capital expenditure (CAPEX) norm set by CERC 2010a at INR 153 million per MW (US$3400/kW),[2] the target (pretax) return on an equity basis on this levelized tariff is calculated to be 19 percent per year for the first 10 years and 24 percent per year from the 11th year onward.

Solar energy priced at INR 15.31/kWh stands out as much more expensive than conventional power, which tends to cost on average about INR 2.5/kWh or less in India. Power from grid-connected PV is even more expensive, with the levelized CERC approved tariff for Phase 1 at INR 17.91/kWh. To sell this energy to distribution utilities, the nodal agency—NTPC Vidyut Vyapar Nigam Ltd. (NVVN), the trading arm of the national power utility National Thermal Power Corporation Ltd. (NTPC)—will be bundling solar power with electricity from coal and possibly nuclear plants. In one useful illustration (IDFC 2009), the proportions between solar and conventional energy bundled by NVVN for sale to state distribution utilities could be 1:4,[3] with the electricity from the unallocated quota costing INR 2.5/kWh. This would result in an overall (weighted average) price of about INR 5–6/kWh.

It should be noted, however, that the levelized tariff of INR 15.31/kWh for CST (as well as the respective tariff for PV) is not intended to be used as a guaranteed, European-style FiT. The price eventually included in the PPA between the solar power producer and NVVN is reduced by the competitive procurement procedure mentioned earlier. The bidding round completed in November 2010 for the first 470 MW of CST capacity saw investors offering discounts in the range of 20–31 percent from the ceiling price of INR 15.31/kWh. As many as 66 bids for CST projects were received by the government by the closing date (in addition to 363 for solar PV),[4] while only 7 CST companies were eventually short-listed (Panchabuta 2010b). In the bidding scheme to procure the first 470 MW of CST capacity, the preferential tariff of INR 15.31/kWh was used as a ceiling price with many bidders have offering prices below that level. The seven winning bids were between INR 10.49 and 12.24/kWh.

Other incentives

Besides the RPO, the competitive procurement scheme and the preferential tariff, another element of the incentive scheme included in the guidelines is the Renewable Energy Certificate (REC) mechanism. The certificates will be specific to solar energy and will be bought and sold by utilities and solar power generation companies to meet their solar power purchase obligations (MNRE 2008).

In addition to the core elements of the incentive scheme already mentioned, other incentives available to CST developers in India include (a) accelerated depreciation and (b) generation-based incentives (MNRE 2008).[5] In both cases, the CERC position is that such incentives and subsidies should be taken into account when calculating the applicable tariff. In other words, these incentives should not be additional to the preferential tariffs offered under the JNNSM.

Finally, a peculiar feature in India is the Clean Development Mechanism (CDM) benefit-sharing provision, under which CDM credits earned by renewable energy projects must be shared between the project developer and the buyer of renewable energy. In Tamil Nadu, for example, the regulator issued guidelines under which CDM credits would accrue to the developer in the first year, but then the developer's share would decrease by 10 percent every year in favor of the power purchaser until it reaches a 50:50 ratio (TNERC 2010). The concept of CDM sharing has been criticized by those who believe that CDM benefits should belong only to the developers, who deserve them by virtue of going through the cumbersome process of CDM, including required additional tests for their projects (Sarangi and Mishra 2009).

Issues Related to India's Incentive Schemes

As described in the previous chapter, the regulatory environment for deployment of solar energy in India is rapidly evolving and can be characterized as both relatively advanced and rather complex. In fact, the multiplicity of the incentive instruments introduced under the JNNSM can be a source of confusion about the nature and role of each instrument. Under the NNSM, as long as a sufficient number of suppliers are willing to bid below the ceiling price (which so far has been the case), the incentive scheme operates as a quantity-based scheme that is closer to an RPS than a FiT scheme.[6]

A tendering scheme or auction could be a more accurate description of the Indian incentive framework for CST. Like RPO/RPS, tenders and auctions are quantity-based instruments—that is, the required quantity is specified in advance and the price is set by the market. The process of an RPO/RPS, however, is somewhat different from that of a tender—for example, an RPO/RPS does not usually involve sealed financial bids. Instead, the price is agreed on between the supplier and off taker through negotiation.

In the international practice, auctions have often been used as the basis for long-term PPAs. Bidders are usually asked to compete on the basis of price per kilowatt-hour, with the starting (ceiling) price announced in advance. The capacity to be built by each supplier, as specified in the bid, becomes part of the contract for the winning bidders. Each winning bidder gets the off take price at the level that was bid.[7] The procurement procedure used in India for CST is essentially the same—that is, an auction for a certain aggregate CST plant capacity to be built by several winning bidders.

Tendering procedures and auctions have worked well in many cases in developed markets (such as in Europe), at least to kick-start the market. One of the system's drawbacks, however, is that if competition is too strong, the prices offered are sometimes very low and thus pose a risk of projects not being implemented. By contrast, it has the advantage of fast deployment to kick-start the market in a specific technology sector. However, it is not well suited for a large and rapidly growing market because of its high administrative costs, the risk of unrealistic bids and the potential for creating administrative barriers (World Bank/ESMAP 2010).

It is too early to evaluate the effectiveness of the incentive scheme in terms of its ability to attract the investment capital to the most promising locations, and select projects and companies most likely to deliver results. In both the PV and CST tenders, new entrants dominated the list of successful candidates. Many established players have been unable to win. This may be a good result if the new entrants can deliver, thus becoming established players themselves and making the solar thermal industry more competitive. By contrast, if the new entrants fail to fulfill their contractual obligations, the effectiveness of the process will be questioned for its failure to accommodate the established players at a higher off take price. It is clear that some new entrants may not even be able to secure the needed loans, whereas established players would have an advantage because of their balance-sheet strength. A survey of 25 potential CST project developers in a World Bank–commissioned study showed that many of the interviewed developers felt that in the PPAs concluded with NVVN, the buyer would not be "bankable"—(that is, financial closure would be unlikely)—unless the PPAs are guaranteed by the GOI, or backed by some other dedicated source of funds. In their view, the banks might not be convinced that the PPA alone is a bankable source of revenue (World Bank/ESMAP 2010).

The comparison of the incentives under the JNNSM in regard to those available at the state level may require further analysis. As noted earlier, the GOI has offered the state-level developers the option of switching ("migrating") to the JNNSM. However, relatively few developers have taken this opportunity, and only 16 projects with a total capacity of 84 MW (of which 30 MW is CST) have migrated. It is important to note that the state-level schemes, such as the one in Gujarat, do not involve competitive bidding. Thus, developers and investors might have felt that the competitive bidding (the reverse auction) under the JNNSM might eliminate the initial price advantage while at the state level, procurement is of the type "what you see is what you get." Secondly, the process of switching to the JNNSM was competitive as well, and the time window for such migration was rather short.

Concerns have also been expressed on the bundling scheme introduced under the JNNSM. First of all, this is fundamentally a cross-subsidy scheme with its inherent economic distortions. Secondly, the cost of bundled (solar plus coal or nuclear) power is still above the average system cost. At INR 5–6/kWh, while much more affordable than "pure" CST power costing three times as much as an average wholesale rate, as such this cost may still be a challenge for the distribution utilities. Many of the state distribution utilities are in a poor financial state to begin with (World Bank/ESMAP 2010). The difference between this cost and the average cost of conventional power (about INR 2.5/kWh) must be covered either by the rate payers, or through an incremental cost recovery mechanism, which, however, does not seem to be explicitly funded.

India Incentive Conclusions

The GOI has made a strategic choice to promote grid-connected solar power, and the introduced incentive package is impressive. India has a vibrant economy, and has a good chance to emerge as a major player in the CST industry.

India's policy on CST is designed to be largely private sector–driven, with the government creating an enabling environment for investors. For all the concerns on the guidelines, developers still see success in the early bidding stages as important for strategic positioning in the market. This may explain why the first round of bidding for CST under Phase 1 of the JNNSM was oversubscribed. However, it remains to be seen how effective the whole package of incentives will be. Over the longer term, it needs to be well integrated and coherent—in terms of the instruments (the current process mixes RPO and FiT elements), as well as coordination between state and central governments.

Given a great degree of uncertainty about the required (or "justified") level of capital costs for CST projects in India, the quantity-based approach may be a good choice. An RPO scheme may not be as aggressive a strategy as a FiT in securing a massive expansion of solar power capacity, but it facilitates the price discovery process better than a FiT system. This may result in substantial cost savings both for the public sector and for the final consumer. At the same time, the support schemes available at the state level (notably, in Gujarat) have demonstrated the effectiveness of fixed FiTs (rather than tariff-setting schemes involving competitive bidding) in attracting private investors into PPAs. Overall, the effectiveness of the incentives for solar power development is still to be demonstrated by financial closures for concluded PPAs.

South Africa's Incentive Schemes

The 2003 White Paper on Renewable Energy (Departments of Minerals and Energy Republic of South Africa 2003) set a target of 10,000 GWh, to be produced from biomass, wind, solar, and small-scale hydro by 2013. The South African Department of Energy, in consultation with the National Energy Regulator of South Africa (NERSA) and Eskom, the national utility, developed a plan for capacity additions called the Integrated Resource Plan 1 (IRP1), which was signed by the Department of Energy on December 16, 2009. IRP1 laid out additional capacity that is required to reach the objective of 10,000 GWh of renewable by 2013 (Department of Energy 2009).

A draft version of the new Integrated Resource Plan, named IRP2010, was published in October 2010. It details the plan for capacity additions for the next 20 years in South Africa (Integrated Resource Plan for Electricity 2010). The plan included 1,025 MW from wind, CST, landfill, and small hydro, supported by the renewable energy feed-in-tariff (REFIT). In March 2011, the final version of IRP2010 was approved by the cabinet, specifying that over the next 20 years, 17.8 GW should come from renewable sources (Engineering News 2011). Specifically, 1 GW of CST, 8.4 GW of solar PV, and 8.4 GW of wind are expected to be added between 2010 and 2030 (Integrated Resource Plan for Electricity 2010–2030, 2011). The contribution of renewables supported by the REFIT was similar to the draft, although an additional requirement of a solar program of 100 MW each year from 2016 to 2019 was added.

Feed-in Tariff

In March 2009, NERSA announced Phase I of the REFIT. Similar to standard FiTs, the REFIT requires Eskom, the national utility, to buy electricity from eligible generating units at a tariff set by NERSA that can be passed on to the rate payers. As part of the REFIT phase I, on March 31, 2009, NERSA set the REFIT tariff for parabolic trough plants with 6 hours' storage per day at ZAR 2.1/kWh, which is equivalent to approximately US30¢/kWh, assuming an exchange rate of ZAR 7 to the U.S. dollar (NERSA 2009b). On

November 2, 2009, NERSA announced Phase II of the REFIT, expanding eligibility for more technologies under the policy. The announcement added two further tariffs for CST at ZAR 3.14/kWh (US45¢/kWh) for parabolic trough without storage, and ZAR 2.31/kWh (US33¢/kWh) for power tower with 6 hours' worth of storage per day (NERSA 2009a). Fossil backup for CST is permitted, but must be limited to 15 percent of the total primary energy input.

Eskom's Single Buyer Office acts as the Renewable Energy Power Purchase Agency (REPA) and, as such, is obliged to buy power through PPAs regulated by NERSA. The tariff was based on LCOE calculations, and will be reviewed annually for the first five years after implementation, which will begin once all conditions of the REFIT and the final regulatory structure are finalized, and then every three years thereafter.

At the time of writing, NERSA was still in discussions with the Department of Energy, the National Treasury, the Department of Public Enterprises, the Department of Environmental Affairs, and Eskom to finalize the PPA rules that will govern the operation of the REFIT. NERSA has already published Regulatory Guidelines, a draft PPA, and rules on selection criteria for projects under the REFIT. On September 30, 2010, the Department of Energy announced the start of the procurement process and the government's intentions to ensure an investor-friendly enabling environment by developing a set of standardized procurement documentation for the PPA. The Department of Energy also announced an official Request for Information (RFI) aimed at potential private power developers to gain understanding on the progress of their projects under the REFIT. The RFI was intended as a "market sounding" to obtain information on projects that will be ready and able to add capacity (MW) and energy to the system before March 2016 (Department of Energy 2010b). The Department of Energy stated that before the procurement documentation is finalized and released, a "ministerial determination" regarding the buyer under the REFIT, as given in the Electricity Regulation Act, would be undertaken first (Aphane 2010).

The RFI received 384 responses, identifying a total of approximately 20 GW of REFIT technologies, although less than 30 had received an indicative quote and a preliminary timeframe for connection (Department of Energy 2010a). In March 2011, the cabinet approved the Independent System and Market Operator Bill for tabling in parliament, which is intended to ensure that IPPs are included in the addition of new generation capacity in South Africa, rather than just from Eskom. Although this is not a bill exclusively for IPPs under the REFIT, its purpose is to promote the role of IPPs that are the entities that will benefit from the REFIT once it gets underway.

The IRP2010 resolves the uncertainties around long-term capacity addition targets, and includes the recommendation to finalize the REFIT process as quickly as possible. Although the PPA process is still being finalized, Eskom claims to have received 156 applications from IPPs already, representing a combined total capacity of 15,154 MW, 13,252MW of which is wind (Van de Merwe 2010). This leaves 1,902 MW of different technologies under the REFIT, which include the three CST technologies, namely trough, power tower, and power tower with storage, and also solar PV, solid biomass, biogas, land-fill gas, and small hydro, among which the distribution of applications is as yet unannounced. The RFI shed light on the breakdown of potential IPP projects, to be supported by the REFIT and broken down by technology. Of the 384 RFI responses, one-third were wind projects, one-third were solar PV projects, and 5 percent of responses with 10 percent of capacity came from CST projects. The remainder consisted of biomass, hydro, landfill gas and biogas, and cogeneration.

Aside from the REFIT, US$350 million of the US$500 million CTF investment plan for South Africa has been awarded to Eskom to develop wind and CST projects. The IBRD and AfDB are also proposing loans each of US$260 million to further co-finance the projects. Combining the CTF, IBRD, AfDB contributions with those from other bilateral and commercial lenders, the project's total budget is US$1.228 billion. The CST component is estimated to require US$783 million, while the wind component will cost US$445 million. The CST project will be located in Upington in the Northern Cape Province, where Direct Normal Insolation (DNI) is approximately 2,800kWh/m^2 per year, one of the highest levels of solar potential in the world. Eskom has indicated that the preferable technology is power tower with storage, although the decision on the technology to be used has yet to be finalized.

South africa incentive issues

The REFIT program is not yet fully established as the procurement process remains under discussion. As a result, concerns have been raised concerning REFIT's effectiveness in encouraging investments in CST and other renewables. The issues raised include whether the targeted goal of 10,000 GWh from renewable sources in 2013 acts as a capacity "cap" of PPAs eligible for the REFIT, whether NERSA will assess the eligibility criteria for projects, and whether Eskom's Single Buyer Office can process all applications efficiently. In addition, the question remains whether NERSA's proposed tariffs are high enough to induce investment (Bukala 2009).

In March 2011, one week after the government passed IRP2010, which specified that 17,000 MW should come from renewable energy, NERSA announced a review of the REFIT tariffs and proposed that they should be cut. The announcement of high renewable energy targets, combined with the cut in tariffs that are in place to reach this target, could be interpreted as somewhat conflicting, since lower tariffs could attract fewer renewable project developers. Parabolic trough with storage faces a cut of 41.5 percent, which is one of the largest cuts of all REFIT tariffs. The paper also specifies that the tariff for power tower technology should be reduced by 39.4 percent, and CST trough without storage should fall by 7.3 percent (NERSA 2009b). NERSA predicts that the tariff review procedure will be completed by the end of May 2011, when the final approved tariffs will replace the original figures developed in Phases I and II. The discussion over changing the tariffs is likely to further delay the awarding of PPAs as IPPs as project developers wait for the final announcement and plan investments accordingly.

One goal of the Upington CST project, funded with support of the MDBs, is to resolve some uncertainties over cost and risk, thereby encouraging IPPs to enter into PPAs under the REFIT. It is believed that the general visibility of CST will rise with the national utility running a large-scale CST project, signaling that the government is committed to a future with renewable energy technologies. Without Eskom's participation and a visibly successful large-scale project, the private sector is unlikely to make significant investments to allow for rapid diffusion of CST technology in South Africa.

South africa incentive conclusions

Since the REFIT is not yet operational in South Africa, it is premature to predict how successful it will be in encouraging investments in CST, and the other energy technologies it covers. There are concerns over the lack of a defined structure of the REFIT, and uncertainty over what the final tariffs will be. However, many of these concerns could be addressed once NERSA and Eskom finalize the process for arranging the

PPAs, tariff levels are decided, and the role of the single buyer as Eskom or an independent third party is determined. During the consultation processes of setting the tariffs, NERSA received a significant number of comments, demonstrating the sensitivity of the process and the importance of the outcomes for stakeholders. It is conceivable that the REFIT may encourage more investment for certain technologies than for others. In the same way that an RPS scheme induces investments predominantly in the cheapest technology, the REFIT may only promote significant investments in more established and less risky technologies, such as wind power, rather than CST. The fact that the vast majority of applications, which Eskom has received so far, have been for wind projects could indicate the disparity in effectiveness of the policy across different technologies.

Notes

1. The capacity of CST projects supported under NSM is specified as between 5 MW and 100 MW.
2. The methodology for arriving at the tariff level of INR 15.31/kWh involves assumptions, such as the normative CAPEX of INR 153 million/MW (about US$3.4 million/MW), a project life of 25 years, a debt-to-equity ratio of 70:30 with debt of 10-year maturity available at 12 percent, and a capacity utilization factor of 23 percent. No thermal storage is assumed.
3. NSM documents stipulate that for each megawatt of solar capacity signed by NVVN, an equivalent megawatt of capacity from the unallocated quota of NTPC stations shall be allocated. Hence, during the first phase, 1 GW of solar capacity will be coupled with 1 GW of NTPC coal plants. However, the amounts of electricity produced by coal plants may be four times as much as that coming from solar plants, because of a much higher plant load factor.
4. According to EVI 2011, 66 bids were received.
5. Generation-based incentives (GBIs) have been introduced by MNRE, in a scheme separate from the JNNSM, first for wind and then in January 2008 for grid-connected solar power, including CST. Under this scheme, the ministry would provide an incentive of a maximum of INR 12/kWh for PV and INR 10/kWh for CST. The maximum amount of incentive applicable for a project would be determined after deducting the power purchase rate for which a PPA has been signed by the utility with a project developer from a notional amount of Rs. 13/kWh. This incentive would be provided to project developers at a fixed rate for a period of 10 years, but the maximum amount of GBI offered for new plants would be decreasing over time. The scheme was designed mainly to support smaller entrepreneurs with a total proposed plant capacity of 5 MW or less.
6. By adopting RECs as a mechanism supplementary to RPOs, the Indian system adopts another feature typical of the schemes in the United States and United Kingdom.
7. A recent report on auctions (World Bank/ESMAP 2011a) classifies such auctions as "pay-as-bid" or "discriminatory" auctions. This is a form of a sealed-bid auction in which each bidder submits a schedule of prices and quantities (that is, a supply function). The auctioneer gathers together all the bids, creating an aggregate supply curve, and matches it with the quantity to be procured. The clearing price is determined when supply equals demand. The winners are all bidders whose bids, or sections of their bids, offered lower prices than the clearing price. The winners receive different prices based on their financial offers. The auctions for electricity contracts carried out in Panama and Peru have used a pay-as-bid design. Mexico also uses a pay-as-bid design for its auctions for PPAs.

PART III
Financing CST—How to Bring Technology Costs Down

CHAPTER 5

Cost Drivers and Cost Reduction Potential

Different CST technologies have, at present, reached varying degrees of commercial availability. While commercial cost data exist for parabolic trough, and to a slightly lesser degree for power tower, such cost data has yet to be established for the Fresnel and Dish Stirling technologies. Under these circumstances, a thorough assessment of the main cost drivers and the cost reduction potential will be key when considering the economic viability of CST in general and different CST technologies in particular. Based on an assessment of LCOEs for different CST technologies in some of the main emerging markets for CST—India, Morocco, and South Africa—and a review of typical cost structures for parabolic trough and power tower plants derived from projects developed or under preparation in developed markets, this chapter provides (a) an assessment of the main cost drivers, (b) an affordability assessment of different regulatory and financial incentives used to lower LCOEs in various emerging market conditions, and (c) an economic analysis of reference CST plants in the main emerging markets for CST that are considered.

LCOEs for CST in Specific Developing Country Markets

A common way to assess the financial cost of a particular power technology and/or compare the financial cost of alternative technologies is to express the cost of producing electricity for a certain plant as the LCOE (see box 5.1). The latter allows setting all the costs incurred by a particular plant over its lifetime (fixed capital cost elements, as well as variable O&M cost elements) in relation to the value of total electricity produced over its lifetime. LCOE is usually highly sensitive to changes in the underlying variables. Therefore, future variations of any of the cost elements for CST might well have an impact on the actual CST technology-specific LCOEs.

A detailed financial LCOE analysis was conducted for some of the major emerging markets for CST—India, Morocco, and South Africa—comparing parabolic trough and power tower technologies. The assumptions used in the analysis are listed in table B.11 in Appendix B. The results of the analysis are shown in figure 5.1. The analysis was based on a set of assumptions regarding the economic parameters (for example, interest rate and inflation), and the technical conditions prevalent in each country. Although LCOEs for CST are highly sensitive to the site-specific solar resource, DNI, there is no clear pattern of the sensitivity to the DNI resources available for analysis[1] because of widely differing financial conditions in each scenario considered. Generally however—under the assumption that the optimal amount of storage (the amount of storage which minimizes LCOE for each plant) is available—power tower technology offers lower LCOEs compared to parabolic trough in all three scenarios. Notwithstanding the lack of comprehensive data for power tower plants with the amount of storage assumed here (because

Box 5.1: LCOE structure

LCOE generally represents the cost of generating electricity for a particular plant or system. The concept is basically a financial assessment of all the accumulated costs of the plant over its life cycle relative to the total energy produced over its life cycle. More specifically, LCOE is a financial annuity for the capital amortization expenses, including fixed capital costs (for example, equipment, real estate purchase, and lease) and variable O&M expenses (for thermal plants mostly consisting of fuel expenses and O&M expenses, for CST plants mostly of O&M expenses), taking into account the depreciation and the interest rate over the plant's life cycle, divided by the annual output of the plant adjusted by the discount rate. If the discount rate is assumed to be equal to the rate of return LCOEs reflect the price that would have to be paid to investors to cover all expenses incurred (for example, capital and O&M) and hence the minimum cost recovery rate at which output would have to be sold to break even (Kearney 2010):

$$\mathrm{LCOE} = \frac{\dfrac{\sum_{t-1}^{N} I_t + M_t}{(1+r)^t}}{\sum_{t-1}^{N} \dfrac{E_t}{(1+r)^t}}$$

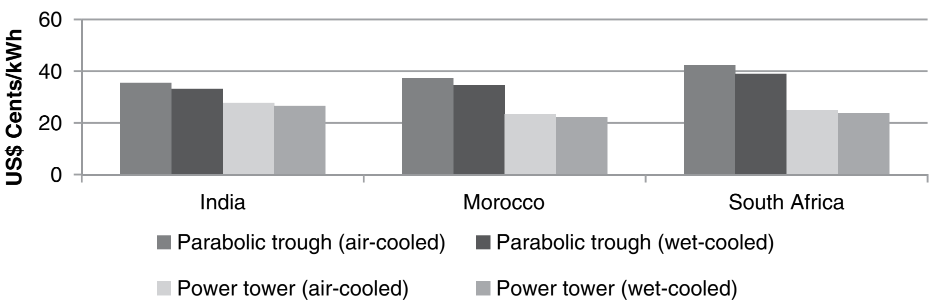
where r = discount rate | N = the life cycle of the plant | t = year | I_t = Investment costs in year t | M_t = O&M costs in year t | E_t = electricity generation in year t

of a limited number of these plants having been constructed so far—see Chapter 2), the lower LCOEs for power tower are mainly because of certain technical advantages, like for example, the ability to reach higher operating temperatures and higher operating rates (for more information see Chapter 2).

Overview of the Cost Structure

Internal cost structures of CST projects are often not readily available. However, examples for potential cost breakdowns with regard to total CAPEX and operational expen-

Figure 5.1: LCOEs for parabolic trough and power tower in India, Morocco, and South Africa



Source: Authors' data, using Solar Advisor Model (NREL).

ditures (OPEX) for reference parabolic trough and power tower plants with 100MW and 50 MW capacity, and different amounts of Thermal Electricity Storage (TES), could be presented as in tables 5.1–5.4 and figures 5.2 and 5.3.

Assessment of the Cost Drivers for CST

The cost elements listed in table 5.5, which comprise the typical cost structure of a CST project, are influenced by a variety of cost drivers, including the production and competition related issues, available financing conditions, changes in the underlying prices for key input commodities, and for land and labor inputs. Their respective impact has been assessed accordingly.

Local Inputs: Changes in Land and Labor Prices

Land-related expenses for a plant can account for a considerable share of the overall investment costs for most CST technologies. The actual share, however, will depend on land availability, ownership, and taxation issues. The second major issue will be the actual amount and price of local labor, relative to the total labor inputs needed to build and maintain the plant. The actual price of labor will obviously depend on local labor market conditions, but in nearly all cases and for nearly all parts of the value chain (project development; components; engineering, procurement, and construction (EPC); and O&M), will be lower in emerging market conditions. The share of local labor inputs partly depends on the chosen technology, the degree to which local services can be employed in different stages of the project value chain and on the degree of local manufacturing of the CST component. A detailed assessment of the potential of local manufacturing potential to reduce CST investment costs in several emerging markets is provided

Table 5.1: Estimate of capital expenditures—parabolic trough

		Option parabolic trough			
		100 MWe			50 MWe
Item	**Unit**	**TES 4.5 h**	**TES 9.0 h**	**TES 13.4 h**	**TES 9.0 h**
Nominal plant size					
Exchange rate	Euro/US$	1.40	1.40	1.40	1.40
Rated electric power, gross	MWe	100	100	100	50
EPC Contract Costs	**mln US$**	**704.2**	**721.1**	**872.7**	**388.8**
Solar field	mln US$	323.6	284.4	334.2	142.5
HTF system	mln US$	68.1	59.9	70.3	30.0
Thermal energy storage	mln US$	62.7	123.6	184.4	62.7
Power block	mln US$	107.7	107.7	107.7	67.3
Balance of plant	mln US$	45.0	46.0	55.7	24.2
Engineering	mln US$	36.4	37.3	45.1	29.4
Contingencies	mln US$	60.7	62.2	75.2	32.7
Owners' costs	**mln US$**	33.4	34.2	41.4	21.6
CAPEX grand total (± 20%)	**mln US$**	**737.6**	**755.3**	**914.1**	**410.4**
Specific CAPEX	**US$ / kW**	**7,376**	**7,553**	**9,141**	**8,207**

Source: Fichtner 2010.

Table 5.2: Estimate of capital expenditures—reference power tower

Item	Unit	Option central receiver			
		100 MWe			50 MWe
		TES 9.0 h	TES 12.0 h	TES 15.0 h	TES 15.0 h
Nominal plant size					
Exchange rate	Euro/US$	1.40	1.40	1.40	1.40
Rated electric power, gross	MWe	100	100	100	50
EPC contract costs	**mln US$**	**679.7**	**798.0**	**926.7**	**501.0**
Site preparation	mln US$	27.0	33.0	42.4	19.9
Heliostat field	mln US$	218.3	267.6	323.3	165.4
Receiver system	mln US$	106.4	125.8	144.3	85.8
Tower	mln US$	15.0	15.0	15.0	8.8
Thermal energy storage	mln US$	58.7	77.1	95.3	49.3
Power block	mln US$	110.0	110.0	110.0	65.4
Balance of plant	mln US$	40.7	47.6	55.0	30.0
EPC contractors engineering	mln US$	46.1	54.1	62.8	34.0
Contingencies	mln US$	57.6	67.6	78.5	42.5
Owners' costs	**mln US$**	37.4	43.9	51.0	27.6
CAPEX grand total (± 20%)	**mln US$**	**717.1**	**841.9**	**977.7**	**528.6**
Specific CAPEX	**US$/kWT**	**7,171**	**8,419**	**9,777**	**10,572**

Source: Fichtner 2010.

in Chapter 6. Current local content sensitivities and local staffing demand for a reference 100 MW parabolic trough plants in the Middle East and North Africa region (MENA) are given in table 5.6.

Changes in Underlying Commodity Prices

As in most energy industries, CST's cost structure depends, to a certain degree, on price fluctuations of the underlying nonfuel commodity inputs. The impact of price fluctuations of these commodities on the actual cost structure is partly determined by both the respective CST technology's commodity needs and the degree to which commodities can be supplied locally. Concrete and steel for all Spanish plants and for El-Kureimat plant in Egypt were, for example, supplied locally, resulting in lower investment costs. Commodities used for CST components include steel, concrete, sand, glass, plastic, and a variety of different metals, such as silver, brass, copper, or aluminum, as well as nitrates or molten salts for storage systems and a variety of other chemicals. Several input commodities—such as steel or concrete—are difficult to substitute for. Sharp price movements for these commodities can lead to potential fluctuations in the final costs of plant components and/or O&M expenses.

Economies of Scale and Volume Production

Mass production of components would most likely make CST technologies more economically viable because of the high standardization potential of several components,

Table 5.3: Estimate of operational expenditures—reference parabolic trough

Item	Unit	Option parabolic trough			
		100 MWe			50 MWe
		TES 4.5 h	TES 9.0 h	TES 13.4 h	TES 9.0 h
Technical-financial constraints					
Exchange rate	EURO/US$	1.4	1.4	1.4	1.4
Power generation	GWh/a	441.1	492.4	583.8	237.2
Number of operating staff	—	60	60	75	45
Manpower cost (average)	1000 $/a	58.8	58.8	58.8	58.8
Price diesel fuel	$/liter	1.1	1.1	1.1	1.1
Fuel consumption	1000 Liter/a	200	200	200	120
Raw water	US$/m^3	0.70	0.70	0.70	0.70
Annual raw water consumption	1000* m^3/a	132,330	147,720	175,140	71,160
HTF Consumption	t/a	61	54	64	26
HTF price	US$/t	3,000	3,000	3,000	3,000
Annual OPEX (costs as of 2009)					
Fixed O&M Costs:	**mln US$**	**13.4**	**13.6**	**16.5**	**8.0**
Solar field & storage system	mln US$	4.5	4.7	5.9	2.4
Power block	mln US$	2.3	2.3	2.5	1.4
Personnel	mln US$	3.5	3.5	4.4	2.6
Insurance	mln US$	3.0	3.1	3.8	1.6
Variable O&M Costs (Consumables):	**mln US$**	**1.2**	**1.2**	**1.4**	**0.6**
Fuel	mln US$	0.2	0.2	0.2	0.1
Water	mln US$	0.1	0.1	0.1	0.0
HTF	mln US$	0.2	0.2	0.2	0.1
Other consumables & residues[a]	mln US$	0.7	0.7	0.9	0.4
Total OPEX	**mln US$**	**14.6**	**14.9**	**17.9**	**8.6**
Percentage of CAPEX	**%**	**1.97%**	**1.97%**	**1.96%**	**2.10%**

Source: Fichtner 2010.
a. Electricity import, HTF, nitrogen, chemicals.

including most of the reflecting devices.[2] However, different cost reduction mechanisms will most likely apply to each component. In the case of parabolic trough and Fresnel, receiver costs will depend largely on the size scale-up, production volume, and increased competition, which could result in a 45 percent cost reduction by 2025 (Kearney 2010). The cost reduction of reflectors will largely depend on alternative or new material compositions and production methods for mirrors, with overall prices expected to come down by 20 percent until 2020 for parabolic trough and 25 percent until 2025 for power tower and Fresnel (Kearney 2010). Considering general experience curve concepts and progress ratios quantifying the effect of cost decrease for increased production and experience, a range of the cost scale-down from 5 percent to 40 percent can potentially be expected, according to different estimates (Kearney 2010).

Table 5.4: Estimate of operational expenditures—reference power tower

Item	Unit	Option central receiver			
		100 MWe			50 MWe
		TES 9.0 h	TES 12.0 h	TES 15.0 h	TES 15.0 h
Technical-financial constraints					
Exchange rate	EURO/US$	1.4	1.4	1.4	1.4
Power generation (net)	GWh/a	430.8	538.3	629.6	315.5
Number of operating staff	-	60	68	77	52
Manpower cost (average)	1000 $/a	59	59	59	59
Price diesel fuel	$/liter	1.1	1.1	1.1	1.1
Fuel consumption	1000 Liter/a	300	300	300	150
Raw water	US$/$m^3$	0.7	0.7	0.7	0.7
Annual raw water consumption	1000* m^3/a	116,323	145,340	169,982	85,183
Annual OPEX (costs as of 2009)					
Fixed O&M Costs:	**mln US$**	**12.29**	**14.19**	**16.24**	**9.47**
Solar field & storage system	mln US$	3.83	4.71	5.63	3.00
Power block	mln US$	2.26	2.37	2.48	1.43
Personnel	mln US$	3.53	3.98	4.50	3.06
Insurance	mln US$	2.67	3.14	3.64	1.98
Variable O&M Costs (Consumables)	mln US$	1.32	1.57	1.78	0.89
Fuel	mln US$	0.34	0.34	0.34	0.17
Water	mln US$	0.08	0.10	0.12	0.06
Other consumables & residues[a]	mln US$	0.90	1.13	1.32	0.66
Total OPEX	**mln US$**	**13.6**	**15.8**	**18.0**	**10.4**
In percent of CAPEX	**%**	**1.90%**	**1.87%**	**1.84%**	**1.96%**

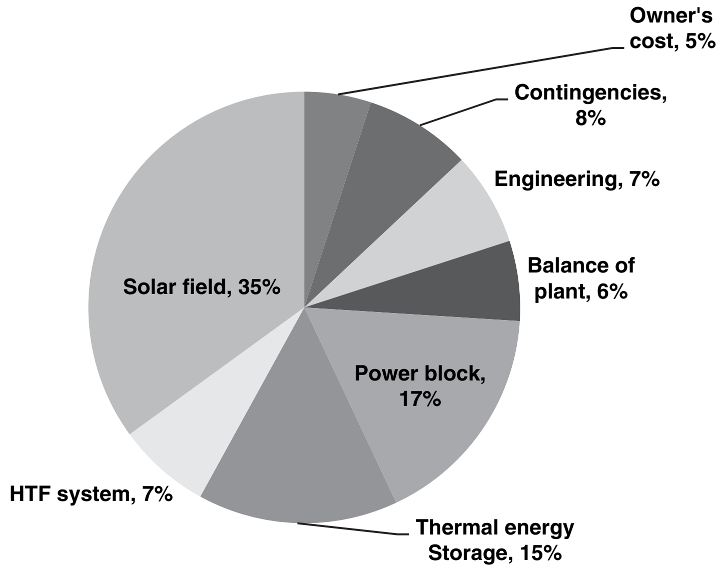
Source: Fichtner 2010.
a. Electricity import, HTF, nitrogen, chemicals.

A potentially important side effect would be that, unlike most components for fossil fuel plants that require skilled labor, mass-manufactured CST components could be designed to minimize the need for highly skilled labor for assembly, and hence open the opportunity for local manufacturing in several emerging markets, providing an opportunity for further potential cost decreases (Shinnar and Citro 2007). While the basic values are provided in table 5.7, a more detailed discussion on cost reduction potential in several emerging markets is provided in Chapter 6.

Monopoly Rents and Supply Chain Bottlenecks for CST Components

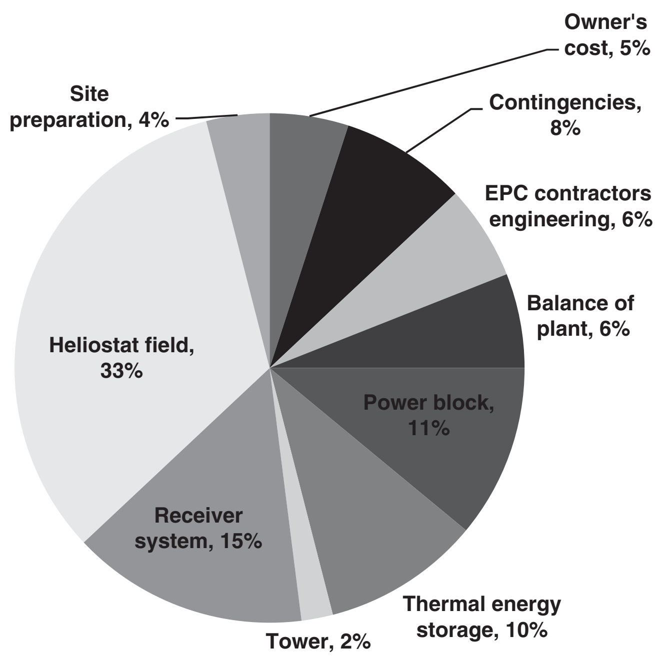
Monopolistic or oligopolistic market situations, especially in terms of the supply of critical, CST-specific components, might cause the respective components to be overpriced, thereby negatively affecting the overall investment costs and hence the CST-specific

Figure 5.2: CAPEX breakdown—parabolic trough (100 MW—13.4 h TES—US$914 m)



Source: Fichtner 2010.

Figure 5.3: CAPEX breakdown—power tower (100 MW—15 h TES—US$978 m)



Source: Fichtner 2010.

Table 5.5: Overview of cost elements and cost drivers

Cost elements	Cost drivers
Cost of land	• Space availability and cost • Taxation issues • Financing conditions available
Cost of solar field	• Cost of commodities • Monopoly/oligopoly rents • Economies of scale in production • Financing conditions available • Market demand
Cost of power block	• Cost of commodities • Financing conditions available • Market demand
Transmission connection cost	• Regulation • Distance from load centers • Technology • Financing conditions available
Storage	• Cost of commodities • Monopoly/oligopoly rents • Economies of scale in production • Financing conditions available
O&M costs	• Local content sensitivities • Local labor costs • Water availability and cost

Source: Authors' data.

Table 5.6: Local content sensitivities—Middle East and North Africa case study

	Local content (%)	Foreign share (%)	Local staffing demand (person years/ 1,760 hrs/yr)
Project development	0–10%	90–100%	6–20
Engineering planning	30–50%	50–70%	75–95
Technology (procurement)	30–60%	40–70%	145–220
Construction and site improvement	100%	0%	320
Operations and maintenance	90–100%	0–10%	40–45

Source: Kearney 2010.

Table 5.7: Cost reduction potential of economies of scale/volume production

Component	Reduction potential	Cost drivers
Receivers	45% by 2025 (for parabolic trough and Fresnel)	• Size scale-up • Production volume • Increased competition
Reflectors	20% until 2020 (for parabolic trough) 25% until 2025 (for power tower and Fresnel)	• New material compositions • Production methods

Source: Kearney 2010.

LCOEs. Such an inflated cost profile might seriously slow the development of the technology in general and in particular in an emerging market setting. This is because the more specialized and technically challenging the respective component is, the fewer the number of qualified competitors. For example, there are very few companies specializing in production of receiver tubes for parabolic trough, and Fresnel (Schott Solar and Siemens—formerly Solel) basically share the market and have relatively high earnings before interest and taxes (EBIT) margins of around 20–25 percent (Ernst & Young and Fraunhofer Institute 2010) or in supplying heat storage systems, thermal oils and central control systems. Also, as CST technologies are reaching a higher degree of commercialization, market consolidation has already taken place and is expected to progress. This would reduce the number of players in each segment of the value chain even further. With regard to developers, the first consolidation round has already taken place as large integrated infrastructure companies started buying up smaller start-ups to get access to their respective technologies. For example, Areva had bought Ausra (now Areva Solar), Siemens had acquired Solel Solar, Acciona had secured a majority share in Solargenix, and Alstom has a strategic relationship with BrightSource Energy.

Financing Conditions Available

The availability and type of financing for CST as for any other major energy installment will depend on the following: (a) the technology-specific overall capital requirements; (b) the perceived performance risk by investors and lenders, which in turn will depend on available performance data, the financial position of developers and the provision of performance assurance by developers; (c) the creditworthiness of the off taker; and (d) the regulatory and financial framework of the respective jurisdiction. The latter will not only determine the applicable taxation rates, but also the availability, viability, and predictability of any financial incentive provided, whether in the form of a FiT or the different incentives provided under an RPS regime. How these incentives are designed will have a considerable influence on the availability of financing as a properly designed regulatory framework can help mitigate risks and increase considerably investment for developers.

Technical and Scale-Related Cost Reduction Potential

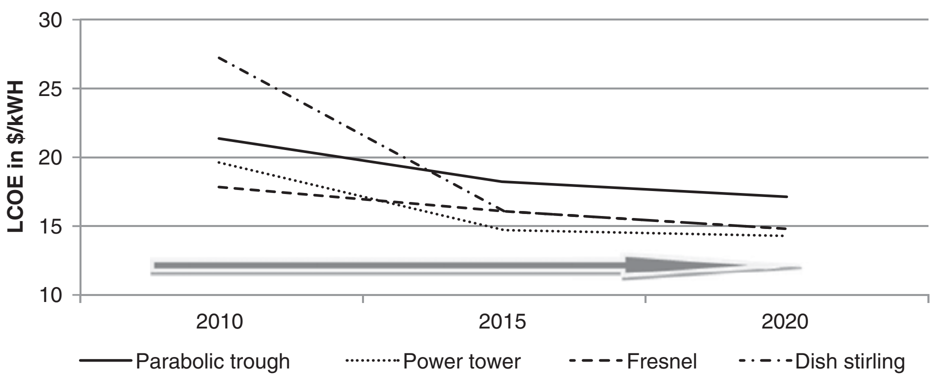
Component-Specific Cost Reduction Potential

Detailed component-specific cost reduction potentials for each CST technology are given in tables A.7–A.10 in Appendix A. These estimates are based on a detailed assessment of the respective cost drivers for each component and the underlying situation in the respective industries producing these components (YES/Nixus/CENER 2010). In summary, parabolic trough components showing the most potential for cost reduction include the reflectors (18–22 percent), reflector mounting structures (25–30 percent), receivers (15–20 percent), the heat transfer system (15–25 percent), and molten salt system (20 percent). Power tower system components showing the most cost reduction potential are the reflector mounting structures (17–20 percent), heat transfer system (15–25 percent) and molten salts (20 percent). Linear Fresnel system components showing the most cost reduction potential are the reflector mounting structures (25–35 percent) and receivers (15–25 percent), while for the Dish Stirling engine, it is the reflectors (35–40 percent) and reflector mounting structures (25–28 percent).

Technology-Specific LCOE Cost Reduction Potential

Based on these cost reduction potentials for individual components, the overall cost reduction potential for each CST technology is described in figure 5.4. The respective reduction potential was assessed through the modeling of reference plants, whereby calculations were performed without accounting for any costs related to the connection to the transmission system, costs related to the purchase of land or the use of water. A comprehensive picture of the actual cost reduction potential in each case emerges through the assessment of the cost reduction potential of all components for a specific technology provided in table B.7–B.10 in Appendix B.

Figure 5.4: Cost reduction potential for CST technologies

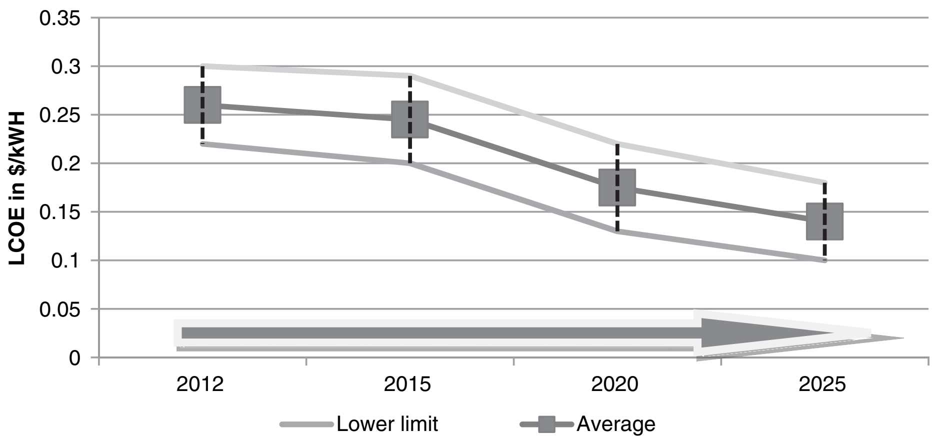


Source: YES/Nixus/CENER 2010.
Note: Numbers converted at EX US$1.35/Euro, based on averages of LCOE percentage cost reduction by 2015 and 2020.

Overall LCOE Cost Reduction Potential

A. T. Kearney (2010) performed a slightly different cost reduction potential evaluation on the basis of initial investment cost and performance data for a series of seven different reference plants spanning all CST technologies available, with the aim of calculating LCOE as the minimum required tariff necessary to ensure coverage of project financing, based on a 25-year plant runtime. This calculation took financing prerequisites (such as a typical debt service coverage ratio (DSCR) of 1.4) into account to derive cost reduction potentials for respective minimum required tariff CST-based output needed to repay debt, earn an adequate return on invested capital, and secure long-term financing. Figure 5.5 shows upper and lower estimates for LCOE reductions until 2025. The respective cost reduction projections can also be used to evaluate CST's future position within the overall supply mix (figure 5.5). In the best case scenario, CST might, for example, in the long term be able to substitute CCGT and potentially other fossil fuel–based plants as a peak to mid-load provider, depending on future fossil fuel prices. The hybridization of CST and the introduction of a carbon price could increase the likelihood of such a replacement.

Figure 5.5: LCOE reduction potential for CST



Source: Kearney 2010.

Financial Sustainability Assessment of Financial and Regulatory Incentives

In the near to midterm, well-tailored and appropriately designed regulatory and financial incentives will not only be necessary to ensure a particular project's financial viability, but most likely remain crucial in order to realize the projected cost reduction trajectories outlined above. Without such incentives, a major rollout of the technology seems uncertain or would most likely be delayed, which could alter the cost reduction trajectories considerably. By contrast, regulatory and financial incentives always entail a societal cost, either in terms of a fiscal expenditure or lost fiscal revenues, or in terms of increased electricity tariffs for consumers, if the cost of incentives is directly passed through to final consumers.

Even though these societal costs can be limited by applying recent lessons learned when designing the respective incentive framework—especially with regard to the design of FiTs (see Chapters 3 and 4)—most incentives granted to stimulate investment will still cause a more or less considerable societal cost burden which, depending on the respective jurisdiction, is ultimately to be borne by either the taxpayer or the final consumer, or both. Limiting the societal cost of incentives is therefore central to ensuring the sustainability of the incentives granted. This is even more crucial under developing country conditions where the overall fiscal position and individual income levels in most cases limit the overall resources that can be allocated to scaling up renewable energies.

The following pages entail a basic affordability and sustainability analysis for a variety of regulatory and financial incentives granted in three major emerging markets for CST—India, Morocco, and South Africa[3]—based on their impact on the LCOEs of 100MW reference plants in these markets. The main aim of this analysis is to find ways of optimizing regulatory and financial incentives in order to minimize both CST generation cost and the societal cost in purely financial terms. The tested incentives range from tax holidays to more favorable depreciation schemes and the use of concessional financing schemes (such as the IBRD, CTF, GEF, donor-supported output-based approach (OBA), and others). The analysis therefore generally aims to (see also table 5.8):

➪ *Determine the cost-effectiveness of different regulatory incentives and approaches in terms of their* ***impact on LCOEs*** *and hence their ability to facilitate investments* ***per dollar spent.***

Assessments were made for parabolic trough and power tower technologies, as well as both wet- and air-cooling methods, although, with the scaling up of CST in most emerging markets, the authors expect the majority of future plants in emerging markets to be air-cooled. All scenarios are based on the optimal amount of thermal electrical storage (TES)[4] for each reference plant,[5] which is determined by the combination of storage and solar multiple that minimizes LCOEs for parabolic trough and the optimal combination of storage and tower height and receiver dimensions for the power tower systems.

Table 5.8: Definitions used

Impact of a policy instrument	Impact of a regulatory incentive or approach on lowering LCOEs and hence facilitating investments
Cost-effectiveness of a policy instrument	Impact of a regulatory incentive or approach on lowering LCOEs and hence facilitating investments *per dollar spent.*
Societal cost	Total additional expenses caused by a particular policy instrument to either the taxpayer and/or the final rate payer.

Source: Authors' definitions.

Assumptions regarding prevailing capital and O&M costs, as well as macroeconomic, financial, and regulatory conditions in both markets, are outlined in table B.11 in Appendix B and were based on a variety of sources: (a) information regarding the actual capital and O&M costs and the financial and regulatory conditions faced in a particular jurisdiction, provided by developers;[6] (b) respective applicable regulatory documents in the cases of India and South Africa (CERC 2009a); (c) financial assumptions made for an internal analysis for an IBRD co-financed CST development in the MENA region, for the Moroccan case; and (d) informed assumptions by World Bank staff. The analysis generally assumes nonrecourse financing.

Impact Assessment of Different Regulatory Approaches to Lower LCOEs

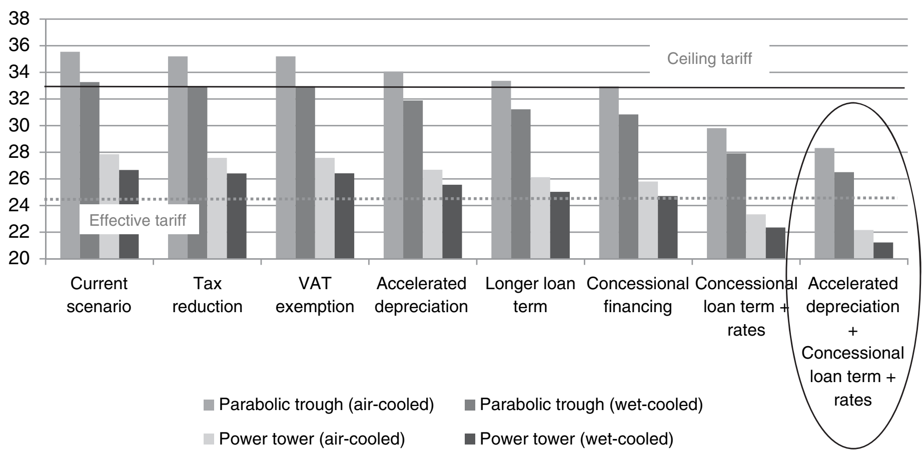
To determine the impact of different regulatory incentives and approaches in terms of their ability to lower LCOEs, and thereby facilitate investments, sensitivity analyses were run for the following incentives under the outlined assumptions:

- **Tax holidays/reductions** lowering the applicable corporate income tax rate by 50 percent.
- **VAT exemptions** lowering the amount of direct cost to which VAT applies from 100 percent to 70 percent.
- **Accelerated depreciation schemes** allowing for straight line depreciation over seven years.
- **Concessional loan terms** allowing for loan terms of 25 years.
- **Concessional loan rates** lowering the applicable debt interest rate by 3 percent, by blending concessional and commercial financing.[7]

INDIA

In the Indian case, the concessional financing terms—especially the concessional loan terms—have a far larger impact on LCOEs than simple tax reductions or exemptions. While relatively substantial tax cuts and exemptions only lower LCOEs by less than a percentage point, more favorable depreciation schemes can lower LCOEs by several percentage points. Concessional schemes, however, have the highest impact, with a 3 percent lower debt interest rate resulting in an approximately 7.3 percent lower LCOE in all four cases. The specific impact of each incentive for each technology in terms of their ability to lower LCOEs and facilitate investments is shown graphically in Figure 5.6 and numerically in table B.12 in Appendix B.

Figure 5.6: Impact assessment of different regulatory approaches on LCOE in India



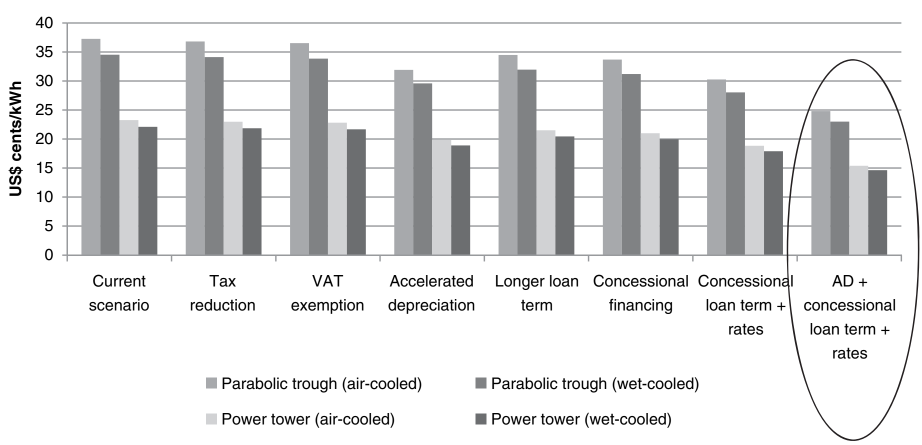
Source: Authors' data, using solar advisor model (NREL).

Given the current nominal CERC FiT, only power tower technology would currently pose a financially viable option. However, because of the program's reverse auction mechanism, the lowest bidding criteria lower the effective FiT available to a minimum of Rs. 10.49, or US$23.3 cents (which was the lowest winning bid in the recently concluded Phase I of the JNNSM). At this level, a modification of the current financial and regulatory incentive framework would be needed to allow LCOEs to drop under the threshold of the effective FiT level. A combination of concessional loan terms and rates is the single most effective incentive in ensuring that LCOEs—at least for power tower—would drop below the threshold.

Morocco

Under the Moroccan scenario, results are similar (see also figure 5.7), as concessional schemes again have a larger impact in terms of lowering LCOEs than simple tax reductions or exemptions. A combination of concessional loan terms and rates would lower LCOEs in all four cases by around 19 percent, whereas tax reductions or exemptions only lower LCOEs by 1–2 percent (see numerical presentation in table B.13 in Appendix B). The important difference, however, is that, opposed to the Indian case, accelerated depreciation proves to have a higher impact on lowering LCOEs in this scenario because of the much higher assumed corporate income tax rate in Morocco (accelerated depreciation creates a large tax shield in the first years of operation, which lowers the NPV of the total amount of taxes paid over the project's lifetime). Under our assumption of straight-line depreciation over seven years, LCOEs drop by around 14.5 percent in all four cases.

Figure 5.7: Impact assessment of different regulatory approaches on LCOE in Morocco



Source: Authors' data, using solar advisor model (NREL).

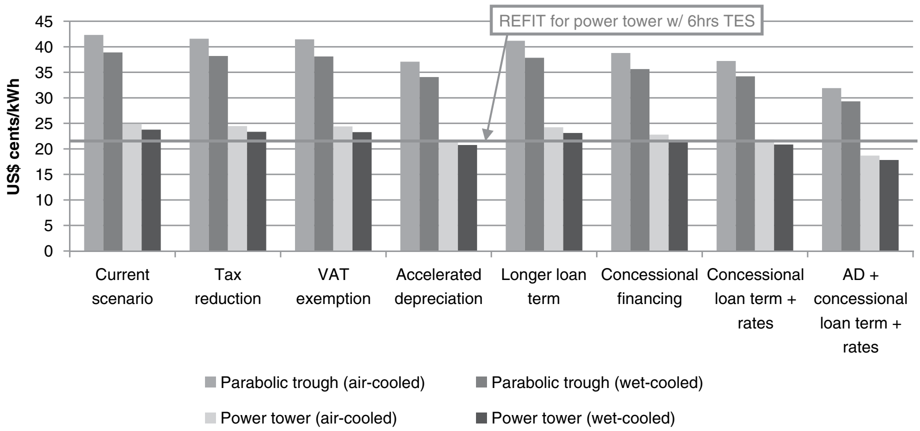
South Africa

Regarding South Africa, the same picture as in Morocco was observed (see also figure 5.8). In all four cases, the effect of the accelerated depreciation is a 12.5 percent lower LCOE, slightly larger than the one of combined concessional loan terms and rates, whereas again tax reductions or exemptions only have a minor impact on levelized cost (table B.14 in Appendix B). This would be even more important, given the slightly higher capital costs and less favorable financial conditions assumed for South Africa.

To allow power tower plants to become financially viable, a tariff of around ZAR 2.5 would be sufficient under the assumptions taken for this analysis. The tariff of ZAR 2.31

that would theoretically be available for power tower under phase two of the REFIT is already relatively close to this level, but is only guaranteed for 20 years—shorter than the expected lifetime of the plant. In addition, the REFIT tariff would only allow for power tower plants with up to six hours of storage which, based on this analysis, would not allow for the use of the optimal amount of storage to minimize LCOE for a particular power tower plant in South Africa. The tariff offered for parabolic trough under phase two of the REFIT at ZAR 3.14 seems unlikely to ensure the financial viability of any parabolic trough plant under the assumed circumstances.

Figure 5.8: Impact assessment of different regulatory approaches on LCOE in South Africa



Source: Authors' data, using solar advisor model (NREL).

Cost-Effectiveness of Different Regulatory Approaches to Lower LCOEs

Ultimately the financial cost-effectiveness of each incentive has to be determined in terms of its *impact on LCOEs and hence its ability to facilitate investments per dollar spent.* In order to provide more illustrative numbers, cost effectiveness was calculated in terms of the dollar amount that would have to be spent or the tax revenue that would have to be foregone in order to lower LCOE by 1 percent. By assessing cost-effectiveness, the report aims to provide policy makers with the information they need to choose a set of regulatory incentives that can both (a) maximize the impact on LCOEs and therefore facilitate investments; and (b) limit the overall societal cost in financial terms by maximizing impact per dollar spent. To represent the financial burden of an incentive program better, costs were extrapolated for 500 MW capacity, which was expected to come in the form of five individual 100 MW plants.

The actual composition of the societal cost mainly comes in the form of lower tax revenues (when tax reductions, VAT exemptions, and/or accelerated depreciation are granted) or in the form of additional expenditures (when concessional loan terms and/or rates are provided—in our example by blending concessional and commercial financing so as to lower the applicable debt interest rate for the debt share of each individual plant by 3 percent). The final value was calculated as the NPV of the difference in cash flows for income tax payments (for tax reduction and accelerated depreciation), the difference in upfront VAT payments on total direct costs (VAT exemptions) and the indicative cost of upfront fees and guarantees (in the case of concessional loan terms and rates).

In the latter case, it was assumed that concessional financing would be channeled to developers through a government intermediary that would cover expenses related to upfront fees and the purely administrative cost of providing the necessary guarantees. Under the assumption of a zero percent probability of default and not accounting for their economic opportunity cost, guarantees would under this framework have a relatively low societal cost in financial terms.[8] The analysis, however, quantifies the amount of guarantees that would have to be granted to allow for an easy calculation of societal cost if a higher probability of default is to be assumed. The overview of the results for India, Morocco, and South Africa are provided in tables 5.9–5.11. Since the differences between wet- and air-cooled assumptions are negligible, we omitted the wet-cooled cases to allow for a better overview.

All three concessional schemes—with longer loan terms (25 years in all three scenarios) combined with lower loan rates (3 percent, lower applicable debt interest by blending concessional and commercial financing)—are the most cost-effective ways of lowering LCOEs for both technologies in financial terms, as long as the assumed probability of default is less than 25 percent. The amount of concessional financing necessary to lower applicable loan rates would, however, be considerable—from around US$877 million for

Table 5.9: Sensitivity analysis India—cost-effectiveness of regulatory approaches

Technology	Incentive granted	Reduction in LCOE (%)	Cost effect	Cost impact for 500 MW (US$)	US$ per 1% LCOE
Parabolic trough *(Air-cooled—with storage)*	Tax reduction	**–00.96**	Lower tax revenues	81.7 million	85.1 million
	VAT exemption	**–0.96**	Lower tax revenues	47.2 million	49.1 million
	Accelerated depreciation	**–4.16**	Lower tax revenues	149.2 million	35.9 million
	Concessional loan terms	**–16.12**	Upfront fees and guarantees	2.2 million[a] (877 million in guarantees)	0.14 million
Power tower *(Air-cooled—with storage)*	Tax reduction	**–0.97**	Lower tax revenues	88.1 million	90.8 million
	VAT exemption	**–0.97**	Lower tax revenues	50.9 million	52.5 million
	Accelerated depreciation	**–4.17**	Lower tax revenues	160.8 million	38.6 million
	Concessional loan terms	**–16.19**	Upfront fees and guarantees	2.4 million[a] (945 million in guarantees)	0.15 million

Source: Authors' data.
a. These numbers were calculated assuming that the societal cost of guarantees, in financial terms and not accounting for economic opportunity cost, would consist of the front-end fee of 0.25 percent of the total loan amount. The actual loan amounts were calculated to cause a 3 percent drop in the cost of debt for the total debt capital share, based on a concessional fixed LIBOR + 1.5 percent rate.

Table 5.10: Sensitivity analysis Morocco—cost-effectiveness of regulatory approaches

Technology	Incentive granted	Reduction in LCOE (%)	Cost effect	Cost impact for 500 MW (US$)	US$ per 1% LCOE
Parabolic trough *(Air-cooled—with storage)*	Tax reduction	**−1.21**	Lower tax revenues	156.3 million	129.2 million
	VAT exemption	**−1.93**	Lower tax revenues	117.9 million	61.1 million
	Accelerated depreciation	**−14.31**	Lower tax revenues	296.1 million	20.7 million
	Concessional loan terms	**−18.77**	Upfront fees and guarantees	3.0 million[a] (1,189 million in guarantees)	0.16 million
Power tower *(Air-cooled—with storage)*	Tax reduction	**−1.20**	Lower tax revenues	188.4 million	157.0 million
	VAT exemption	**−1.98**	Lower tax revenues	142.3 million	71.9 million
	Accelerated depreciation	**−14.48**	Lower tax revenues	357.0 million	24.7 million
	Concessional loan terms	**−19.04**	Upfront fees and guarantees	3.6 million[a] (1,434 million in guarantees)	0.19 million

Source: Authors' data.

Table 5.11: Sensitivity analysis South Africa—cost-effectiveness of regulatory approaches

Technology	Incentive granted	Reduction in LCOE (%)	Cost effect	Cost impact for 500 MW (US$)	US$ per 1% LCOE
Parabolic trough *(Air-cooled—with storage)*	Tax reduction	**−1.75**	Lower tax revenues	144.0 million	82.3 million
	VAT exemption	**−2.01**	Lower tax revenues	126.2 million	62.8 million
	Accelerated depreciation	**−12.41**	Lower tax revenues	262.0 million	21.1 million
	Concessional loan terms	**−12.03**	Upfront fees and guarantees	2.4 million[a] (967 million in guarantees)	0.2 million
	Concessional loan rates		Upfront fees and guarantees		
Power tower *(Air-cooled—with storage)*	Tax reduction	**−1.77**	Lower tax revenues	168.1 million	95.0 million
	VAT exemption	**−2.05**	Lower tax revenues	146.6 million	71.2 million
	Accelerated depreciation	**−12.60**	Lower tax revenues	306.0 million	24.3 million
	Concessional loan terms	**−12.24**	Upfront fees and guarantees	2.8 million[a] (1,124 million in guarantees)	0.23 million

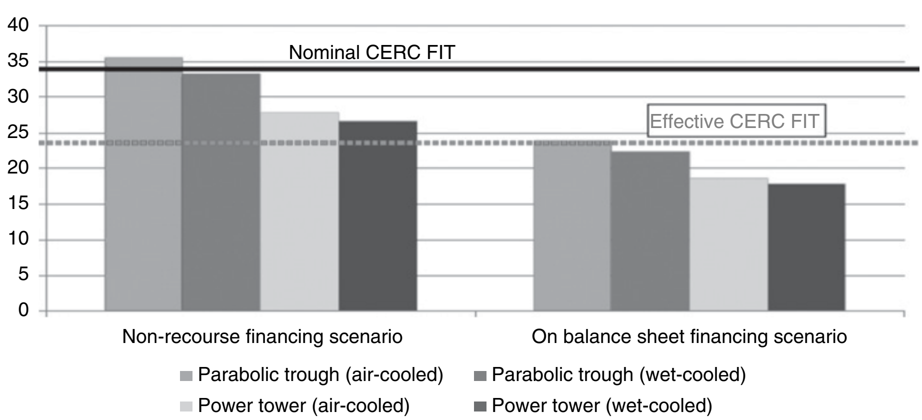
Source: Authors' data.

parabolic trough plants in India to more than US$1.4 billion for power tower plants in the case of Morocco, assuming a total capacity of 500 MW. Compared to simple tax reductions or exemptions that proved to be by far the least cost-effective incentive across all scenarios and technologies, requiring up to US$90 million in order to reduce LCOEs by 1 percent, accelerated depreciation seems by far a superior option. Although at US$21 to US$38 million per 1 percent reduction in LCOE is not that inexpensive, they might be worth considering in cases where—as seen in the case of South Africa—the existing regulatory incentive framework just needs to be moderately adjusted to lower LCOEs to the threshold where stand-alone projects become financially viable.

Balance Sheet vs. Off-Balance-Sheet Financing

All LCOE calculations in this chapter assumed largely nonrecourse or off-balance-sheet financing under the applicable financial and regulatory conditions in the respective jurisdiction, albeit complete nonrecourse project financing may be unrealistic for the first generation of such projects, since lenders may seek some limited recourse to the assets of the sponsor, particularly until the construction phase is completed and any cost overruns have been fully accounted for and paid by the sponsor. LCOE estimates, however, can in theory drop considerably if plants are financed on balance sheet, depending on the financial standing of the respective company. If a plant is to be financed on balance sheet, the assumption would be that the weighted average cost of capital (WACC) for the project would equal the general cost of capital of the respective company, which might be lower than the commercial loan rate a stand-alone project could receive. In addition, balance sheet financing might also avoid the need to cope with other constraints that nonrecourse financing entails, including the need to fulfill a minimum debt service coverage ratio (DSCR) and requirements for positive cash flows. By contrast, balance sheet financing increases the risk profile of a company's investments and might require cross-subsidization between projects, since the financial viability of a project on a stand-alone basis is no longer guaranteed. In the case of India (see figure 5.9), LCOEs would

Figure 5.9: Balance sheet versus off-balance-sheet financing effects on LCOE in India



Source: Authors' data.

drop considerably by around 33 percent for each technology under the assumption of a WACC based, for example, on a cost of capital of 8 percent for a large integrated infrastructure company, a repayment period that would stretch over the plant's economic lifetime (25 years), and no minimum DSCR requirements. This would bring LCOEs under the threshold of the effective CERC FiT (based on lowest bid), but would not necessarily make projects financially viable on a stand-alone basis.

Conclusions

Based on the above results, the following observations can be made:

- DNI accuracy matters—any underlying financial analysis for a CST plant is only as good as the quality of the DNI data the plant is modeled on. Given the inverse relationship between DNI and LCOE for CST plants, any analysis not based on data measured on the ground at the actual site of the project over the course of at least a full year will not provide sufficient grounding for a diligent financial model.
- For all technologies in all three scenarios considered, the LCOEs for stand-alone projects are most likely too high to allow for cost recovery and meeting financing constraints at present. This is specifically the case when the LCOEs are compared to the FiTs available for CST-generated electricity in Phase 1 of the JNNSM in India and the FiTs that have been proposed for Phase 2 of the REFIT scheme in South Africa. LCOE calculations based on balance-sheet financing might be considerably lower than calculations based on nonrecourse (off-balance-sheet) financing assumptions, such as the ones made for this analysis. However, balance-sheet financing increases the risk profile of a company's investments and might require cross-subsidization between projects, since the financial viability of a stand-alone project is no longer guaranteed.
- Financial and regulatory incentives, as well as concessional financing schemes, can significantly lower LCOEs. Within the range of considered financial and regulatory incentives, simple tax reductions and exemptions tend to have the lowest impact and are most likely the least cost-effective incentives in financial terms (not considering economic opportunity cost). By contrast, concessional financing schemes tend to have the highest impact and are likely to be the most cost-effective incentives in terms of their impact on LCOE on a per-dollar spent basis.
- With regard to the other incentives considered, accelerated depreciation, especially when compared to simple tax reductions or exemptions, seems to be the superior option. Although far from cheap, it might be worth considering in cases where—as seen in the case of South Africa—the existing regulatory incentive framework just needs to be moderately adjusted to lower LCOEs to the threshold where stand-alone projects become financially viable.

Economic Analysis of Reference CST Plants

This section presents an economic analysis, based on current investment costs, for reference 100 MW CST plants—both parabolic trough and power tower—in the respective three countries considered for the analysis—India, Morocco, and South Africa. The economic analysis consists of estimating full economic costs and benefits of individual projects, and calculating the economic net present value (ENPV) at a 10 percent discount rate and the internal economic rate of return (ERR). In addition, a sensitivity analysis was performed for the following scenarios: (a) 10 percent and 20 percent higher total project cost; (b) a 20 percent lower load factor; and (c) a 60 percent higher value of power. The main cost assumptions are provided in table B.15 in Appendix B, which in general summarizes the assumptions used in the analysis. The main results for the three countries are given in tables 5.10–5.12, respectively, for India, Morocco, and South Africa. The following general observations can be made across all three countries:

1. In none of the countries does the ERR achieve a rate required for infrastructure projects of over 10 percent. Without the carbon and other environmental benefits the ERR ranges from -0.65 percent to 4.8 percent for the power tower and from -2.55 percent to 3.8 percent for the parabolic trough. With carbon (and local pollutant benefits for Morocco), the ERR ranges from 2.1 percent to 8.8 percent for the power tower and from 1.1 percent to 7.4 percent for the parabolic trough.
2. Valuing carbon using the wider social costs of carbon rather than a single value increases the ERR by 1–2 percent (South Africa). If a single value is used the ERR goes up by about 0.5 percent.
3. The carbon values needed to achieve an ERR would be implausibly large in India and Morocco. In South Africa they would also be quite high, but one could argue that carbon emissions reduction projects with costs in that range (US$80–100/ton CO2) have been undertaken in other sectors.
4. The sensitivity analysis shows approximately a 1 percent reduction in the ERR for a 10 percent higher project cost and a further 1 percent reduction for a 10 percent

Table 5.12: Economic analysis for CST reference plants in India

India: central receiver power tower			Sensitivity analysis for the base case: Cost overrun		Load factor	Value of power
	Base Case	5Yr Delay	10%	20%	20% Lower	60% Higher
No carbon benefits	0.00%	2.39%	–0.74%	–1.39%	–2.64%	5.55%
Revised carbon benefits	3.95%	6.88%	3.10%	2.34%	1.30%	8.38%
Carbon price for 12% IRR						
US$/Ton CO_2	153.3	97.0	174.7	196.0	215.4	97.0
India: central receiver-parabolic trough			**Sensitivity analysis for the base case: Cost overrun**		**Load factor**	**Value of power**
	Base Case	**5Yr Delay**	**10%**	**20%**	**20% Lower**	**60% Higher**
No carbon benefits	2.11%	3.83%	1.47%	0.90%	–0.19%	7.00%
Revised carbon benefits	5.57%	7.95%	4.81%	4.14%	3.23%	9.53%
Carbon price for 12% IRR						
US$/Ton CO_2	137.8	87.3	159.0	178.5	196.0	81.5

Source: Macroeconomica 2011.
Note: the carbon price is for 2012 or 2017 in the case of the 5-year delay. The central value for 2012 is US$38.8/ton and the central value for 2017 is US$43.1/ton.

Table 5.13: Economic analysis for CST reference plants in Morocco

Morocco: Central receiver power tower			Sensitivity analysis for the base case: Cost overrun		Load factor	Value of power
	Base Case	5Yr Delay	10%	20%	20% Lower	60% Higher
No carbon benefits	–0.65%	1.46%	–1.46%	–2.18%	–3.45%	5.27%
Original carbon benefits	1.77%	3.94%	0.90%	0.13%	–0.98%	6.93%
Revised carbon benefits	2.07%	4.76%	1.19%	0.40%	–0.70%	7.15%
Carbon price for 12% IRR						
US$/Ton CO_2	252.3	159.0	291.1	302.40	357.1	157.2
Morocco: Parabolic trough			**Sensitivity analysis for the base case: Cost overrun**		**Load factor**	**Value of power**
	Base Case	**5Yr Delay**	**10%**	**20%**	**20% Lower**	**60% Higher**
No carbon benefits	–2.93%	–0.02%	–3.54%	–4.07%	–6.66%	–2.93%
Original carbon benefits	0.23%	2.14%	–0.45%	–1.06%	–2.85%	0.23%
Revised carbon benefits	0.87%	2.82%	12.04%	–0.45%	–2.12%	8.65%
Carbon price for 12% IRR						
US$/Ton CO_2	295.0	217.40	333.7	368.7	411.4	201.0

Source: Macroeconomica 2011.
Note: the carbon price is for 2012 or 2017 in the case of the 5-year delay. The central value for 2012 is US$38.8/ton and the central value for 2017 is US$43.1/ton.

higher project cost. A reduction in the load factor of 20 percent has a bigger impact—reducing the ERR by 2.5–3 percent.

5. The value of power is a critical factor in the ERR. Ideally it should be measured as the willingness-to-pay for the additional power. Using the market price as a proxy would result in an underestimated willingness-to-pay, since it ignores the consumer surplus, but the adjustment is small if the project adds only a small amount to the total generation and does not supply individuals who are currently without power or with limited access to electricity. In countries with power shortages, some adjustment for this factor has to be warranted. In any event, if the power supplied has a higher value, the ERR goes up a lot and can even exceed 12 percent (see, for example, table 5.12).
6. A delay in starting the project has two effects. First, there is a reduction in cost because of technology developments, and second there is an increase in the value of power, as consumers' willingness-to-pay increases. Decreases in the capital costs are assumed to be around 10 percent in the case of the parabolic trough and around 8 percent in the case of the power tower over the five years of delay assumed. The results of a five-year delay are to increase the ERR by 1–3 percent, depending on how much future power benefits rise (see tables 5.13 and 5.14).

Table 5.14: Economic analysis for CST reference plants in South Africa

South Africa: Central receiver power tower			Sensitivity analysis for the base case: Cost overrun		Load factor	Value of power
	Base case	5Yr delay	10%	20%	20% Lower	60% Higher
No carbon benefits	4.80%	5.55%	3.76%	2.85%	1.63%	12.00%
Original carbon benefits	7.04%	7.88%	5.92%	4.94%	3.80%	13.65%
Revised carbon benefits	8.81%	11.96%	7.65%	6.62%	5.55%	14.93%
Carbon price for 12% IRR						
US$/Ton CO_2	76.9	62.1	95.1	112.50	128.1	0.0
South Africa: Central receiver-parabolic trough			**Sensitivity analysis for the base case: Cost overrun**		**Load factor**	**Value of power**
	Base case	**5Yr delay**	**10%**	**20%**	**20% Lower**	**60% Higher**
No carbon benefits	3.80%	4.31%	2.97%	2.24%	1.04%	9.93%
Original carbon benefits	5.72%	6.39%	4.81%	4.02%	2.94%	11.33%
Revised carbon benefits	7.41%	8.63%	6.47%	5.65%	4.76%	12.52%
Carbon price for 12% IRR						
US$/Ton CO_2	104.8	78.7	124.2	143.6	158.9	31.1

Source: Macroeconomica 2011.
Note: the carbon price is for 2012 or 2017 in the case of the 5-year delay. The central value for 2012 is US$38.8/ton and the central value for 2017 is US$43.1/ton.

Country-specific observations include the following:

1. In the case of **India,** the results show that a parabolic trough has a higher return than power tower; a five-year delay increases the ERR by nearly 3 percent.
2. In the **Moroccan** case study, the delay is not as effective in increasing the ERR (possible because the increases in power value are more modest). Even with carbon and local pollutant benefits, the ERR is well below a test rate. Power tower appears to exhibit slightly better economics than parabolic trough.
3. For the **South African** case, because of the higher value of power and the revised carbon benefits, a 12 percent ERR can be exceeded with both technologies, although the power tower has a higher return by 1–2 percent. Including benefits of reduced local pollutants would increase the ERR further—by up to 1 percent.

When comparing air- and wet-cooling technologies, it becomes evident that there are clear differences between the technologies with respect to performance and cost, which are as summarized in table 5.15.

To indicate the impacts of the technologies on the ERR, the base case for each country has been rerun with the alternative technology. The results are given in table 5.16.

Table 5.15: Performance and cost penalties

Technology	Process	Performance Penalty	Cost Penalty
Power tower	Wet cooling Air cooling	None 1–3%	None 5%
Parabolic trough	Wet cooling Air cooling	None 4.5–5%	None 2–9%

Source: Macroeconomica 2011.

Table 5.16: Impacts of dry versus wet cooling technologies

	India	Morocco	South Africa
Parabolic trough			
Dry-Cooling Wet-Cooling	5.6% 6.7%	–0.5% 0.9%	7.4% 8.9%
Power Tower			
Dry-Cooling Wet-Cooling	4.0% 4.2%	1.8% 2.1%	8.8% 9.1%

Source: Macroeconomica 2011.

Wet-cooling technology increases the ERR in the case of the parabolic trough by around 1.5 percent and 0.2 percent in the case of the power tower.

The analysis presented here indicates that while power tower technology has a slightly higher return than parabolic trough, and the use of wet cooling can slightly improve the ERR, CST plants in general, assuming current prices, do not have an ERR that would meet commercial infrastructure investment requirements. However, investment costs are projected to decrease considerably over the coming years—a development that is expected to largely alter the economics of CST technologies. Further on, the decision to uptake CST technology might not necessarily be based on economic considerations alone, but might include other aspirations, such as gaining market leadership and experience through technology development or targeting the building-up of a local manufacturing industry. There are also potential ways of improving the economics of CST even under current investment cost assumptions through, for example, hybridization and the large-scale application of storage—areas that, however, remain outside the scope of this report.

Notes

1. The necessary physical weather data with regard to Direct Normal Irradiation (DNI) were taken from the U.S. Department of Energy's EnergyPlus Energy Simulation Software weather database.
2. An often-cited example of the lack of economies of scale in production is that the relatively high estimated LCOE for Dish Stirling at US$0.28–0.35/kWh will only be feasible with production levels above 500 Dish Stirling per year, which is unlikely in the short term. This leaves an increased interest in Dish Stirling as a source of distributed, off-grid generation in areas where fuel costs and fuel supply costs would make Dish Stirling competitive relative to fossil-based capacity.
3. To perform the affordability and sustainability analyses, this report relied on the Solar Advisory Model (SAM)—Version 2010.11.9—provided by the U.S. National Renewable Energy Laboratory (NREL) in cooperation with Sandia National Laboratories and the U.S. Department of Energy

Solar Energy Technologies Program (SETP). The model is widely used for planning and evaluating research, and developing cost projections and performance estimates, and it relies on NREL's and Sandia's long-standing experience with CSP. The necessary physical weather data with regard to DNI were taken from the U.S. Department of Energy's EnergyPlus Energy Simulation Software weather database. When no site-specific DNI data were available, mock DNI data for comparable sites and DNI resources were chosen.

4. The respective combination of storage and solar multiple/tower height and receiver dimensions was identified by running parametric simulations for a range of solar multiple, tower height, and receiver dimensions values.

5. The optimal amount of storage for each parabolic trough plant was based on the parametric simulation for a range of solar multiple values are the following: India, 6 hours with a solar multiple of 2.5; Morocco, 3 hours with a solar multiple of 1.75; and South Africa, 3 hours with a solar multiple of 1.75. For power tower plants, optimal storage is 15 hours in all three cases with a solar multiple of 3.

6. This information was provided by developers active in the respective country on a nondisclosure basis to bank staff. It reflects the assumed actual financial and regulatory conditions independent developers would be facing when considering the construction of a reference 100 MW CSP plant in their respective jurisdiction.

7. This assumes that concessional financing can be blended with commercial financing up to the amount of concessional financing necessary to lower the overall interest rate of the debt share of an individual plant by 3 percent, whereby the actual amount of concessional financing needed to reach a 3 percent reduction of the average debt interest rate depends on the commercial rate available. The assumption for concessional financing was a LIBOR + 1.5% interest rate.

8. In economic terms, guarantees indeed have an opportunity cost, since the money could have been used for activities with a higher economic rate of return. However, given that the use of available concessional financing is often limited to the financing of renewables, this opportunity cost can be regarded as relatively negligible. Likewise, the effect of guarantees on a respective country's balance sheet—potentially affecting a country's general interest rate—might not be sizeable in the case study countries considered for this analysis.

CHAPTER 6

Assessment of Local Manufacturing Capabilities for CST

To realize the cost reduction trends described in Chapter 5, a major scale-up of CST developments would be necessary, both in the already established markets, as well as in emerging markets in the MENA region, India, and South Africa. A major increase in CST capacity in emerging markets is, however, only likely when the countries concerned benefit from the technology for their economic development in general. One of the primary means to foster development could be the establishment of local manufacturing capacities. Local manufacturing would have the added benefit of reducing the cost of local projects in the near term and bringing down the cost for a variety of components and CST-related services in the mid- to long term. This chapter assesses local manufacturing capabilities in several emerging markets for CST, including the MENA region and South Africa. It also provides some estimates on the economic benefits and potential employment opportunities that could be generated. It should be noted that such estimates have been carried out on a gross basis, without considering the cost for reducing or not expanding alternative technologies.

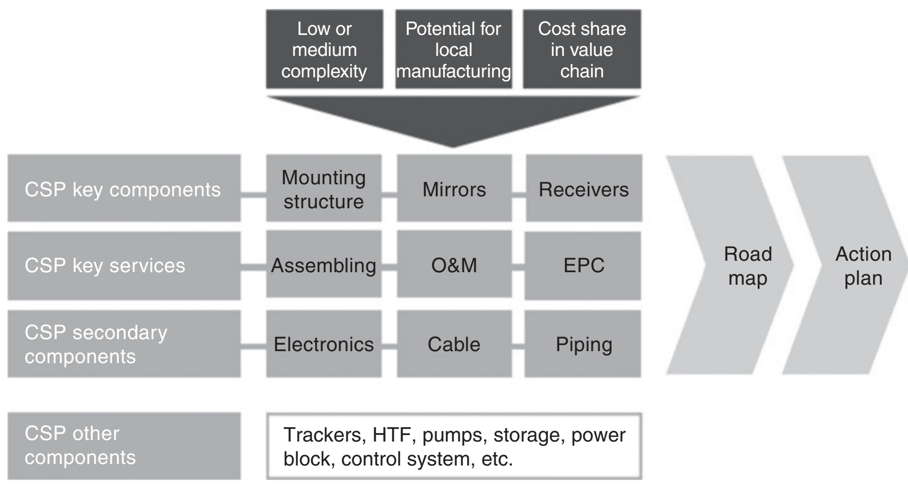
Local Manufacturing Capabilities in MENA[1]

The CST Value Chain in MENA

An evaluation of the MENA region's potential for developing a home base for CST requires a detailed analysis of the CST value chain: the technologies and services, the production processes, and the main industrial players. It is also important to review the cost of CST and contributions from individual components of the CST value chain. Based on the complexity level and the potential for local manufacturing, as well as the share of added value in the CST value chain, a number of key components and services can be identified that are most promising: key components include mounting structures, mirrors, and receivers, while key services range from assembling and EPC to operation and maintenance (O&M). Single countries within 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 CST projects, although their share in the overall value chain might yet be of minor importance. Figure 6.1 shows the different components and services linked to the production and use of CST.

Based on a detailed analysis of these components, it seems evident that there are a variety of opportunities for local manufacturing and the local provision of services all along the value chain.

Figure 6.1: Components and services for CST



Source: Ernst & Young and Fraunhofer 2010.

Drawing on a detailed analysis of (a) the global CST value chain (an overview is provided in table B.16 in Appendix B) and (b) a detailed assessment of the opportunities for MENA industries to manufacture CST components in the value chain, including an analysis of technical and economic barriers for local manufacturing (see table B.17 in Appendix B), the following SWOT analysis of MENA industries illustrating the respective strengths, weaknesses, opportunities, and threats for the industries with regard to participating in the CST value chain can be provided (see table 6.1).

- Aside from the SWAT analysis, the following general conclusions can be drawn: 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, such as parabolic mirrors or receivers, which nevertheless offer the highest reward in terms of value added.
- Some sectors and companies, such as receiver suppliers, strongly depend on CST market demand and growth. Other firms have built their production and manufacturing capacities to respond to the demand of other markets (CST is a niche for them).
- Some components (piping, HTF, electronics, power block) can be produced by companies without extensive CST know-how or background because this equipment is used for many other applications (chemical, electronic, and electric industries).
- The potential of MENA CST may be achieved by the manufacture of components by local, regional, and international companies, and the construction of CST plants in MENA by local construction companies and subsidiaries of international CST companies.

Table 6.1: SWOT analysis of MENA industries suitable for CST

Strengths	Weaknesses
• Low labor cost (especially for low-skilled workers) • One of the highest solar potentials in the world • Strong GDP growth over the past five 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 (for example, the automotive industry and, to a lesser extent, aeronautics) • SCCS plants in three countries constructed by 2010	• Insufficient market size • Administrational and legal barriers • Lack of financial markets for new financing • Higher wages for international experts and engineers • Higher capital costs • Energy subsidized up to 75% in some countries • Weak or nonexistent fiscal, institutional, and legislative frameworks for RE development • Despite regulations, implementation and enforcement of environmental regulations often deficient • Need for network of business and political connections • Lack of specialized training programs for renewable • Partly insufficiently developed infrastructure
Opportunities	**Threats**
• Further cost reduction of all components • Attractive to external investors • Solar energy: Moroccan Solar Plan (2 GW), Tunisian Solar Plan, and premises of an Egyptian Solar Plan, for example • Possibility of technology transfer or spillover effects from foreign stakeholders in MENA • Political will to develop a local renewables industry • Export potential (priority given to export industries)	• Training of workforce and availability of skilled workers insufficient • Technical capacities of local engineering firms • Low awareness of management of CST opportunities • Access to financing for new production capacities • Competition with foreign stakeholders: German players and strong interest of the United States in the Egyptian market • Higher costs compared to international players • High costs because of insufficient infrastructure

Source: Ernst & Young and Fraunhofer 2010.

- Production capabilities for some key components (mirrors and receivers) moved to the current CST markets in Spain and the United States as soon as the market (or prospects for the market) had attained a sufficient size. They could move to MENA when the CST market takes off in the region.

Potential for Local Manufacturing

In the near- to midterm, 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 CST projects and their customers. The companies employ local and international workers and engineers for projects in the countries. Comparable with conventional power plants, CST companies also expect a large share of project development, management, and engineering from international companies with extensive technical expertise and project experience. Table 6.2 provides an overview of the possible local content of different parts in the value chain as seen by international players.

Several industrial sectors with the potential to integrate the CST value chain in the MENA region are dynamic and competitive on a regional, and sometimes international, scale. The glass industry, for example, 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 Egypt, Morocco, and Tunisia. 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 industries was driven by the low cost for labor and energy (the latter in

Table 6.2: Possible local content by component of CST power plants

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%

Source: Ernst & Young and Fraunhofer 2010.

particular for Algeria and Egypt) and by the geographic proximity to Europe. To position themselves for the CST market, MENA industries face several challenges, mainly in adapting their capacity to 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 countries are aiming to be considered centers of excellence instead of low-cost and low-skilled workshops. Key findings on the status quo and future perspectives of local manufacturing include the following:

- Successfully constructed integrated solar combined cycle system (ISCCS) projects have increased CST 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 seen progress.
- Specialization of each country would be beneficial because local demand will probably be relatively low in the short and 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 CST mirror industry in MENA countries has significant potential.
- Involvement of international companies will play an important role in the midterm development of the CST 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 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 CST investment for a reference plant or approximately US$1 million per megawatt).
- **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.

- **CST-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 to a 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.

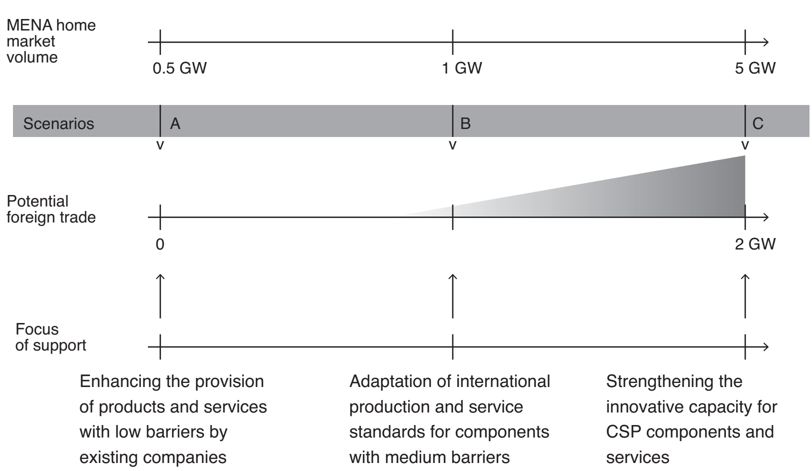
Possible evolutions of local CST industries for some of the key components (mirrors, mounting structure, and electrical and electronic equipment) in the MENA region are provided in Figure B.1 in Appendix B, taking into account the market size for different components.

Scenarios for Local Manufacturing in MENA Countries

It is assumed that the volume of installed CST capacity within the MENA region (the 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 therefore represent critical levels of market development for local manufacturing (for an overview, see figure 6.2).

Scenario A—Stagnation: The home market volume amounts to only 0.5 GW. Strong obstacles to local manufacturing of CST components remain in the country

Figure 6.2: Interrelations between MENA home market size, possible export volume and focus of support for local industries



Source: Ernst & Young and Fraunhofer 2010.

markets, and most components, particularly those whose production requires high investment costs, are imported from more advanced markets.

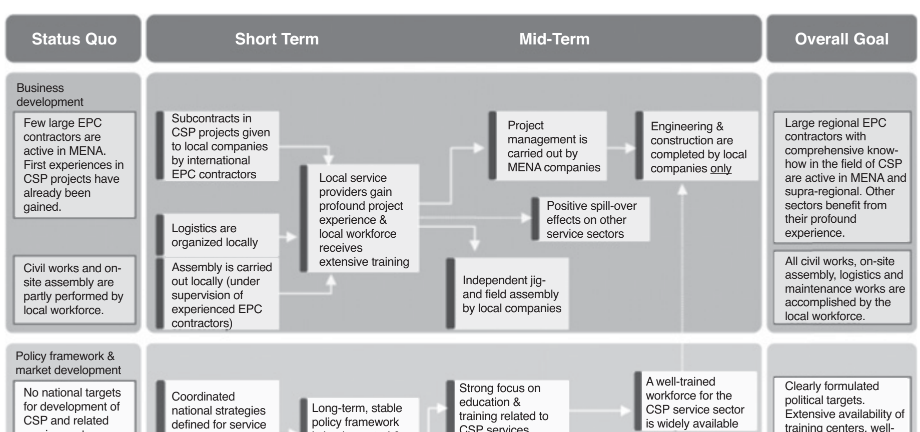
Scenario B—No-replication: The home market volume amounts to 1 GW in 2020. In this scenario, the market offers some opportunities for the development of local manufacturing of CST components and provision of CST services. This scenario aims at an adaptation of international production standards and techniques in existing industries, and leads to a region-wide supply of suitable CST components produced locally in the MENA 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 CST capacity. National CST 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 CST components.

Roadmaps for the Development of Local Manufacturing of CST Components in the MENA Region

Based on the assessment and identification carried out of existing and potential domestic and foreign players, potential routes to developing local manufacturing capabilities were identified. The aim of the roadmap is to show 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. Figure 6.3 provides a detailed roadmap for EPC services in CST projects. A further roadmap for key mirrors is to be found under figure B.3 in Appendix B.

Figure 6.3: Potential roadmap for EPC and services in MENA CST projects



Source: Ernst & Young and Fraunhofer 2010.

A detailed action plan for stimulating CST manufacturing and service provision in the MENA region was developed for all relevant actors (see also table B.18 in Appendix B) summarizing the potential measures addressed to different actors to stimulate the production of CST components and provide CST-related services in the MENA region that most likely would have to include the following:

- The creation of a stable policy framework and sustained domestic market for CST is a key precondition for the development of local manufacturing in MENA countries. Long term, the annually installed capacity should be on a gigawatt scale for the development of production lines, particularly in the case of mirrors and receivers.
- National strategies for industrial development and energy policy should be well coordinated and involve clear targets for the market diffusion of CST, substantial R&D efforts, strategy funds for industrial development of CST industry sectors, and stronger regional integration of policies.
- A provision of low-interest loans and grants specifically designed for local manufacturing of renewable energy components might help local companies raise the funds for the innovation of production lines or new company start-ups.
- Another direct political measure to foster a long-term demand for CST components would be the introduction of local (domestic) content clauses within CST tenders and other support instruments.
- To enhance the innovative capacity of the industrial sectors, the creation of a larger number of technology parks or clusters and regional innovation platforms should be pursued. This would particularly help small and medium-size firms overcome innovation barriers and 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, for example, in the form of joint ventures and licensing. In the case of receivers, subsidiaries of foreign companies will most likely be the relevant business model in the beginning. Governments could assist the private sector in the matchmaking process leading to such cooperation.
- The investment in new production lines based on highly automated processes for the mounting structure and glass production, as well as adaption of techniques for coating and bending mirrors, will be a crucial first step.
- Establishing local manufacturing will involve comprehensive education and training programs for the industrial workforce in relevant sectors. Universities should be encouraged to teach CST technology-based courses to educate the potential workforce, particularly engineers and other technical graduates.
- Additionally, to ensure regional and international quality requirements and to strengthen the competitiveness of future Middle Eastern and North African CST industries, implementing quality assurance standards for CST components should be considered in the medium to long term.
- For the service sector, local assembly of the plants and involvement of local EPC contractors are important initial steps for increasing the local component.

Potential Economic Benefits of Developing a CST Industry in North Africa

The economic benefits of developing a CST industry were evaluated for the three CST scenarios (stagnation, no replication, and transformation) for northern Africa.

The economic impact on GDP is depicted in table 6.3—economic impact is strongly related to the market size of CST in the Middle East and North Africa region. Scenario C creates a local economic impact of US$14.3 billion, roughly half of which is from indirect impacts in the CST value chain (excluding component exports), compared to only US$2.2 billion in scenario B.

Table 6.3: Direct and indirect local economic impact in scenarios A, B, and C

in Mio US$ (cumulated)	2012	2015	2020	2025	Local Share by 2025	Cost Reduction by 2026
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		

Source: Ernst & Young and Fraunhofer 2010.

The impact in terms of labor generation would be a permanent workforce of 4,500 to 6,000 local employees by 2020 under scenario B (for more information on estimating employment generation, see box 6.1). In contrast, in scenario C 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). Additional impacts for job creation and growth of GDP could come from export opportunities for CST components. Exporting the same components that are manufactured for local markets to the European Union, United States, 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 CST industries.

Local Manufacturing Capabilities in South Africa

The Potential CST Value Chain in South Africa[2]

Based on an in-depth analysis of the main CST related companies and sectors in South Africa—assessed were the glass, steel and allied industries, electronics, and cable manufacturing industries, as well as engineering consulting and project management and EPC firms, in order to determine the respective component-specific potential for local manufacturing (for details see table B.19 in Appendix B)—a SWOT analysis of RSA's potential CST value chain is shown in table 6.4.

Box 6.1: Estimating employment generation of CST development

One of the main justifications for providing financial incentives not only to CST, but to emerging energy technologies in general, is the employment generated by the specific energy sector. The actual amount of employment generated, however, can be estimated in different ways, making simple comparisons between studies of employment generated by a particular incentive framework potentially misleading. A recent World Bank paper by Robert Bacon and Masami Kojima (2011) describes the various measures of employment generation that are widely used and discusses the definitions and methodologies used. The paper compares for example approaches focusing on (a) estimating the incremental employment created by a specific project vs. (b) evaluating the total employment supported by an energy subsector at a moment in time; (c) evaluating the incremental employment effects of different forms of a stimulus program in which the energy sector is one possible recipient of government spending; or (d) comparing the employment creation of alternative energy technologies to achieve the same goal, whether it be the amount of power delivered or million dollars of expenditure. Generally the paper categorizes employment generated as either direct (those employed by the project itself), indirect (those employed in supplying the inputs to the project), or induced (those employed as a result of spending from the incomes of the direct and indirect employment), while a further distinction is made between employment for construction, installation, and manufacture (CIM), and employment for operation and maintenance (O&M). This report relies on studies that capture both the direct (project associated) as well as indirect (resulting from increased local manufacturing) employment.

Table 6.4: SWOT analysis of CST value chain in South Africa

Strengths	Weaknesses
• High growth in electricity demand resulting in substantial investments in the energy sector • Low labor costs • Diversified industry and strong financial institutions • Well-regulated public sector finances • Comparably high DNI • High manufacturing capabilities for float and bend glass, as well as for glass coatings • Strong presence of large power plant equipment manufacturers with significant manufacturing facilities • South Africa hosts some of Africa's largest steelworks and electrical cable manufacturers • Well-established supply industry—three of Africa's largest EPC companies • Highly reputable R&D institutions and universities staffed by highly rated scientists and engineers	• Sensitivity of local currency • Deficient transport and energy infrastructure • Administrative barriers and delays • Shortage of skilled employees and insufficient training of workforce • Scarcity of ground water resulting in cooling and wash water limitations
Opportunities	**Threats**
• Renewable Energy FiT encouraging CST activities • CST project pipeline of up to 5 GW, indicating high potential of CST implementation • Export potential to Sub-Saharan countries • South African leadership in CRS technologies in the long term in case of successful implementation • High potential for cost-effective CST component manufacturing • Attractiveness to external investors, developers, and manufacturers by large market demand • Improvement of energy security	• Restrictive labor regulations • Difficulties regarding access to financing • Lack of CST track record • Lack of bankable PPAs for renewable energy projects • Energy policy uncertainty regarding the role of IPPs in the renewable energy sector, as well as power sector reform • Governmental support for potential CST component manufacturers unclear • Competition with other emerging countries

Source: Fichtner 2011.

Box 6.2: Illustrative industrial development in RSA: automotive industry

The potential of local industries in South Africa to develop CST activities is confirmed by the phenomenal success of the automotive industry in South Africa established in the 1920s, which manufactures 83 percent of Africa's vehicle output (DTI, State of the Automotive Industry Report, September 2003), employs more than 200,000 people (NAAMSA Statistics), and has a local content ratio of at least 60 percent, meaning there are significant benefits to the local downstream industries, such as the fitting and turning factories within South Africa (NAAMSA statistics). Most importantly, the great majority of the more than 200 component manufacturers are South African companies.

Several lessons learned are identifiable from the automotive sector experience that could be rather valuable for CST manufacturing in South Africa, including the following:

(1) Lack of bank financing or fundraising might inhibit the industry's growth: The understanding of the financing of CST projects is still low in South Africa. The raising of finance on the local market could be a challenge.
(2) CST development might be more capital intensive than automotive sector investments. It would be difficult for the state to finance a CST project without adversely affecting its sovereign credit rating.
(3) There is no clarity on the administrative requirements yet for CST projects from the Departments of Public Enterprises and Energy.
(4) Despite the preliminary research that has been done on CST technologies, the CST industry is still in its infancy in South Africa. It will take several years before the knowledge of CST technology is widespread and able to sustain CST plants locally.
(5) Clarity on the contribution of CST to the power generation mix is required. The IRP2 has allocated a figure for renewable power generation that is being contested by most organizations. Finality of this issue is required so as to send a signal to potential CST power plant developers.
(6) Clarity on the role of IPPs in the power sector is urgently needed. Most of the people interviewed as part of this research have indicated that IPPs are expected to drive investment in future power plants. The power sector regulatory framework needs to be clarified urgently by the Department of Energy in order to give investment signals to investors.

Source: Fichtner 2011.

Potential for Local Manufacturing

As in the MENA region, the uptake of local manufacturing capabilities will be partly driven by major international CST industry players that have already established a presence in South Africa and are assembling land, organizing permits, and developing local partnerships, in order to prepare themselves to get involved on a significant scale in large-scale CST projects in South Africa.

The report has analyzed the status quo of the manufacturing capacity for CST components and the capacity to provide CST-related professional services, including EPC services (an overview is provided in table B.20 in Appendix B). The overall current proportion of local manufacturing for power plant projects is expected to be up to 60 percent, depending on whether specific CST components—for example, receiver tubes, HTF pumps, and swivel joints—can be locally developed and manufactured. For the "stagnation scenario," the local share is expected to be considerably lower for construction and components.

Under scenario C—the accelerated scenario—the local share in some projects could increase further. Local mirror and receiver production is seen as starting as early as 2015 for the acceleration scenario, which would also see the local production of other specialized, high-precision steel accessories for CST applications. Beyond 2020, the share of local manufacturing would increase even further because of more technology transfers and knowledge sharing through the realization of more CST plants in South Africa, since the learning effect is expected to fully play out around this time. This would also lead to a drop in the cost of locally manufactured CST components because of technological advancements, economies of scale, and competition in the CST component manufacturing sector.

The modeling for the local share of manufacturing does not include the modeling of local content requirements set out by the South African government, which would require foreign contractors to procure some material locally. A stable market and large market demand, as well as incentives for investors to venture into the renewable energy sector, will influence many investment decisions on the local production of CST components.

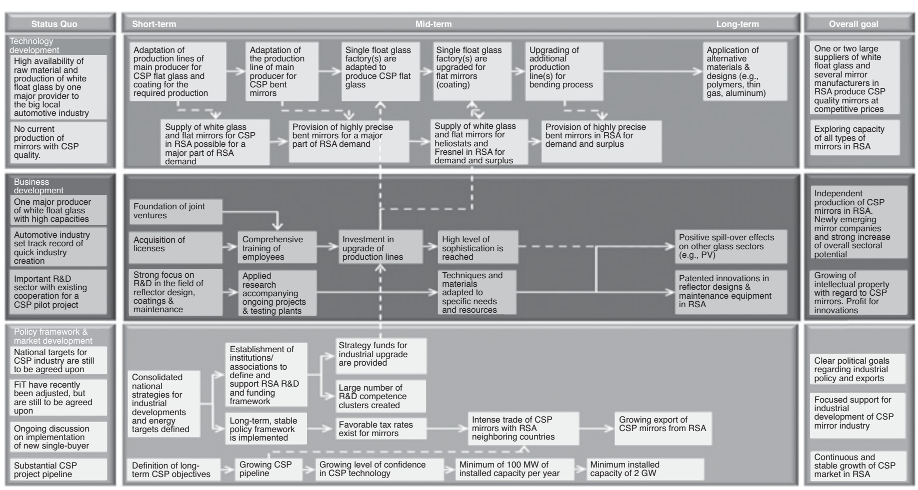
Roadmaps for the Development of Local Manufacturing of CST Components in South Africa

Figure 6.4 identifies potential routes for the development of local manufacturing capacities for glass mirrors in the short (up to 5 years), medium (between 5 and 10 years), and long term (beyond 10 years), setting out the main milestones required to provide both the local and export market. A roadmap for metal structures can be found as figure B.3 in Appendix B.

Potential Economic Benefits of Developing a CST Industry in RSA

New CST projects in South Africa will add valuable economic benefits to the country's economy and could support significantly the industrialization of South Africa and Sub-Saharan Africa, as well as the political endeavor of creating jobs. The creation of jobs will

Figure 6.4: Potential roadmap for the production of glass mirrors in RSA



Source: Fichtner 2011.

enhance the number of people with disposable income, which means an increased purchasing power of goods and services, which in turn increases the Foreign Direct Investment (FDI) by foreign companies wanting to take advantage of the improved disposable income in South Africa.

The socioeconomic and foreign trade impacts from CST plant development and component manufacturing in South Africa were analyzed based on a multistage modeling approach incorporating component specifications, based on technology requirements, as well as country and project-related assumptions for local manufacturing of components and plant construction.[3] The model applied used a cost build-up approach, which considers the effect of cost, economic and job effects on a component by component basis. The approach considered the same three scenarios as for the MENA region including scenarios, stagnation, and acceleration. The numbers indicated below are modeled for individual 100 MW reference CST plants using different technologies.

Direct and indirect economic impacts

Direct and induced economic impact values were calculated for each of the three scenarios using NREL's Jobs and Economic Development Impact (JEDI) model[4] and are depicted for a single 100 MW plant in table 6.5. In addition to the local manufacturing of components and the construction of CST plants, O&M services will also have a considerable positive impact. Direct economic impacts are related to the design, construction, operation, and maintenance of the CST power plants. Induced effects are economic impacts because of increased demand in the supply value chain, as well as multiplier effects resulting from increased disposable income.

Table 6.5: Estimated economic impacts for different CST technologies

Parameter	CST technology	Stagnation scenario (EUR million)	Base case scenario (EUR million)	Acceleration scenario (EUR million)
Estimated Direct and induced economic impacts over the project life cycle (project development, construction, O&M phase)	PTC without storage	140	180	280
	PTC with storage	374	412	475
	CRS without storage	182	230	334
	CRS with storage	358	392	448

Source: Fichtner 2011.

Impact in terms of labor generation

O&M services for CST plants will add a considerable number of jobs over a longer period once a particular plant is constructed. Wages and the number of employees were adapted to South Africa's lower wages and low mechanization of tasks, leading to more workers being employed over the lifetime of the plant. The increasing use of automated plant condition monitoring systems in power plants over time could, however, lower the number of jobs created during the O&M phase. The *estimated* results of the job impact assessment per single 100 MW plant are given in table 6.6.

Trade impact

With regard to the trade impact of CST component manufacturing in South Africa, the model is based on the assumption that exports will only take place if local demand exists

Table 6.6: Estimated job creation up to 2020 for different CST plant technologies

Parameter	CST technology	Stagnation scenario	Base case scenario	Acceleration scenario
Estimated number of jobs created over the project lifecycle (project development, manufacturing, construction, O&M)	PTC without storage	956	1,257	1,479
	PTC with storage	1,023	1,480	1,662
	CRS without storage	867	1,107	1,337
	CRS with storage	945	1,330	1,592

Source: Fichtner 2011.

in the region. Respectively, the modeling for this aspect considered only scenario C, under which components like mirrors or receivers are exported to markets in the European Union, United States, and MENA. If industry competition increases and costs of components are reduced after 2020, exports are expected to begin soon after 2020. In such a scenario, labor generation and direct economic impacts would increase significantly. It is expected that after extrapolating the CST capacity curve for the "acceleration scenario" beyond 2020, more than US$3.6 billion could be earned by exporting CST components to CST projects in Sub-Saharan Africa and the global market by 2030.

Notes

1. This section is based on the report of Ernst & Young and Fraunhofer 2010.
2. This section is based on the Fichtner report 2011.
3. Further assumptions included the following:
    - The job creation impact assessment has been done on an economy-wide basis.
    - The Jobs and Economic Development Impact (JEDI) model developed by the National Renewable Energy Laboratory (NREL) of the United States has been used as reference for this study, but the input figures have been changed to suit South Africa.
    - Effects of an internal CST market growth are considered to be linked with the export of CST components to the world market, such as to other Sub-Saharan African countries.
    - Scenarios cover the different cases of market development that will have different implications on the economic benefit and implementation of local supply and component manufacturing in factories of South Africa.
    - The JEDI model has been used to analyze the impacts for both the PTC and CRS technologies, with and without thermal storage.
    - The capacity factors assumed are less than 30 percent without thermal storage and 56 percent with storage.
    - The basis of the modeling is the impacts accruing from one CST plant, which is 100 MW.
    - The level of job mechanization has been taken to be low.
    - The DNI figures for the Northern Cape Province in South Africa have been used for modeling.
    - The job market in South Africa is highly influenced by low labor costs, limited availability of skilled workers, and lower productivity of the workforce. As a result, twice as many workers as needed are used for construction. Low worker productivity is due to low mechanization of construction-related tasks in South Africa's construction industry. The South African government has outlined its intention of creating jobs in its New Growth Path (NGP) economic policy. Labor Intensive Construction (LIC) methods are recommended for use by the South African Government on all large-scale projects.
4. Here a link to NREL's JEDI website and some information would have to be provided.

CHAPTER 7

Assessment of Procurement Practices

This chapter describes and analyzes various tendering models, practices, and the bid selection criteria typically used for CST projects based on current information available from the developers and utilities in developed markets, and then provides recommendations on tailoring these practices, criteria, and PPA structuring for developing country markets to help facilitate business transactions for CST projects. Recommendations are provided for key elements of each subtopic.[1]

Tendering Models and Practices

The procurement process should be examined in the context of the type of solicitation that is desired. Solicitations can be grouped into two main types: power procurement and project development. Power Procurement involves the purchasing of power by a regulated or public sector utility. This is a hands-off approach where the solicitor does not get deeply involved in the project details. Project Development, by contrast, requires significant involvement and expertise from the solicitor. The characteristics, as well as the advantages and disadvantages of each, are highlighted in table 7.1.

Table 7.1: Solicitation types summary

Solicitation types	
Power procurement	
Pros:	Cons:
Simplified role for solicitor—no detailed engineering or construction requirements generated	Potentially higher final cost because of mark-ups in value chain
Minimal expertise in project development needed	Little control over project
Project development	
Pros:	Cons:
Increased control over project structure and implementation	More time and effort from solicitor necessary to develop bid packages, evaluate bidders, and oversee construction and implementation
Potential for lower cost because of fewer steps in value chain	Significant expertise in project development required

Source: NOVI Energy 2011.

Once the motivations for the procurement are established, the next step is to determine the procurement process that will be used to implement the project. Options include procuring by Sole Source or by Competitive Bidding. Sole Source procurements involve selecting one contractor to perform the scope of work without holding a competitive bid. This is prevalent in the industry in the form of conglomerate companies taking on multiple roles in a project (owner/developer/EPC). Competitive Bidding is the alternative to Sole Source where requests for proposals (RFPs) are circulated, and multiple bidders respond with proposals. Each of these methods has been used in the past for CST and other renewable energy projects, and each has its advantages and disadvantages as summarized in table 7.2.

Table 7.2: Procurement methods summary

Procurement methods		
Sole source		
	Pros:	Cons:
	Minimal time spent on the selection process	Lack of competitive pricing that may result in higher project cost
		Repeated use may prevent new entrants into the industry
Competitive bidding		
Sealed bidding	Pros:	Cons:
	Competitive pricing	Potential to under-design systems to satisfy low price, which may affect performance and longevity
	Transparency	Inability to discuss complex procurements to make sure bid offering covers solicitation requirements
	Less time consuming than Open Bidding	
Open bidding	Pros:	Cons:
	Competitive bidding of the entire construction contract provides the lowest cost for the design requirements specified	Bid clarifications and negotiations can be very time consuming
	Provides the best assurance that bid content meets RFP requirements and is not over/under designed	

Source: NOVI Energy 2011.

The next step in the procurement process is to determine the contract structure that will be used for the procurement. Although there are numerous options for contract structuring, contracts used in renewable energy projects can be grouped into two broad categories: EPC Contracts and Multiple Contracts. The main characteristic of an EPC contract is that it offers protection to the owner from performance and/or cost overrun risks by bundling multiple services into one contract with these risks taken on by the contractor. However, this comes at the price of a risk premium charged by the EPC contractor. The Multiple Contracts approach minimizes the risk premium, but requires the owner to have expertise in managing multiple contractors to deliver the plant on time and within the budget and requires the owner to bear most of the risk.

Pricing Structure (table 7.3) also plays an important role in the procurement process. Pricing structures can be manipulated to shift risk from the owner to the contractor or vice versa, depending on the needs of the various players involved in the project. Pricing structures used in the renewable energy industry (presented in figure 7.1) include firm-fixed-pricing, time-and-materials pricing, and hybrids of the two that are meant

Table 7.3: Pricing structure summary

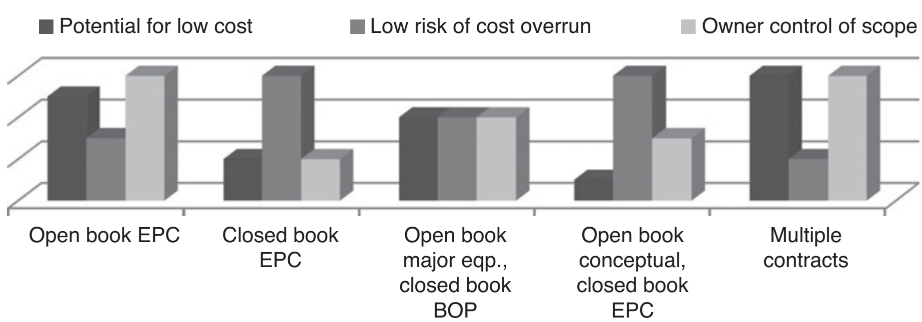
Pricing structure	
Firm-fixed-price	
Pros:	Cons:
Developer-owner completely protected from cost overrun risk	Highest risk premium from contractor may lead to highest overall project cost
	Fewer contractors may be willing to bid with this type of pricing structure because of unwillingness to take on risk
	Quality of subcontractors and products may be reduced in order to minimize cost overruns
Time-and-materials	
Pros:	Cons:
No risk premium; therefore, potential for lowest project cost	Highest cost overrun risk, no defined cap on the expenses incurred by the contractor
	No incentive for the contractor to stay within a project budget
Hybrid pricing	
Pros:	Cons:
Allows optimal balancing of cost overrun risk between parties	Some level of risk premium will be included in project cost
Maintains incentive for contractor to stay within budget	Quality of subcontractors and products may be reduced in order to minimize cost overrun

Source: NOVI Energy 2011.

to reallocate risk between the parties to accomplish certain objectives (such as incentive alignment).

Renewable energy based incentives are usually designed to achieve certain key policy goals and are usually developed in consideration with their setting. Renewable energy incentives affect the procurement behavior of utilities and in turn influence implementation of renewable energy projects. The schedule sensitivity of expiring incentives and availability of financing, as well as the mitigation of the numerous risks inherent in renew-

Figure 7.1: Contract type characteristics



Source: NOVI Energy 2011.

able energy projects, also influence the procurement and implementation of CST projects in developing nations.

Bid Selection Criteria

The choice of bid selection criteria is critical to the success of the procurement process. Effectively designed criteria help convey the needs of the solicitor and allow bidders to make optimal tradeoffs when developing project proposals. Multiple categories of bid selection criteria were considered for the planned and implemented CST projects, including cost-based, feasibility-based, value-based, and policy-based. Any one of these categories taken alone is insufficient to ensure an optimal match between the proposed projects and the solicitor's needs. Given the limited experience on bid selections in developing countries analyzed in this report, solicitors should be allowed to consider a range of project attributes and select the project that represents the best combination of tradeoffs for the solicitor's needs, by varying the weight applied to each factor. Thus, a recommended option for bid selection criteria design for CST projects in developing countries would be the weighted matrix evaluation approach. The weighted matrix evaluation method also allows the solicitor to more clearly convey their needs by way of published matrix weights as part of the RFP, thus increasing the likelihood that bidders will make appropriate tradeoffs. Without an advanced notice of bid matrix weights, bidders with the capability to provide an optimized proposal may fail to submit it because they would not know that it was, in fact, an optimal balance of the solicitor's needs. Minimum recommended criteria from each subcategory that should be included in a weighted bid matrix for CST projects in the case study of developing countries are provided in box 7.1. The weights should be selected by each individual solicitor to best reflect the relative importance they place on each factor, and therefore no weight recommendations are provided in box 7.1.

Box 7.1: Recommended bid selection criteria for CST in developing countries

Cost-based
Level of concessional financing

Feasibility-based
Company/team experience*
Company financial stability*
Technology maturity
Interconnection feasibility
Site control
Environmental approvals
Ability to raise financing
Levelized cost of electricity (LCOE)

Policy-Based
Speed of implementation (schedule)

Value-Based (optional)

Source: NOVI Energy 2011.
*These criteria are optional as separate requirements if "Ability to Raise Financing" is an included criterion.

Cost-Based

If a FiT is the primary incentive granted in a particular jurisdiction, choosing the lowest level of concessional financing as the cost-based criterion can be recommended. Since the payment to the winning bidder under a FiT is set regardless of the cost of their project ("guaranteed payment rate"), using a cost-based criterion, such as lowest up-front CAPEX or LCOE to choose the winning bidder would not be effective. The result of using one of these criteria would be that all bidders would understate their up-front and/or O&M costs so that their bid would appear to be the lowest, knowing that they would receive the guaranteed payment rate regardless of the cost they report. This incentive misalignment makes it difficult (if not impossible) to select the project with the lowest cost. Evaluating bids based on the lowest level of concessional financing provides an alternative that minimizes this issue. Bidders will want to use the highest level of concessional financing possible to maximize their project returns. However, they will want to use the lowest level in order to be selected as the winning bidder. This healthy competition will serve to minimize the likelihood that a bidder will understate the level of concessional financing required. Use of this criterion will help maximize the benefit from the concessional financing available through organizations offering such financing. The use of this criterion should not affect the attractiveness of the procurement to potential bidders. Bidders will be attracted to the procurement if the FiT is high enough to make a project profitable. Requiring bidders to use the lowest level of concessional financing possible will just change the way they structure their project.

It is worth noting that if the FiT were structured as a "cost-plus" payment, where it pays a set premium over the selected bidder's LCOE, this would reduce the incentive for bidders to understate their costs and make the LCOE measure more useful as a cost-based bid selection criterion. This could be a consideration of incentive design. However, this solution is not without its drawbacks. Structuring the FiT as "cost plus" may make it less desirable for the more cost-efficient bidders, since their lower costs will no longer result in a greater profit. For example, the level of the FiT could be set based on the understanding by the tariff setter (for example, a regulator) of what an average plant of the type considered should cost to set up and operate. Since the FiT is fixed for all bidders, the regulating body should pick this average value (or somewhere above the lowest value) because they do not want to excessively limit the number of bidders who will find the tariff attractive. In the case of a fixed, average-cost FiT, the lowest cost generator will realize a greater profit from the FiT than an average cost generator, incentivizing the low-cost generator to develop as many projects as possible (good for the country). If a "cost plus" tariff were implemented, both the low cost and average cost generators would have a similar incentive to participate.

Another potential option is that taken by India's JNNSM bid selection criteria. The JNNSM guidelines contain a provision that requires bidders to propose a discount to the offered FiT. Using these proposed discounts, the solicitor chooses the projects equaling the desired capacity with the largest discount offered. While it is not a method of determining the underlying cost of the project or selecting the bidder with the lowest cost structure, it results in lower-priced electricity for customers, as long as the winning bidders can actually deliver the bid capacity at the respective discount they offer. This method would only work, however, if bidders are offering more capacity than desired, because otherwise, the risk of nondelivery can undermine the targeted policy goals regarding the total installed capacity.

Feasibility-Based

Consideration of feasibility-based criteria is critical to ensure that time and money are not wasted by selecting projects with a low likelihood of success. Company and team experience should be considered, since it has a direct effect on the likelihood of project success. If a similar project has been successfully completed by the team, the chances of their completing the next project successfully are increased. Financial stability of the bidder is also important to assure that the project won't be jeopardized by bankruptcy and/or other financial issues with the project developer.

While CST technology is constantly evolving and improving, some consideration should be given to the maturity of the proposed technology to minimize risk. The weight applied to this factor can be small if the solicitor feels that the benefits of improved technology efficiency outweigh the risks of successful implementation. It is recommended that early phases of CST program implementation for a given country place a higher weight on technological maturity to ensure that the program has a successful start. Once several successful projects have been completed and the country has experience implementing CST projects, they should consider reducing the weight of technological maturity. This will allow for newer, more efficient technologies to be employed and reduce the average capital cost per MW and O&M expenses (and thus the LCOE) of the industry. A failure of a new technology would not be as damaging to the program after it has already been implemented in other projects, since it would be if one of the first projects had failed. This appears to be the approach taken by India in its JNNSM. The technical requirements state that during Phase I only CST technologies "which have been in operation for a period of one year or [. . .] for which financial closure of a commercial plant has already been obtained" will be considered. While it is not explicitly stated in the documentation, the notice that these requirements apply for Phase I, could infer that less mature technologies may be eligible for the Phase II implementation.

Some consideration should be given to the ability to raise financing. An assessment will have to be made regarding the project's "bankability." Factors, such as the types of contracts and pricing used (for example, Full-Wrap EPC with Firm-Fixed-Price vs. Multiple Contracts with Time-and-Materials), the maturity of the technology, and the security of the off take agreement (resulting from a stable legal and regulatory structure), will help determine the ability to secure project financing. The solicitor should also consider any existing commitments from debt or equity providers and their terms and conditions. If a project proposal shows that it can raise financing (that is, the project already has firm debt and equity commitments), the above criteria regarding team experience and company financial stability can be considered optional. This is because equity providers and lenders typically go through substantial due diligence to examine team experience and company financial stability before agreeing to provide capital for a project.

While LCOE is typically used as a cost-based measure, the previous discussion highlighted why it should not be used as one in the case of a procurement offering a guaranteed payment rate (FiT or generation-based incentive), as is the case in Algeria and South Africa. However, it can effectively be used as a feasibility-based criterion to understand if the project developer will be able to implement the project at the cost reported. By requiring bidders to submit their estimated LCOE, the solicitor will be able to use its previous experience, an outside contractor (such as the owner's engineer), or a comparison with other bidders' responses to make a judgment regarding the feasibility of achieving the cost presented. If costs appear to be unrealistically low, the score for this criterion can be lowered.

Policy-Based

The only policy-based criterion called out in the minimum recommended bid matrix is speed of implementation ("schedule"). However, more policy-based criteria should be included in the evaluation, depending on the specific policy goals of each individual solicitor. The project schedule should be considered by all solicitors, since it will directly affect the achievement of their phased renewable energy policy goals. It is important that the weight of the schedule criterion be chosen carefully by the solicitor. If too much weight is given to the schedule, it can drive up the project cost.

It was not prudent to provide a minimum recommendation for other policy-based criteria because of the variability and range of potential policy goals that different solicitors may wish to factor into their evaluation. Examples include (but are not limited to) local employment and content requirements, preferences for certain technologies and preference for distributed generation over large centralized plants. In considering other policy-based criteria, the solicitor must be careful not to create overly restrictive policy-based requirements. To ensure that the maximum number of bidders respond to the RFP, restrictive criteria, such as minimum domestic content or required use of local labor, should be used sparingly and with caution. In many cases, the project economics will drive the developer to use domestic content and local labor; however, in other cases these restrictive criteria may reduce the attractiveness of the RFP and discourage qualified bidders from responding.

Value-Based

Value-based criteria are considered optional in the minimum recommended bid matrix criteria for CST projects in developing nations. Examples of value-based criteria include grid stabilization (for example, variability management, known as VAR management), dispatchability and ramp rates (fast start-up), black start capability, and time of day of power supply. While this category can theoretically add value to the bid selection process, if the solicitor does not see value in the characteristics presented or does not anticipate variation among bids, this category might add unnecessary complexity to the bidding and evaluation process. For example, if the solicitor cannot easily quantify the benefit of VAR reduction or if the nature of the transmission and distribution system in the country necessitates that all of the bids submitted have black start capability (because of frequent blackouts), it would not be necessary to include these characteristics.

Additional Considerations

Fostering competition

When choosing bid selection criteria, the solicitor should consider each criterion's affect on increasing or reducing the pool of eligible and willing bidders. Feasibility-based criteria are primarily employed to ensure that the probability is high that the project will be successful, enabling the policy goals of the solicitor to be met. If no feasibility-based criteria are employed, the solicitor may end up choosing project proposals with little chance of success because of the immaturity of the technologies proposed or to developer inexperience. However, if the feasibility-based criteria chosen are too restrictive, they may eliminate many potential bidders and leave the solicitor to choose from only a few options. This would most likely result in higher project costs and suboptimal realization of policy goals. An example of this would be if the solicitor required a high experience threshold for potential bidders, such as experience with multiple projects that have been in operation for several years, using the proposed technology in the proposed scale.

Reducing project cost

As discussed above, it is difficult to control the cost of a project and ensure that the lowest-cost projects are selected when the incentive offered is a fixed FiT- or generation-based incentive that is not based on the specific project's cost of power (as is the case in Algeria and South Africa). With this incentive structure, the IPP will receive a predetermined amount per kilowatt-hour regardless of the actual cost to produce power. Therefore, there is no incentive for them to report accurate cost information as part of the bid process. If the FiT were structured as a "cost-plus" tariff as suggested above, this would allow the solicitor to use the LCOE method to choose the lowest-cost project because the bidder would have incentive not to overestimate or underestimate their cost of generation. So unless the incentive structures are revised in the case study countries, it would be difficult for them to choose bid selection criteria that effectively reduce project costs and result in selection of the lowest cost bids.

PPA Structuring

From the prospective of a project developer (seller), the primary purpose of a PPA is to provide revenue security to the project. A well-crafted PPA assures that if the project is built and operated properly, the electricity it generates will be purchased by an off taker at a predetermined price. Given the large capital cost required and the specificity of generation assets, such a revenue guarantee is required to secure financing for the project.[2] This is especially the case with regard to projects structured with high levels of non- or limited-recourse debt. For balance sheet financing (owner or utility financed), the need for a PPA is dependent on specific circumstances.[3]

From a buyer's prospective, the primary purpose of the PPA is to provide power supply assurance at the lowest possible cost. Therefore, from a buyers' point of view, the PPA should warrant that the project is completed on schedule and that it delivers the promised capacity and energy generation.

With these primary purposes identified, PPAs were analyzed along with other industry feedback to determine the different ways the goals of the seller and buyer could be met by the PPA, and recommendations are provided for the components that should be included in an optimal PPA for CST projects. Considerations when selecting the recommended PPA elements included characteristics of solar technologies, as well as aspects that may be applicable to projects in developing countries, such as concerns over transmission and distribution system reliability, off taker credit strength and the stability of the government, which will determine whether the executed contracts or promised government incentives are honored. The recommended elements were chosen to help alleviate these concerns and ultimately make a PPA more attractive to sellers and financiers, while still meeting the needs of buyers. These recommended elements are shown in box 7.2.

Dispatch Agreement

Based on the various PPAs reviewed, including both CST and other types of renewable energy generation, the best practice for solar PPAs is to include a fixed dispatch agreement

Box 7.2: Recommended PPA elements for CST projects in developing countries

Fixed dispatch with sharing of curtailment risk
Energy payment adjusted using PPI/CPI/exchange rates/LIBOR
Time of delivery factors for energy payments
Renewable energy credits bundled with energy
Seller development security (refunded at commercial operations)
Seller performance security (throughout term of PPA)
Buyer payment security (throughout term of PPA)
Opportunities to rectify default before contract termination
Seller repricing or exit on incentive cancellation
"Political" force majeure provisions

Source: NOVI Energy 2011.

that allows the project to deliver power whenever the solar resource is available (subject to transmission constraints and energy caps). The risks associated with an intermittent resource with a variable dispatch agreement would make it particularly difficult to finance the project. As thermal storage systems mature, allowing longer storage times and more control over when the power can be delivered, it is recommended that any CST PPA be structured as a fixed or "as-available" dispatch agreement to help minimize revenue risk.

The risk allocation of curtailment should be addressed by the PPA as well. If the buyer has responsibility for the transmission system, the buyer should bear at least some (if not all) of the risk that the project would be curtailed because of transmission system constraints or problems. This is especially important in developing countries because of limitations with respect to transmission and distribution systems, and the seller may not have control over those issues.

Energy Payment

PPAs for projects in developing countries may need several forms of adjustment to protect both the buyer and the seller from large operating costs, exchange rates, and interest rate changes. It can be recommended that adjustment clauses in CST PPAs use indexes that track the cost of labor, if available, since it is typically the greatest component of CST operating costs. If a labor cost index is unavailable, an alternative would be to use a consumer price index (CPI) as a proxy for labor cost. Along with the labor cost index, a targeted PPI should also be used to adjust a portion of the payment if operating costs other than labor may vary significantly over the term of the agreement.

The buyer and seller should also consider currency exchange rate adjustments if input costs or debt are in a foreign currency to protect against appreciation of the input cost or debt currency relative to the revenue currency. Additionally, LIBOR-based (or the locally applicable interest rate benchmark) adjustments should be considered if the debt interest rate is variable. If the renewable energy incentive present in the market is a FiT (and therefore not subject to adjustment), the seller can reduce its exposure to exchange rate risk by sourcing equipment from the local area and securing capital denominated in the local currency. Interest rate risk can be mitigated by financing the debt with a fixed interest rate.

A fixed escalation percentage based on historical price inflation can be used; however, the volatility (or standard deviation) of the historical inflation is a key factor. If volatility is high,[4] a fixed escalation percentage would leave the seller exposed to large potential input cost increases, which would make the PPA less attractive to the seller and potential sources of financing. Algeria, India, Morocco, South Africa, and Tunisia all have moderate PPI/Wholesale Price volatility (see table B.21 (Producer Prices) and table B.22 (World Bank) in Appendix B), which may allow for agreements on a negotiated fixed escalation percentage, while Egypt and Jordan have relatively high volatility, making adjustments using an index more appropriate for these markets.

The energy payment should also be structured to account for the time of day and time of year that the project supplies energy (time of delivery factors). This allows the buyer to communicate to potential sellers the value of energy provided at different times of the day and allows CST sellers to receive the justified premium for their power since it is typically generated during peak demand periods.

Capacity Payment

None of the PPAs reviewed (including one project with thermal energy storage) contained capacity payment provisions, since capacity payments are typically designed to cover the fixed costs of the project. Solar generating facilities have high fixed costs with low variable costs (fuel is free) and therefore, if a capacity payment covering the majority of the project's fixed costs was included in a CST PPA, the seller would have less incentive to produce any energy. However, having some portion of the fixed costs covered by a capacity payment guaranteed by a PPA would serve the purpose of reducing project risk and increasing the likelihood of securing financing. As a result, the inclusion of capacity payments that pay for a portion of the upfront fixed costs should be considered by both the seller and the buyer.

Renewable Energy Credits

Renewable energy credits can either be bundled with the energy sold to the buyer or can be retained by the seller to be sold through third-party contracts or in the spot market. Given the relatively unknown price volatility of green attributes, it is recommended that any renewable energy credits be sold along with the energy from the project to lock in those revenues and help reduce the overall risk of the project.

Non-performance and Default

Development security

The existence of a development security in the PPA is a good incentive to help ensure that bidders don't overpromise and underdeliver. It also prevents the seller from being granted rights resembling a put option where the seller could walk away from the PPA and sell its output to another off taker if electricity prices increased (abandon the option). In the event of decreasing electricity prices, the seller could "exercise" the put option and receive the "strike price" (also known as the PPA energy payment rate) by delivering under the PPA (Lund and others 2009). This would be unacceptable to buyers since their long-term capacity planning would be affected if a seller were to walk away from the PPA and would then have to procure the shortfall at now-higher market prices. Additionally, a development security helps to ensure that the project remains on schedule and becomes operational in time for the buyer to meet customer obligations.

Performance security

A performance security would help ensure that the buyer receives the energy promised by the seller throughout the term of the PPA. This security could be provided in the form of a letter of credit from the seller or an escrow account. The escrow account could be funded by withholding a small portion of each monthly payment due to the seller. Once an agreed-upon escrow account cap is reached, there would be no more withholding unless an event occurred that required withdrawal from the account. A drawback of the proposed escrow account is that it builds over time and a large amount would not be available at the start of commercial operations. However, smaller developers may have difficulty securing a letter of credit to provide this security, so alternatives such as an escrow account should be considered. While it was not observed in any PPAs reviewed, a combination of an escrow account and a letter of credit could also be used to mitigate these issues. Penalties for non-performance can be viewed as a substitute for easy exit clauses, since they both provide incentives to perform. However, performance penalties are more palatable from the perspective of potential lenders, since PPA termination puts debt service in serious jeopardy, while performance penalties (assuming they are not overly severe) will still allow the project to recover and remain in operation.

Payment security

In situations where the buyer's credit quality is weak, it is recommended that a payment security be included in the PPA, similar to the provisions in the JNNSM template PPA. These could include an irrevocable letter of credit and/or an escrow account to provide security that those payments will be made. The escrow account in this case could be funded by diverting some portion of the buyer's revenues (from other activities not part of this PPA) into the account, up to an agreed-upon cap. This would help reduce the buyer's default risk and would help secure project financing.

Exit clauses

Exit clauses should not allow for too easy of an exit for either party. If the buyer could easily exit from the PPA, financing the project would be difficult. If the seller could easily exit, it would have rights resembling a put option. However, a specific exit clause related to the uncertainty around any government incentives should be considered to allow the seller to reprice or terminate the contract if planned incentives are not implemented. In general, it is better to use performance penalties to provide assurance that the seller meets its obligations than allowing the buyer to terminate the PPA at the first sign of default.

Substitution Rights

The need for substitution rights in a PPA can be determined by the severity of the exit clauses and performance penalties mentioned above. If the buyer is unwilling to give sufficient time[5] for the seller to rectify any issues that lead to a loss of generation or imposes high penalties for non-performance, the contract should include some form of substitution rights to allow the seller to fulfill its obligations through another means. If the seller is given reasonable time to prevent any defaults prior to the buyer being able to terminate, contract substitution rights would not be necessary. This is the preferred method, since it avoids introducing operational, delivery and reliability concerns that may result from substituted power coming from an uncertain or changing source.

Force Majeure

A good force majeure clause should include separate lists of events that *are* and *are not* force majeure to help reduce ambiguity that can be present in this clause. Additionally, force majeure should only be used when events are out of both parties' control and should not be used to remove the risk from a party that is primarily responsible for the outcome (Lund and others 2009).

Force majeure typically includes acts of war and natural disasters. However, events that may occur in developing countries (such as government failure to act, a change in law, or a boycott or embargo of the country by others) should be captured as "political" force majeure to protect both buyer and seller.

Purchase Obligation

While not mandatory, a purchase obligation requiring the buyer to purchase the project under certain circumstances (for example, prolonged force majeure) would serve to improve the project's chances of obtaining financing, since it would give potential lenders the assurance that the debt service would still be covered if unexpected events occur. However, the value of this type of obligation is entirely dependent on the credit quality of the buyer.

Notes

1. This chapter is based on the NOVI Energy report 2011.
2. Assets can be considered "specific" when they can only be used for one purpose (cannot make other products or products cannot easily be sold to other buyers). Solar generation assets are highly specific because they are often located in remote areas with limited off taker options, and are not easily moved.
3. There are many combinations of financing structures that will have different needs with regard to revenue security. If a utility is building its own self-financed plant and "selling" to them, a PPA may not be necessary. The key point is that the purpose of a PPA is to provide revenue security when necessary, given the specific financial and ownership structure of the project.
4. The definition of "high" will depend on the risk tolerance of the seller and its financing sources. Developed nations typically have PPI volatility in the range of 1–4 percent (see table B.23 in Appendix A).
5. The length of time that qualifies as "sufficient" will be different, depending on the cause of the default. The key point here is that if the buyer is unwilling to allow some flexibility regarding the curing of a default, the seller should negotiate for substitution rights to be included in the contract.

Source: NOVI Energy 2011.

APPENDIX A

Overview of Concentrating Solar Thermal Technologies

Applications of solar thermal technologies (including CST) are best suited for regions that experience high levels of DNI. These regions are typically located in dry areas such as deserts, which also have the advantage of plentiful land unused for agricultural or industrial purposes, see figure A.1.

The Prometheus Institute investigated the use of solar technologies and found that CST technologies are primarily suited for larger scale installations, while PV-based technologies are more suited for smaller scale or distributed generation applications (Grama, Wayman, and Bradford 2008). Photovoltaic panel theoretically are applicable wider geographically, but a certain level of diffused radiation is needed in order to make the electricity generation economically viable.

Solar thermal technologies also have geographical limitations and work only in regions that possess a certain level of DNI, not lower than 2,000 kWh/m^2/year. The main advantages of CST applications include less intermittency because of the system inertia; the possibility to use CST in a utility scale operations and the option to integrate thermal storage, thus making power generation possible during extended hours when the sun doesn't shine.

The following factors are typically cited as drawbacks of the current application of CST technologies:

- CST-based plants are presently characterized with high electricity generation costs, which can be decreased by technological innovations, and economies of scale, that is, volume production, and larger-sized units.
- Only locations with irradiations of more than 2,000 kWh/m^2/yr are suited to a reasonable economic solar thermal performance (Viebahn and others 2008).

The four primary CST technologies differ significantly from one another, not only with regard to technical and economic aspects, but also in relation to reliability, maturity and operational experience in utility scale conditions. Given the different levels of technological maturity of the technologies, the biggest experience is accumulated through implementation of projects using the parabolic trough technology and, to a lesser extent, the central receiver application. The main results of the technical assessment of the technologies are summarized in tables B.1 and B.2 in Appendix B

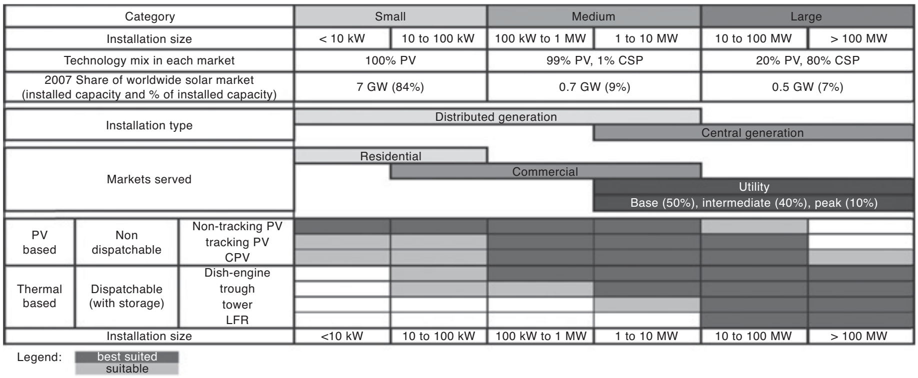
In the sections below, relevant design features of each technology are briefly discussed and a review of the status of technological maturity is presented.

Parabolic Trough

Overview[1]

Parabolic trough power plants consist of many parabolic trough collectors, an HTF system, a steam generation system, a Rankine steam turbine/generator cycle and optional thermal storage and/or fossil-fired backup systems. The collector field is made up of a

Figure A.1: Markets and applications for solar power

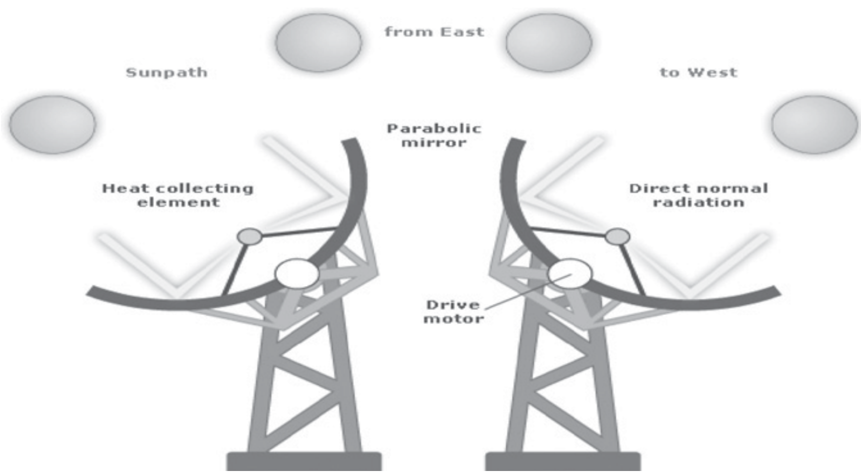


Source: Grama, Wayman, and Bradford 2008.

large number of single-axis-tracking parabolic trough solar collectors. The solar field is modular in nature and comprises many parallel rows of solar collectors, normally aligned on a north-south horizontal axis. Each solar collector has linear parabolic-shaped mirrors that focus the sun's direct beam radiation on a linear absorber pipe located at the focus of the parabola. The collectors track the sun from east to west during the day to ensure that the sun is continuously focused on the linear absorber (see Figure A.2).

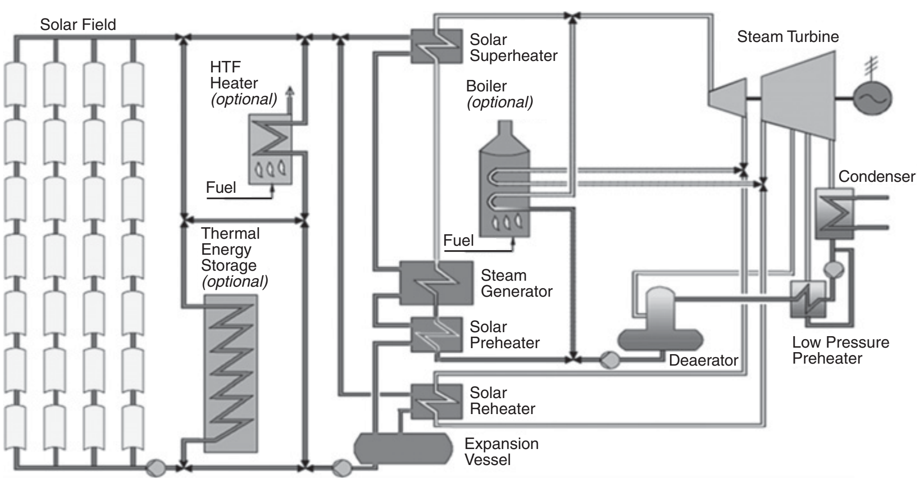
An HTF is heated up as it circulates through the absorber and returns to a steam generator of a conventional steam cycle.

Figure A.2: Illustration of parabolic trough collectors and sun tracking



Source: Radiant & Hydronics 2006.

Figure A.3: Basic scheme of a parabolic trough power plant



Source: Ecostar 2005.

The basic scheme of a parabolic trough power plant can be observed in figure A.3. The system can be divided into the following three parts:

- The solar field.
- The power block (with optional re-heater).
- The piping and heat exchangers.

In this scheme, two optional elements of a CST plant are also represented: the Thermal Energy Storage (TES) and the back-up boiler (BUB), usually working with natural gas. Both of them increase the capacity factor of the system, allowing the plant to operate even when there is not enough direct solar radiation, and sometimes to fit to a demand curve. Introducing one of these systems allows solar thermal power plants to deliver reliable, dispatchable, and stable electrical energy to the grid. Moreover, it improves the use and amortization of the power block (YES/Nixus/CENER 2010).

Parabolic trough solar fields are modular; they can be implemented at any capacity, which provides a great versatility. Even so, the optimal capacity for current technology is estimated to be about 150–200 MW.

The key components of parabolic trough systems are the receiver tubes, curved mirror assemblies (concentrators) and HTF.

Receiver tubes

The receiver is the component where solar energy is converted to thermal energy in the form of sensible or latent heat of the fluid that circulates through it. It is a critical component for the performance of the solar power plant because it is where thermal losses are produced. This makes it probably the most important component in the system. Currently, the vacuum tube receiver is the only type of receiver available for parabolic trough power plants. The main providers are Schott and Siemens (Solel Solar Systems), but new manufacturers like Archimede Solar (from the Angelatoni Group) and China entrants have also emerged lately.

Curved mirror assemblies

The purpose of the concentrator mirrors is to concentrate solar radiation on the receiver located in the line of focus. Their parabolic geometry and optical reflectivity are extremely important because they are the basic properties that make it possible to concentrate the solar energy efficiently. For this reason the mirrors usually have a support structure to give them the rigidity they require and on which a film of a highly reflective material is deposited. In general, the support structure that provides the rigidity to the parabolic-trough mirror is a metal, glass or plastic plate, while the reflective material is usually silver or aluminum. The material most commonly used to date for collector reflector mirrors is the glass substrate mirror with silver deposition, which reaches maximum reflectivity of around 93.5 percent.

Heat transfer fluid

The purpose of the HTF is to absorb the energy provided by the absorber tube in the form of enthalpic gain by increasing in temperature as it goes through the solar field collector loops. The hot HTF goes to a heat exchanger to heat water and generate steam at a certain pressure and temperature. The solar field outlet temperature is restricted by the HTF properties, and this means that the fluids that can perform these functions are also limited.

Experience over the years has shown that by increasing the solar field outlet temperature, the performance of the power block and thereby the whole plant also increases significantly. The commercially proven technology is limited to a temperature of around 400°C, after which, in addition to degrading the fluid, thermal losses increase and the selective coatings also may be degraded. Therefore, there are several lines of R&D today directed at studying both working fluids and the rest of the components.

The fluid currently in use in commercial plants is synthetic oil. Synthetic oil's advantages include a much lower vapor pressure than water at the same given temperature, so pressures required in the system are much lower, which allows simpler facility and safety measures. Furthermore, current oils have responded very well to the current needs of commercial plants, as their maximum temperature coincides with the optimum collector operating temperature. Disadvantages include a high price, and a maximum working temperature below 400°C, which limits the power cycle temperature and, therefore, its electrical conversion efficiency.

Molten salt is another alternative HTF. The salt most commonly used in solar applications is nitrate salt with advantages including low corrosion effects on materials used for solar field piping, high thermal stability at high temperatures, low steam pressure making it possible to operate at relatively low pressures in its liquid state and its availability and low cost. The main disadvantage is the high freezing point of the salt, which may range from 120° to 200°C depending on the type used. The freeze-protection strategy is very important in this case, and several different techniques are necessary to maintain the fluid above a certain temperature: constant circulation of salt, auxiliary heating and heat tracing throughout the piping (Kearney and others 2004).

Technological Maturity[2]

Compared to all other CST technologies, parabolic trough is the most mature. Built between 1984 and 1991, the largest operating group of solar plant systems in the world—with a total capacity of 354 MW—is the Solar Energy Generating Systems (SEGS) I–IX parabolic trough plants, in the Mohave Desert in Southern California now owned by Next Era Energy (owned by Florida Power & Light).

In 2007, the first new large parabolic trough power plant, Acciona Solar's Nevada Solar One, started operation in the United States. Nevada Solar One has a net electric output of 64 MW and is a solar-only Rankine cycle power plant generating approximately 130 GWh of peak power a year (equals a capacity factor of about 23 percent).

In 2009, the first large European parabolic trough power plant, Andasol-1, started operation. This was a milestone in the development of the parabolic trough system, since Andasol-1 is the first large-scale, commercial parabolic trough power plant equipped with thermal energy storage. Andasol-1 has a total net electric output of 50 MW and is equipped with a two-tank molten salt storage system with a thermal capacity of 1,050 MWh in combination with an oversized solar field, which enables storage charging during daytime full-load operation, and additional night time operation of up to 7.5 hours. Because of the large storage and a proportionally larger solar field, the 50 MW Andasol I power plant will generate approximately 170 GWh per year, significantly more than the larger Nevada Solar One power plant without storage and with a smaller solar field. Therefore the capacity factor could be increased to above 39 percent.

Andasol-1 was the first of around 50 CST plants under construction or development in Spain. Because of the Spanish FiT for CST plants, there was a CST capacity of more than 2,300 MW preregistered in Spain before the end of 2009, with most of the power plants using parabolic trough technology. At present there is approximately 1.2 GW of CST plants in operation divided nearly equally between Spain and the United States. Besides Spain and the United States, there are also several other parabolic trough power plants in advanced development stages throughout the world. An outline of parabolic trough power plants under operation and construction or development is given in table B.3 in Appendix B.

Linear Fresnel

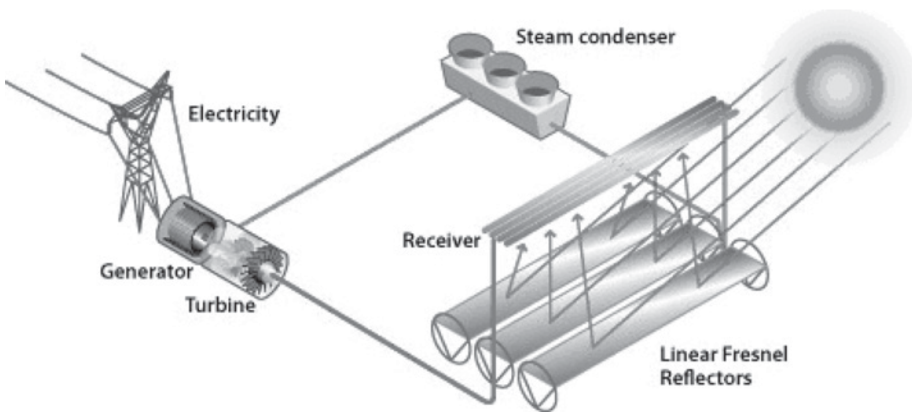
Overview[3]

Linear Fresnel power plants consist of many Linear Fresnel reflectors, an HTF system, a steam generation system (if not direct steam generating), a Rankine steam turbine/generator cycle and optional thermal storage and/or fossil-fired backup systems (see figure A.4).

The main difference between the parabolic trough technology and the Fresnel technology is the reflector configuration. Similar to the parabolic trough, the Fresnel collector is designed as single-axis tracking. Therefore, the Linear Fresnel reflectors concentrate sunlight using long flat-plane mirror strips that are grouped in a mirror field close to the ground. The sunlight is focused onto a linear fixed absorber located above this mirror field and optionally equipped with an additional secondary reflector located above the absorber (see figures A.5 and A.6).

While the Linear Fresnel concept could use an oil HTF, the configurations in development are mainly based on direct steam generation (DSG), that is, circulating water/

Figure A.4: Linear Fresnel system diagram



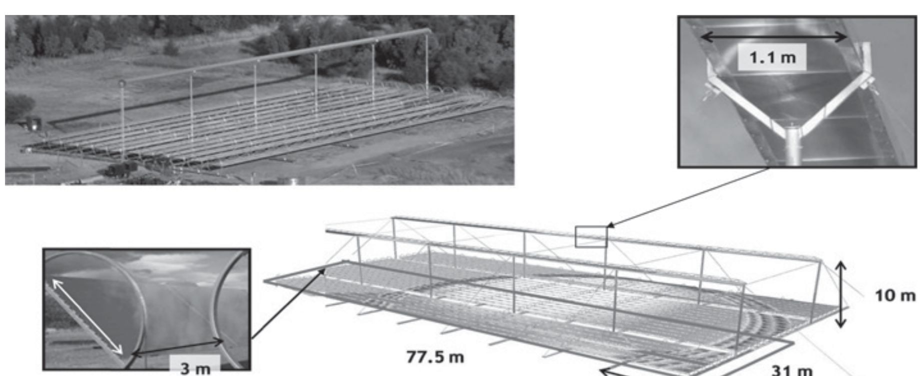
Source: U.S. Department of Energy n.d.

steam in the receiver serves as a heat transfer medium (HTF). Hence, a separate steam generation system is not required in the case of DSG. Those Fresnel trough systems are currently operating with saturated steam parameters of up to 55 bar/270°C, but in the medium and long term, superheated steam generation is proposed. Similar to the parabolic trough system, the Linear Fresnel system can also be operated with HTFs based on molten salt or synthetic oil.

The latest development is called the Compact Linear Fresnel Reflector, which is a new configuration to overcome the limited ground coverage of classical LFR systems.

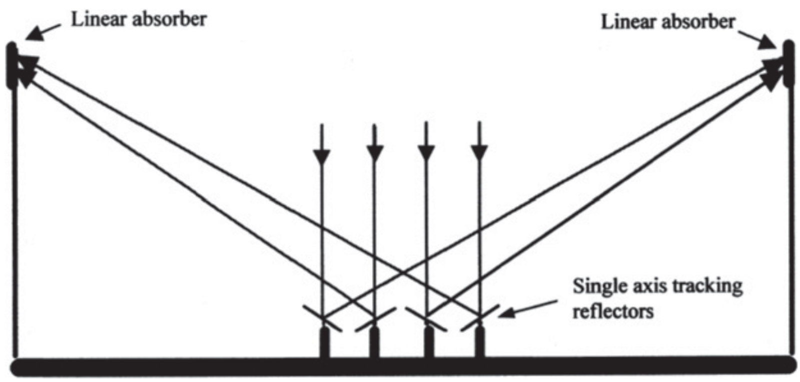
The classical LFR system has only one raised linear absorber, and therefore there is no choice about the direction of orientation of a given reflector. However, for technology

Figure A.5: Views of linear Fresnel reflector arrays



Source: Morrison 2006.

Figure A.6: Example of a CFLR system source



Source: YES/Nixus/CENER 2010.

supplying electricity in the multi-megawatt range, there will be many linear absorbers in the system. If the absorbers are close enough, then individual reflectors can direct reflected solar radiation onto at least two adjacent absorbers. The additional variable in reflector orientation allows much more densely packed arrays with minimal shading and blocking.

The Linear Fresnel technology may be a lower cost alternative to parabolic trough technology for the production of solar steam for power production. The main advantages, compared to parabolic trough technology, are seen as:

- Inexpensive planar mirror and simple tracking system.
- Fixed absorber tubes with no need for flexible high pressure joints.
- No vacuum technology and no metal-to-glass sealing and thermal expansion bellows for absorber tubes for lower temperature configurations.
- Absorbers tubes similar to troughs likely for higher temperature designs.
- Because of the planarity of the reflector strips and the low construction above ground, wind loads and material usage are substantially reduced.
- Because of direct steam generation (DSG) within the absorber tubes, no separate steam generator is necessary.
- Efficient use of land.
- Lower maintenance requirements are postulated.

However, there is also a significant drawback related to the LFR technology. LFR systems suffer from a performance drawback because of higher intrinsic optical losses (fixed absorber) compared to parabolic trough systems. Different studies evaluated a reduction in optical efficiency of around 30–40 percent compared to parabolic trough technology, which then must be compensated for by lower total investment costs.

Technological Maturity[4]

Fresnel technology is still at an early development level compared to other CST technologies like parabolic trough. That is why there are only a few examples of small scale pilot and demonstration projects employing the Fresnel technology. Some existing projects are highlighted in the paragraphs below.

The Liddell Power Station is located in New South Wales, Australia. This power plant is coal powered, with four 500 MW GEC (UK) steam driven turbo alternators for a combined capacity of 2,000 MW. In 2004, AUSRA developed the world's first solar thermal power collector system for coal-fired power augmentation, called the John Marcheff Solar Project. In a first phase, this solar module generated one megawatt equivalent (MW) of solar generated steam. This facility was expanded in 2008 with the construction of a second phase, which has a power capacity of 3 MW.

Another project, known as Fresdemo, is the first LF demonstration power plant built in Spain. It is located in the PSA, Almería. The demonstration LF system, which has a 100-meter-long collector, generates 1 MWh (peak) and is designed as a modular system. The pilot plant was built by Ferrostaal in collaboration with Solar Power Group and the aim of the plant is to produce evidence that electricity can be generated more competitively, proving that Fresnel technology is commercially viable for large-scale projects. It was put into operation in July 2007 and the trial period lasted two years. The results of the operation and testing that took place at the PSA identified several key areas where substantial improvements must be achieved before the technology can be considered ready for commercial deployment. It is unclear, at this stage of development, if the cost reduction of this technology in relation to conventional parabolic trough technology can compensate for its lower solar-to-electricity yearly conversion efficiencies (Bernhard and others 2009).

The 5 MW Kimberlina Solar Thermal Power Plant in Bakersfield, California, started operation in 2008 and is the first commercial solar thermal power plant built by Ausra. Kimberlina uses Ausra's LF technology. It supplies steam to an existing thermal power plant located nearby.

Puerto Errado 1, promoted by Novatec Biosol (now Novatec Solar), is the most recent LF plant put into operation. It has an installed power capacity of 1.4 MW, taking up 18,000 m^2 of mirrored area. This plant will generate an estimated annual electric energy of 2 GWh by using the DSG technology. Novatec has developed its own patented collector technology—the collector Fresnel NOVA-1—which has been implemented for the first time in this power plant that was connected to the grid in 2009. The Puerto Errado 1 plant is, to our knowledge, the only commercial grid-connected plant using dry cooling in Spain.

Besides projects already operating, there are very few announced Linear Fresnel projects in the pipeline. Novatec Solar has a project pipeline, including an additional Linear Fresnel project, included in the register of the Spanish Ministry of Industry. This project, Puerto Errado 2, which is the second phase of the already operating Puerto Errado 1, will have a total installed power of 30 MW and will also be built in Murcia. The largest pipeline belongs to Areva (Ausra), which has announced a project pipeline with a total power capacity of 337 MW, consisting of several projects located in Australia, Chile, Jordan, and Portugal (Emerging Energy 2010).

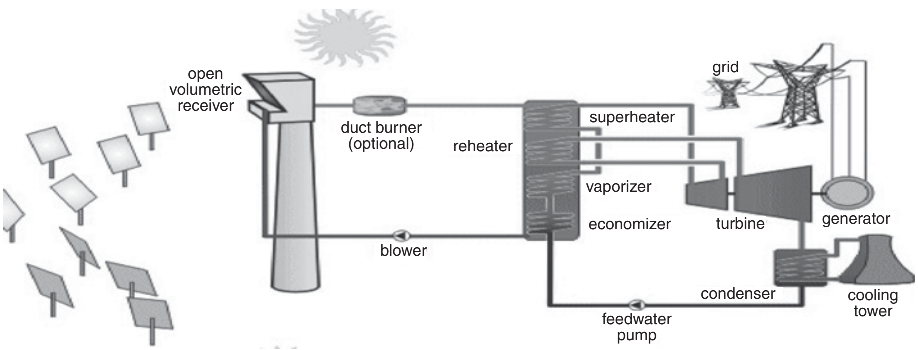
To some market observers Linear Fresnel technology is increasingly being used for steam generation to meet niche market applications that may not depend primarily on power generation (for example, steam flooding for enhanced oil recovery and steam for industrial process use).

Power Tower

Overview[5]

In power tower (central receiver) power plants, a field of heliostats (large two-axis tracking individual mirrors) is used to concentrate sunlight onto a central receiver mounted at the top of a tower (see figure A.7).

Figure A.7: Schematic of open volumetric receiver power tower plant with steam turbine cycle

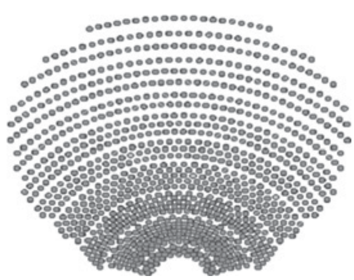


Source: Fichtner 2010; Quaschning 2003.

The field of heliostats, which all move independently of one another, can either surround the tower (Surround Field) for larger systems or be spread out on the shadow side of the tower (North Field) in the case of smaller systems (see figures A.8 and A.9).

Because of the high concentration ratios, high temperatures and hence higher efficiencies can be reached with power tower systems. Within the receiver, an HTF absorbs the highly concentrated radiation reflected by the heliostats and converts it into thermal energy to be used in a conventional power cycle. The power tower concept can be incorporated with either a Rankine steam turbine cycle or a Brayton gas turbine cycle, depending on the applied HTF and the receiver concept, respectively.

Figure A.8: North field layout mills



Source: Mills and others 2002.

Figure A.9: Surround field layout mills

Source: Mills et al. 2002.

Major investigations during the last 25 years have focused mainly on four plant configurations depending on the applied technology and HTF system:

- Water/steam solar tower (Rankine cycle)
- Molten salt solar tower (Rankine cycle)
- Atmospheric air solar tower (Rankine cycle)
- Pressurized air solar tower (Brayton cycle)

Besides the four mentioned plant configurations, liquid metals (mainly sodium) were also investigated as a possible HTF. However, because of different hazards (especially fire) R&D efforts on liquid metals is currently out of focus. Therefore, only the four main plant configuration options are described below.

Water/steam solar tower

Water/steam offers the benefit that it can be directly used in a Rankine cycle without further heat exchange. The production of superheated steam in a solar receiver yields higher efficiencies and has been demonstrated in several prototype projects like the Solar One or CESA-1 projects. However, the operational experience showed some problems related to the control of zones with dissimilar heat transfer coefficients, like evaporators and super-heaters. Difficult to handle were also the start-up and transient operation of the system, leading to local changes of the cooling conditions in the receiver tubes, in particular in the receiver's superheating section.

Because of the abovementioned problems related to superheating steam in central receivers, the first commercial water/steam receiver power plants are producing only saturated steam. The first such plants are the PS-10 and PS-20 power plants built by Abengoa Solar, with 10 MW and 20 MW, respectively.

Molten salt solar tower

Molten salt mixtures combine the benefits of being both an excellent heat transfer and a good high temperature energy storage fluid. Because of a very good heat transfer, the applied heat flux at the receiver surface can be higher compared to other central receiver designs, yielding higher receiver efficiencies. As the molten salt can be stored directly at high temperatures, the specific storage costs are the lowest under all CST technologies. This means that molten salt power tower technology, when proven, will be the preferred choice for applications that require a storage component.

Depending on the specific composition, the molten salt liquefies at a temperature between 120°C and 240°C (in the current state of the technology this is the upper end) and can be used in conjunction with metal tubes for temperatures up to 600°C without imposing severe corrosion problems. As discussed earlier with regard to parabolic trough systems, the challenge is to avoid freezing of the salt in any of the valves and piping of the receiver, storage and steam generation system at any time. The operating range of the state-of-the-art molten nitrate salt, a mixture of 60 percent sodium nitrate and 40 percent potassium nitrate, matches the operating temperatures of modern Rankine cycles.

In a molten salt power tower plant, the cold salt (290°C) is pumped from the cold tank to the receiver, where the salt is heated up to 565°C by the concentrated sunlight. This hot salt is then pumped through a steam generator to generate superheated steam that powers a conventional Rankine cycle steam turbine. The solar field is generally sized to collect more power than demanded by the steam generator system and the excess energy can be accumulated in the hot storage tank. With this type of storage system, solar tower power plants can be built with annual capacity factors of up to 70 percent. Several molten salt development and demonstration experiments have been conducted over the past two-and-a-half decades in the United States and Europe to test the entire system and develop components. The largest demonstration of a molten salt power tower was the 10 MW Solar Two project located near Bartow, California.

Atmospheric Air Solar Tower

Air offers the benefit of being nontoxic, having no practical temperature constraints and is available for free. However, air is a poor heat transfer medium because of its low density and low heat conductivity.

In a central receiver solar power plant with an atmospheric air heat transfer circuit, based on the so-called PHOEBUS scheme, a blower transports ambient air through the receiver, which is heated up by the concentrated sunlight. The receiver consists of wire mesh, ceramic or metallic materials in a honeycomb structure, and air is drawn through this and heated up to temperatures between 650°C and 850°C. On the front side, cold, incoming air cools down the receiver surface. Therefore, the volumetric structure produces the highest temperatures inside the receiver material, reducing the heat radiation losses on the receiver surface.

The hot air is used in a heat recovery steam generator to produce steam at 480 to 540°C/35 to 140 bar. The PHOEBUS scheme also integrates several equivalent hours of ceramic thermocline thermal storage, able to work in charging and discharging modes by reversing air flow with two axial blowers. Current heat storage capacity restrictions lead to designs with a limited number of hours (between 3 and 6). Therefore, higher annual capacity factors can only be reached with backup from a duct burner between the receiver and steam generator. Another option is to use sand as a storage media. However, the heat transfer from air to the sand is poor and the technology has not yet been demonstrated on a larger scale.

Pressurized air solar tower

In this concept, pressurized air (around 15 bar) from the compressor stage of a gas turbine is heated up (to 1100°C) in a pressurized volumetric receiver (REFOS receiver) and then used to drive a gas turbine. At the moment, the concept needs additional fuel to increase the temperature above the level of the receiver outlet temperature. In the future, a solar-only operation at higher receiver outlet temperatures and the use of thermal energy storage might be possible. The waste heat of the gas turbine goes to a heat recovery steam generator that generates steam to drive an additional steam-cycle process. This pressurized air solar tower/CCGT process can reach high efficiencies of over 50 percent.

These systems have the additional advantage of being able to operate with natural gas during start-up and with a high fossil-to-electric efficiency when solar radiation is insufficient. Hence, no shadow capacities of fossil fuel plants are required and high-capacity factors are provided. In addition, the specific cooling water consumption is reduced in comparison with Rankine cycle systems.

Technological Maturity

Although power towers are commercially less mature than parabolic trough systems, a number of component and experimental systems have been field tested around the world in the last few years, demonstrating the technical feasibility and economic potential of different power tower concepts. Furthermore, the already operating power tower plants have proven their feasibility on an entry-commercial scale at small plant capacities The most experience has been collected through several European projects, mainly in Spain at the Plataforma Solar de Almería (PSA) and the Plataforma Solucar of Abengoa Solar near Seville, as well as earlier in the United States (U.S. DOE's Solar One and Solar Two that have since been decommissioned). An outline of solar tower demonstration projects is given in table B.4 in Appendix B.

In 2007, the first commercial power tower plant started operation in Spain. The PS-10 power plant, built by Abengoa Solar, uses saturated steam as the HTF and has a net electrical output of 10 MW. Based on the same receiver concept, the PS-20 plant located in close vicinity to the PS-10 plant has been in commercial operation since 2009 with 20 MW electrical output.

Other plants already in operation are the Sierra Sun Tower in California of eSolar, with an electrical output of 5MW_e and the Solar Tower Jülich with 1.5 MW. These plants represent demonstration/pilot plants for the latest developments on the basis of superheated steam (eSolar) and the volumetric air concept (Solar Tower Jülich). A 1.5 MW eSolar plant is currently also undergoing commissioning in India by Acme. The Solar Tres plant (17 MW), with completion expected in 2011, will operate with molten salt as the HTF and storage medium (direct storage).

After an intermediate scale up to 10–20 MW of capacity, solar tower developers now feel confident that grid-connected central receiver plants can be built up to a capacity of 200 MW solar only units. The largest new solar power tower project currently being constructed is the 392 MW Ivanpah project of BrightSource Energy, Inc. in California.

The two dominating solar tower systems being developed and commercialized by several companies are the ones using water/steam and molten salt as HTFs. While the system using atmospheric air as HTF is expected to be commercially available in the near term, further R&D is required for the commercialization of medium- and large-sized solar tower systems based on the pressurized air receiver concept. The main disadvantage of the power tower system using the atmospheric air is that the storage option cannot be easily integrated, and will most likely be inefficient because of high thermal losses in air-to-water heat exchangers. An overview of already realized and upcoming commercial-scale power tower projects is given in table B.5.

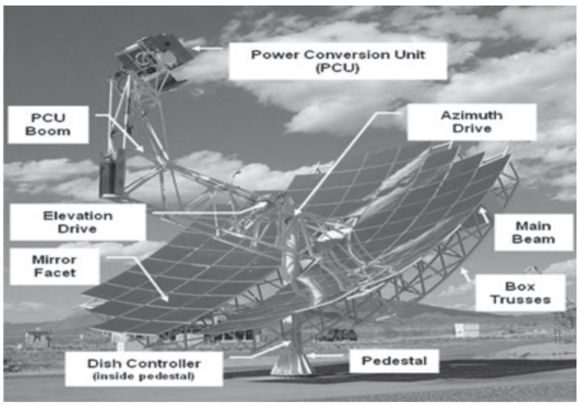
Dish-Engine

Overview[6]

The dish-engine is unique among CST systems in directly heating the working fluid of the power unit rather than an intermediate fluid to produce electricity. Dish-engine systems consist of a mirrored dish that collects and concentrates sunlight onto a receiver mounted at the focal point of the dish.

The receiver is integrated into a high-efficiency engine (the Stirling engine is the most commonly used heat engines because of high efficiency). Solar Parabolic Dish-engine systems include two main parts: a large Parabolic Dish, and a power conversion unit (PCU).

Figure A.10: Dish-engine photo with major component identification



Source: Bill Brown Climate Solutions 2009.

The PCU is held at the focal point of the concentrator dish and includes a receiver, as well as a heat engine and generator assembly for converting the collected thermal energy to electricity (see figure A.10). Typically, a high-efficiency Stirling engine is used. Individual units range in size from 3 to 25 kW and are self-contained and air-cooled, thus eliminating a cooling water requirement, which is a significant advantage of Dish Stirling systems. At the same time, an inherent issue with these systems is that electrical production ceases immediately upon loss of sun. In that respect, they are similar to solar photovoltaic plants. Currently, no concept for commercial thermal storage has been demonstrated and implemented for dish engine systems.

Compared to the other CST technologies, the main advantages of dish-engine systems are as follows:

- Water usage is limited to operational and maintenance activities (such as mirror washing).
- It has attained efficiencies as high as 30 percent in the testing facility at the Sandia Laboratories.
- Its modularity allows for a range of system sizes, from several megawatts to hundreds of megawatts.
- Central or decentralized operations are possible with the scale between 3 kW and several 100 MW.

- High energy density, lower land use.
- Short construction times.

The main disadvantages of dish-engine systems are higher investment costs, lack of existing storage and hybridization solutions, and a concern about higher O&M costs because of the large number of the kW-scale engines in a multi-MW installation.

The two major components of dish-engine systems are the reflective dish and the receiver, or the PCU.

Reflective dish

The concentrator dish is made up of a parabolic shaped reflector, which concentrates the incident solar irradiation into a receiver located at the dish focal point. The ideal shape of the concentrator is a parabloid of revolution, although most designs approximate this shape by using multiple spherical mirrors.

Reflectors used in concentrators consist of a glass or plastic substrate with a thin aluminum or silver layer deposited over it. The most durable material known to the present is the current silver/glass thick mirror, which reaches reflectivity values typically close to 94 percent (Solar Dish Engine n.d.). However, silvered polymer solar reflectors (thin mirror) are finding increasing use in dish concentrator applications (Harrison 2001). An innovative trend toward a new concept that would allow better optical efficiencies was introduced in the 1990s: the stretched membrane mirror, implemented in the SBP design.

The size of the Parabolic Dish is mainly determined by two factors:

- Thermal power demand of the power block (Stirling engine) in nominal conditions.
- Wind loads: restricting the economical viability of large installations.

Power conversion unit

The power conversion unit is the element that absorbs concentrated solar energy and converts it to thermal energy that heats the working fluid (gas) inside the typically 3 kWe to 30 kWe engine. These receivers usually adopt the cavity geometric configuration, with a small aperture and its own isolation system. In order to carry out this energy transformation, it is necessary to reach a high temperature and high levels of incident radiation fluxes while minimizing every possible loss (Gener).

Many different configurations of receivers have been proposed, adapted to different HTFs. These configurations can be gathered in two main groups:

- *Direct Interchange Receiver (DIR):* Fluid absorbs the radiation being directly applied to it.
- *Indirect interchange receivers:* There is an additional element, which transforms solar radiation into heat and then delivers it to the HTF through convection.

Technological Maturity

At the moment, dish-engine systems for large scale applications are considered commercially less mature than other solar power generation systems. A number of component and pilot systems have been field tested around the world in the last 25 years, demonstrating the technical feasibility and the economic potential of the Parabolic Dish collector for small-scale applications and/or remote locations.

Dish Stirling systems are under development and prototype testing in the United States and Europe (for example, by such companies as Tessera Solar/SES, EuroDish, and

EnviroDish). In addition, the use of small solar driven gas turbines at the focus of dishes (dish/Brayton systems) has been investigated. This would offer the potential for high-efficiency operation, with lower maintenance requirements than for the Dish Stirling cycle. An outline of Parabolic Dish collector plants realized and/or under operation, is given in table B.6.

To date, there are no operating commercial plants based on the Parabolic Dish technology. Tessera Solar—a developer, builder, operator and owner of large utility-scale solar power plants—deployed the SunCatcher™ solar Dish Stirling system, using the technology developed and manufactured by the Tessera Solar affiliate Stirling Energy Systems Inc. (SES), headquartered in Scottsdale, Arizona. The company's first plant, Maricopa Solar, began operations in Arizona in January 2010. The other planned projects, such as Calico (850 MW) reportedly had trouble securing financing and the PPA was lost. The project was in part sold to PV developer, but reserved 100 MW of the phase II implementation for SES's Dish Stirling technology with the rest (750 MW) consisting of solar PV technology.

Power Blocks[8]

All CST technologies discussed above, with the exception of the dish-engine type, use a power block to convert the heat generated to electricity. The components that make up the power block in a solar thermal power plant are generally equivalent to the components of conventional thermal power plants. However, certain characteristics of power blocks in CST plants call for specific considerations.

The incorporation of the Rankine cycle into a solar thermal power plant introduces additional operational requirements as a consequence of the cyclical nature of solar energy. While transients can be minimized transients through the use of thermal storage and use of an auxiliary boiler, daily stoppage is prevalent because of legislative limitations on gas consumption or low demand needs at night. Therefore, it is important to keep in mind a series of additional considerations, both in the design of the equipment and in operational practices of the plant. These considerations include:

- Since the plant is not going to operate 24 hours a day, it is important to utilize high efficiency steam turbine cycles to make the project economically feasible. This leads to larger turbines with optimized feed water heating, in turn resulting in a reduced solar field size, which translates into a reduction in investment costs, and, therefore, of the cost of the power generated.
- The thermodynamic cycle can also include a reheat stage depending on the quality of the steam at which it is going to operate. This could improve the efficiency and reduce problems of erosion, corrosion and humidity.
- The annual plant production is affected by turbine start-up time because of the daily starts. Both the daily cyclicality and variations in temperature require special attention. One important characteristic of the turbine is the total mass of its components. Optimizing the mass of machine rotors and cladding can shorten start-up time.
- Another important factor, especially for plants that do not include storage, is the turbine turn-down ratio, which will affect the number of plant operating hours. By being able to operate the turbine at a lower part-load level power generation hours can be gained, although the system is penalized by the reduced efficiency of the turbine at partial loads.

Thermal Storage Options[9]

A distinct advantage of solar thermal power plants compared with other renewable energies, such as PV and wind, is the possibility of using thermal energy storage systems that are substantially cheaper than other current systems for storing electricity. Since there are new storage technologies under development to store electricity on a large scale (such as compressed air and utility scale Na-S batteries), and smart-grids are emerging, the long-term success of CST technology will also depend on the availability of inexpensive and highly efficient thermal energy storage systems for solar thermal power plants.

The basis, on which the use of thermal energy storage systems is determined for solar thermal power plants, depends strongly on the daily and annual variation of irradiation and on the electricity demand profile. The main options for the use of TES are discussed below.

Buffering

The goal of a buffer is to smooth out transients in the solar input as a result of passing clouds, which can have a significant impact on the operation of a solar thermal power plant. The efficiency of electrical production will degrade with intermittent insulation, largely because the turbine-generator will frequently operate at partial loads and in a transient mode. If regular and substantial cloudiness occurs even over a short period, turbine steam conditions and/or flow can degrade enough to force turbine trips if there is no supplementary thermal source to "ride through" the disturbance. Buffer TES systems would typically require small storage capacities (typically 1–2 equivalent full-load hours depending on weather conditions).

Delivery Period Displacement

Thermal energy storage can also be used for delivery period displacement, which requires the use of a larger storage capacity. The storage shifts some or all of the energy collected during periods with sunshine to a later period with higher electricity demand or tariffs (electricity tariffs can be a function of the hour of day, the day of the week and the season). This type of TES does not necessarily increase either the capacity factor or the required collection area, as only solar heat that would have otherwise been used directly throughout the day is stored for later use. The typical storage capacity ranges from three to six hours of the full operational load.

Delivery Period Extension

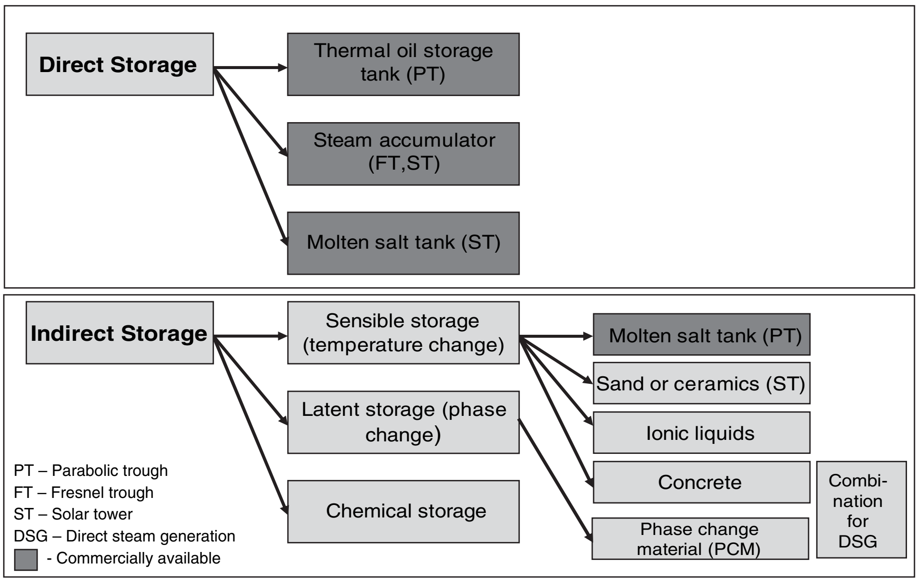
The size of a TES for delivery period extension will be of similar size (3 to 12 hours at full load). However the purpose of the TES in this case is to extend the period during which the power plant operates using solar energy. Such TES increases the capacity factor of the solar power plant and requires larger solar fields than a system without storage.

The optimal storage capacity is site and system dependent. Therefore, a detailed statistical analysis of system electrical demand and weather patterns at a given site, along with a comprehensive economic tradeoff analysis, are desirable in a feasibility study to select the storage capacity for a specific application.

There are a number of storage concepts for CST power plants, which have been either successfully tested and are now commercially available, or which are still under development. An overview on the most promising storage concepts and their status is presented in figure A.11. Current parabolic trough systems are "indirect," in that the oil

HTF flowing through the solar field both charges and discharges molten-salt-filled storage tanks via an oil-to-salt heat exchanger. "Direct" systems are those in which the HTF system and storage medium are the same fluid, without an intermediate heat exchange process. Molten salt power towers and parabolic troughs with a molten salt HTF are examples of such systems.

Figure A.11: Storage concepts for CST



Source: Fichtner 2010.

Hybridization

From an environmental point of view, solar-only configurations are the best as only heat from the solar field is used to generate steam. However, as no mature TES solutions are available for all the CST technologies, hybridization is an interesting alternative to increase the capacity factor of the power plants, increasing their commercial viability. Usually, this type of designs allow three operational modes (solar, fossil or hybrid) providing great levels of versatility and dispatchability.

Hybridization Options

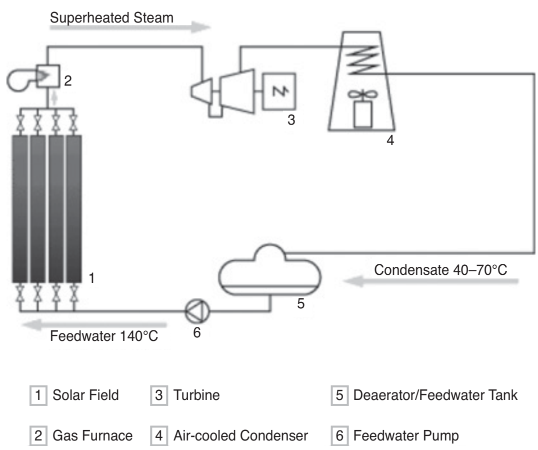
HYBRIDIZATION WITH A FOSSIL FUEL BOILER PLACED IN PARALLEL TO THE SOLAR FIELD.

This option can be used with parabolic trough and Lineal Fresnel power plants (see figure A.2 and figure A.8).

CONVENTIONAL RANKINE CYCLE WITH SOLAR PREHEATING

This concept aims at adding a solar preheater to big fossil power plants in order to reduce their fuel consumption and gases emissions (see figure A.12). It has been demonstrated at Liddell coal power plant in New South Wales, Australia. The annual solar fraction (amount of solar energy in the total thermal energy of the plant) is usually lower than

Figure A.12: Saturated steam hybrid plant configuration



Source: Novosol.

5 percent. However, solar energy is converted to power with high efficiencies and the investment cost is low, so it can be a relevant option to retrofit existing fossil fuel plant already in operation and introduce CST technologies to the market. No solar energy is lost during start-up and shut-down periods.

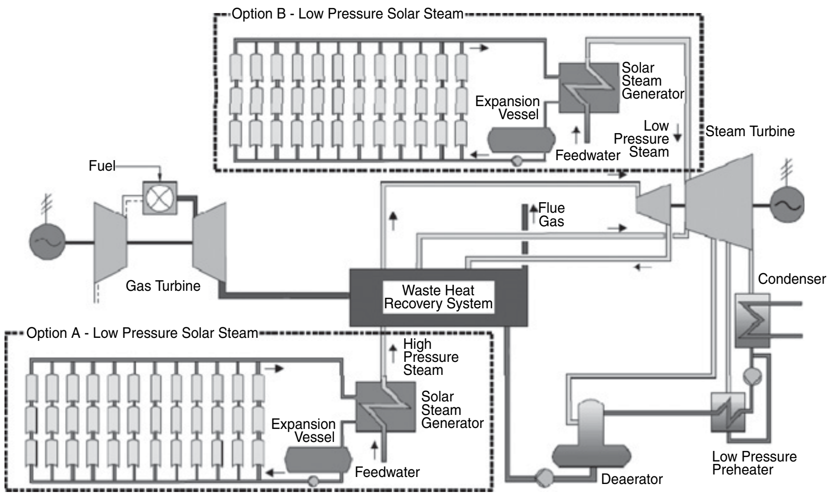
INTEGRATED SOLAR COMBINED CYCLE SYSTEMS (ISCCSS)

These systems consist in integrating solar energy into a combined cycle power plant, as shown in figure A.13. They have been primarily considered for parabolic trough collectors, but the characteristics of Linear Fresnel collectors (low cost, low temperature, DSG) made them very relevant for ISCC systems. They can result very effective, in particular if stable and continuous power production is needed. Solar thermal energy is delivered to the Heat Recovery Steam Generator (HRSG) of the combined cycle, thus the steam turbine receives higher heat input than in classical combined cycles, resulting in higher efficiencies.

ISCCS benefit from the high efficiencies of combined cycles: some studies assess annual fuel-to-power efficiencies of about 60 percent. Besides, as the investment cost for gas turbines is lower than for steam turbines, ISCCS are more cost-effective than hybrid solar Rankine cycles. As in conventional Rankine cycle with solar preheating, no solar energy is lost during start-up and shut-down periods.

The Martin Next Generation Solar Energy Center is a hybrid 75 MW parabolic trough solar energy plant, built by Florida Power & Light Company (FPL). The solar plant is a component of the 3,705 MW Martin County Power Plant, which is currently the single largest fossil fuel burning power plant in United States. The facility will also be the first hybrid facility in the world to connect a solar facility to an existing combined cycle power plant. It is located in western Martin County, Florida. Construction began in 2008 and was completed by the end of 2010. ISCC plants are also being constructed in Algeria (Hassi R'Mel) and Morocco (Ain Beni Mathar) in collaboration with Abengoa Solar. Abengoa Solar is providing the design and will act as the technician of the solar field. The ISCC of El-Kureimat, in Egypt, is being developed by New and Renewable

Figure A.13: Basic scheme of an ISCCS



Source: ECOSTAR.

Energy Authority (NREA), and is expected to start production at the end of 2012. Other projects are under development in Mexico (Agua Prieta) and Iran (Iazd).

In addition to the options above, there are other lines of research in order to develop other hybrid options. As an example, the company AORA-Solar has developed an advanced solar-hybrid power generation unit. A pilot project was built in 2009 in Kibbutz Samar, in the southern desert of Israel. The system offers a modular solution, comprising small Base Units of 100 kWe (comprised by heliostat and solar tower with a micro turbine) that can be strung together, building up into a large power plant. When the available sunlight is not sufficient, the system can operate on any alternative fuel source (fossil fuel, bio fuel).

Hybridization and Regulatory Framework

In Spain, the development of the solar thermal technology has risen because of a favorable regulatory framework. In addition to a FiT policy, it was regulated the possibility of building hybrid plants. However, the range of hybridization was limited to 12–15 percent (fraction of fossil fuel energy in the total thermal energy of the plant) by the legal framework. In the United States, this fraction can reach up to 25 percent.

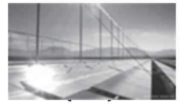
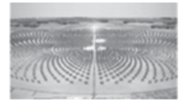
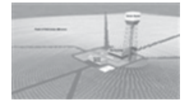
Notes

1. Based on Fichtner (2010)
2. Based on Fichtner (2010).
3. Based on Fichtner (2010)
4. Based on YES/Nixus/CENER (2010).
5. Based on Fichtner (2010).
6. Based on YES/Nixus/CENER (2010).
7. Fichtner (2010).
8. Based on YES/Nixus/CENER (2010).
9. Fichtner (2010).

APPENDIX B

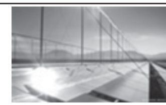
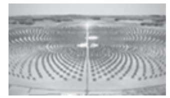
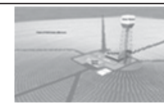
Tables and Figures

Table B.1: Overview of the main technical characteristics of CST technologies

		Technology				
	Units	Parabolic trough	Fresnel trough	Molten salt solar tower	Water steam solar tower	Parabolic dish
Item						
Plant Size, envisaged	[MWe]	50–300[a]	30–200	10–200[a]	10–200	0.01–850
Plant Size, already realized	[MWe]	50 (7.5 TES), 80 (no TES)	5	20	20	1.5 (60 units)
Collector/Concentration	[-]	Parabolic trough (70–80 suns)	Fresnel trough / > 60 suns, depends on secondary reflector	Heliostat field / > 1,000 suns	Heliostat field / > 1,000 suns	Single Dish / > 1,300 suns
Receiver/Absorber	[-]	Absorber fixed to tracked collector, complex design	Absorber fixed to frame, no evacuation, secondary reflector	External tube receiver	External or cavity tube receiver, multi receiver systems	Multi receiver system
Storage System	[-]	Indirect two-tank molten salt (380°C; dT = 100K)	Short-time pressurized steam storage (<10min)	Direct two-tank molten salt (550°C; dT = 300K)	Short-time pressurized steam storage for saturated steam (<10min)	No storage for dish Stirling, chemical storage under development
Hybridisation	[-]	Yes, indirect (HTF)	Yes, direct (steam boiler)	Yes	Yes, direct (steam boiler)	Not planned
Grid Stability	[-]	medium to high (TES or hybridisation)	medium (back-up firing possible)	high (large TES)	medium (back-up firing possible)	low
Cycle	[-]	Rankine steam cycle	Rankine steam cycle	Rankine steam cycle	Rankine steam cycle	Stirling cycle, Brayton cycle, Rankine cycle for distributed dish farms
Steam conditions	[°C/bar]	380°C / 100 bar	260°C / 50 bar	540°C / 100–160 bar	up to 540°C / 160 bar	up to 650°C / 150 bar
Land requirements[b]	[km^2]	2.4–2.6 (no TES) 4–4.2 (7h TES)	1.5–2 (no TES)	5–6 (10–12 h TES)	2.5–3.5 (DPT on the lower site)	2.5–3
Required slope of solar field	[%]	< 1–2	< 4	< 2–4 (depends on field design)	< 2–4 (depends on field design)	>10%
Water requirements[c]	[m^3/MWh]	3 (wet cooling) 0.3 (dry cooling)	3 (wet cooling) 0.2 (dry cooling)	2.5–3 (wet cooling) 0.25 (dry cooling)	2.5–3 (wet cooling) 0.25 (dry cooling)	0.05–0.1 (mirror washing)
Annual Capacity Factor	[%]	25–28% (no TES) 40–43% (7h TES)	22–24%	55% (10h TES), larger TES possible	25–30% (solar only)	25–28%
Peak Efficiency	[%]	22–25%	16–18%	18–22%		31%
Annual Solar-to-Electricity Efficiency (net)	[%]	14–16%	9–10% (saturated)	14–16%	15–17%	20–22%

Source: Fichtner 2010.
[a] Maximum/optimum depends on storage size.
[b] 100 MWe plant size.
[c] Depends on water quality.

Table B.2: Overview of the main commercial characteristics of CST technologies

		Technology				
	Units	**Parabolic trough**	**Fresnel trough**	**Molten salt solar tower**	**Water steam solar tower**	**Parabolic dish**
Item						
Maturity	[-]	- Proven technology on large scale - Commercially viable today	- Demonstration projects, first commercial projects under construction - Commercially viable 2011 onwards	- Demonstration projects, first commercial projects under construction - Commercially viable 2011 onwards	- Saturated steam projects in operation - Superheated steam demonstration projects, first commercial projects under construction - Commercially viable 2012 onwards	- Demonstration projects, first commercial projects (first units) in 2011 - Commercially viable 2012 onwards
Total Installed Capacity (in operation Q4 2010)	[MWe]	1,000	7	10	10 (superheated/demo) 30 (saturated steam)	1.7
Estimated total Installed Capacity (in operation 2013)	[MWe]	3,000–4,000	200–300	200–400	400–500	500–1,000
Number of Technology Provider	[-]	high (>10), Abengoa Solar/ Abener, Acciona, ASC Cobra/ Sener, Albiasa Solar, Aries Ingeniera, Iberdrola, MAN SolarMillenium, Samca, Solel/ Siemens, Torresol etc.	medium (3–4), Areva, Novatec Biosol AG, Sky Fuels, Solar Power Group, etc.	medium (2–5) SolarReserve and Torresol others like Abengoa Solar and eSolar, SolarMillenium are planning entry	medium (3–4), Abengoa Solar, BrightSource Energy, eSolar etc.	medium (4–5), Abengoa Solar, Infinia, SES / Tessera Solar, SB&P, Wizard Power
Technology Development Risk	[-]	low	medium	medium	medium	medium
Investment costs for 100MW	[$/KW]	4,000–5,000 (no storage) 6,000–7,000 (7–8h storage)	3,500–4,500 (no storage)	8,000–10,000 (10h storage)	4,000–5,000 (no storage)	4,500–8,000 (depending on volume production)
O&M Costs	[m $/a]	6–8 (no storage)	5.5–7.5	7–10 (molten salt with TES)	5–7 (water steam, no TES)	10–15 (water steam, no TES)

Source: Fichtner 2010.

Table B.3: Parabolic trough power plant projects

Project name/location	Country	Developer	(Estimated) first year of operation	Peak output [MW_{el}]	Thermal energy storage/ dispatchibility
Nevada Solar One, Boulder City	USA	Acciona Solar Power	2007	74	None
Andasol I–III	Spain	ACS Cobra / Sener Solar Millennium	2008–2011	3 × 50	Molten Salt Thermal Storage
Solnova I–V	Spain	Abengo Solar	2009–2014	5 × 50	Gas heater
ExtreSol I–III	Spain	ACS Cobra / Sener	2009–2012	3 × 50	Gas heater
Kurraymat	Egypt	Iberdrola / Orascom & Flagsol	2010	20 (solar)	ISCC
Ain Beni Mathar	Morocco	Abener	2010	20 (solar)	ISCC
Shams 1	UAE	Abengoa Solar	2012	100	Gas fired superheater
Beacon Solar Energy Project, Kern County	USA	Beacon Solar	2012	250	Gas heater
Blythe	USA	Solar Millennium	2013–2014	4 × 250	Gas heater

Source: Fichtner 2010.

Table B.4: Demonstration central receiver projects

Name/location/country	First year of operation	Electrical output (MWel)	HTF	Thermal energy storage
SSPS, Spain	1981	0.5	Liquid sodium	Sodium
EURELIOS, Italy	1981	1	Water/steam	Salt/water
SUNSHINE, Japan	1981	1	Water/steam	Salt/water
Solar One, USA	1982	10	Water/steam	Synthetic oil/rock
CESA-1, Spain	1983	1	Water/steam	Molten salt
MSEE/Cat B, USA	1983	1	Molten salt	Molten salt
THEMIS, France	1984	2.5	Molten salt (hitec)	Molten salt
SPP-5, Ukraine	1986	5	Water/steam	Water/steam
TSA, Spain	1993	1	Atmospheric air	Ceramics
Solar Two, USA	1996	10	Molten salt	Molten salt
Consolar, Israel	2001	0.5*	Pressurized air	No (fossil hybrid)
Solagte, Spain	2002	0.3	Pressurized air	No (fossil hybrid)
Solair, Spain	2004	3*	Atmospheric air	—
CO-MINIT, Italy	2005	2 × 0.25	Pressurized air	No (fossil hybrid)
CSIRO Solar Tower Australia	2006	1*	Other (gas reformation)	Chemical (solar gas)
DBT-550, Israel	2008	6*	Water/steam (superheated)	—
STJ, Germany	2008	1.5	Atmospheric air	Ceramics
Eureka, Spain	2009	2*	Water/steam (superheated)	—

Source: Fichtner 2010.

Table B.5: Commercial central receiver projects

Name / location	Company	Concept	Size (MWe)	Initial operation year/status
PS 10 / Seville, Spain	Abengoa Solar	Water/Steam	10	2007
Solar Tower Jülich / Jülich, Germany	Kraftanlagen München	Volumetric Air	1,5	2008
PS 20 / Seville, Spain	Abengoa Solar	Water/Steam	20	2009
Sierra SunTower / California, USA	eSolar	Water/Steam	5	2009
Solar Tres / Seville, Spain	Sener	Molten Salt	17	2011/Under Construction
Ivanpah 1–3 / California, USA	BrightSource Energy	Water/Steam	1 × 126 / 2 × 133	2013/Under Construction
Geskell Sun Tower, Phase I–II / California, USA	eSolar	Water/Steam	1 × 105 / 1 × 140	Planning
Alpine Power SunTower / California, USA	eSolar/NRG Energy	Water/Steam	92	Planning
Cloncurry Solar Power Station / Queensland, AUS	Ergon Energy	Water/Steam	10	2010/on hold
Upington / Upington, South Africa	Eskom	Molten Salt	100	2014/Announced
Rice Solar Energy Project / California, USA	Solar Reserve	Molten Salt	150	Planning
Tonopah / Nevada, USA	Solar Reserve	Molten Salt	100	Planning

Source: Fichtner 2010.

Table B.6: Demonstration parabolic dish collector projects

Name/location/country	First year of operation	Net output [MWel]	Heat transfer fluids/PCU	Remark
Rancho Mirage, USA	1983	0.025	Stirling motor	individual-facet Vanguard
Los Angeles, USA	1984	0.025		individual-facet, MDAC-25
Warner Springs, USA	1987			individual stretched membrane facets
Osage City, USA	1987			
Saudia Arabia	1984	2 × 0.05	Stirling motor	SBP, stretched membrane
Freiburg, Germany	1990			fixed focus, Bomin Solar
Lampoltshausen, Germany	1990		Stirling motor	SBP, stretched membrane, 2nd generation
Almeria, Spain	1992–1996	6 × 0.01	Stirling motor	SBP, stretched membrane
Europe (Seville, Milano, etc.)	2002–2004	6 × 0.01	Stirling motor	SBP, stretched membrane EuroDish/ EnvrioDish
Johannesburg, South Africa	2002	0.025	Stirling motor	SES & Eskom, multi-facets
ALBUQUERQUE, New Mexico, USA	2006–2008	8 × 0.025	Stirling motor	SES & SNL, multi-facets
MARICOPA, Phoenix	2010	1.5	Stirling Motor	SES, multi facets

Source: Fichtner 2010.

Table B.7: Component specific cost reduction potential—parabolic trough

Subsystem	Component	Reduction factor	Midterm cost reduction potential (%)	Long-term cost reduction potential (%)
Solar field	Reflectors	New mirror concept	8–10	18–22
	Mounting structure	Mass production and material savings	12–20	25–30
		Standardization	6–12	—
	Tracking system	Experience curve	13–15	
	Receiver	Operational improvements	15–20	
		Size increases	15	—
	Heat transfer system	Experience curve	15–25	
Thermal storage	Molten salts	Thermocline concept	20	—
	Fluid handling system	Thermocline concept	10	—
Power block	Power block	Experience curve	0–1	
	Balance of plant (bop)	Experience curve	5–10	

Source: YES/Nixus/CENER 2010.

Table B.8: Component-specific cost reduction potential—power tower

Subsystem	Component	Reduction factor	Midterm cost reduction potential (%)	Long-term cost reduction potential (%)
Solar field	Reflectors	New mirror concept	4–5	6–8
	Mounting structure	Mass production and material savings	15–18	17–20
		Standardization	6–12	—
	Tracking system	Experience curve	13–15	
	Receiver	Experience curve	5–10	
	Heat transfer system	Experience curve	15–25	
Thermal storage	Molten salts	Thermocline concept	20	—
	Fluid handling system	Thermocline concept	10	—
Power block	Power block	Experience curve	0–1	
	Balance of plant	Experience curve	5–10	

Source: YES/Nixus/CENER 2010.

Table B.9: Component-specific cost reduction potential—linear fresnel

Subsystem	Component	Reduction factor	Midterm cost reduction potential (%)	Long-term cost reduction potential (%)
Solar field	Reflectors	Mass production	4–5	6–8
	Mounting structure	Mass production and material savings	20–25	25–35
		Standardization	6–12	—
	Tracking system	Experience curve	13–15	
	Receiver	Wide operational improvement	15–25	
		Size increase	10	—
Power block	Power block	Experience curve	0–1	
	Balance of plant	Experience curve	5–10	

Source: YES/Nixus/CENER 2010.

Table B.10: Component-specific cost reduction potential—dish engine

Subsystem	Component	Reduction factor	Midterm cost reduction potential (%)	Long-term cost reduction potential (%)
Solar field	Reflectors	Process automation and mass production	20–25	35–40
	Mounting structure	Mass production and material savings	17–20	25–28
		Standardization	6–12	—
Solar to energy conversion	Receiver/electric motor and BOP	Experience curve	5–10	

Source: YES/Nixus/CENER 2010.

Table B.11: Main financial and regulatory assumptions for LCOE analysis

Main financial and regulatory assumptions

	India—parabolic trough	India—power tower	Morocco—parabolic trough	Morocco—power tower	South Africa—parabolic trough	South Africa—power tower
Plant size	100 MW		100 MW		100 MW	
Analysis period	25 years		25 years		25 years	
Inflation rate*	5.5%		2.15%		6.0%	
Real discount rate	11.25%		8.25%		10.5%	
Applicable tax rate	19.93% (MAT)		30% with Tax Holiday of 5 years, from year 1 of construction (3 years construction + 2 of operation)		28%	
Property tax	0%		0%		0%	
Vat	5%		14%		14%	
Depreciation schedule	7% first 10 years—2% thereafter		25 years straight line		25 years straight line	
Loan term (commercial)	14 years		18 years with 4 years grace period		20 years	
Loan rate (commercial)	11.75%		9%		12%	
Debt / equity ratio	70 / 30		80 / 20		70/30	
Roe	19%		15%		17%	
Min required irr	15%		15%		15%	
Insurance	0.5%		0.5%		0.5%	
Exchange rate	45 Rs/US$		8.2 Dhs/US$		ZAR 10/US$	
Capital cost	US$4,500/kW (excluding storage)	US$5,000/kW (excluding storage)	US$4,500/kW (excluding storage)	US$5,000/kW (excluding storage)	US$4,700/kW (excluding storage)	US$5,200/kW (excluding storage)
O&M cost (including Variable cost)	US$32/kW-yr	US$30/kW-yr	US$35/kW-yr (plus Dhs 15 million/year rent)	US$33/kW-yr (plus Dhs 15 million/year rent)	US$70/kW-yr	US$66/kW-yr
Optimal storage	6 hours TES	15 hours TES	3 hours TES	15 hours TES	3 hours TES	15 hours TES
Total installed cost	US$7,707/kW	US$8,306/kW	US$7,385/kW	US$8,909/kW	US$7,900/kW	US$9,171/kW
Capacity factor (air-cooled)	38.5%	52.7%	32.5%	62%	35%	67.9%
Annual mwh generated (air-cooled)	337,341 MWh	461,592 MWh	284,891 MWh	543,348 MWh	306,269 MWh	595,008 MWh
Assumed dni	2,262 kWh/m^2/year		2,578 kWh/m^2/year		2,916 kWh/m^2/year	
System degradation	0.25–0.5% (0.425% assumed)		0.25–0.5% (0.425% assumed)		0.25–0.5% (0.425% assumed)	

Source: Macroeconomica 2011.
*Average CPI-Inflation from 2000 to 2009.

Table B.12: Impact assessment of different regulatory incentives in India

Technology	Current LCOE	Incentive applied	LCOE after incentive	% Change in LCOE
Parabolic trough *(Air-cooled—with storage)*	**35.54**	Tax reduction	**35.20**	**–0.96**
		VAT exemption	**35.20**	**–0.96**
		Accelerated depreciation	**34.06**	**–4.16**
		Concessional loan terms	**33.36**	**–6.13**
		Concessional loan rates	**32.94**	**–7.32**
		Concessional loan terms + rates	**29.81**	**–16.12**
		AD + concessional loan terms + rates	**28.32**	**–20.32**
Power tower *(Air-cooled—with storage)*	**27.85**	Tax reduction	**27.58**	**–0.97**
		VAT exemption	**27.58**	**–0.97**
		Accelerated depreciation	**26.69**	**–4.17**
		Concessional loan terms	**26.13**	**–6.18**
		Concessional loan rates	**25.80**	**–7.36**
		Concessional loan terms + rates	**23.34**	**–16.19**
		AD + concessional loan terms + rates	**22.16**	**–20.43**
Parabolic trough *(Wet-cooled—with storage)*	**33.27**	Tax reduction	**32.95**	**–0.96**
		VAT exemption	**32.95**	**–0.96**
		Accelerated depreciation	**31.89**	**–4.16**
		Concessional loan terms	**31.23**	**–6.13**
		Concessional loan rates	**30.84**	**–7.32**
		Concessional loan terms + rates	**27.91**	**–16.11**
		AD + concessional loan terms + rates	**26.51**	**–20.32**
Power tower *(Wet-cooled—with storage)*	**26.67**	Tax reduction	**26.41**	**–0.97**
		VAT exemption	**26.42**	**–0.94**
		Accelerated depreciation	**25.56**	**–4.16**
		Concessional loan terms	**25.03**	**–6.15**
		Concessional loan rates	**24.71**	**–7.35**
		Concessional loan terms + rates	**22.35**	**–16.20**
		AD + concessional loan terms + rates	**21.23**	**–20.40**

Source: Authors' analysis.

Table B.13: Impact assessment of different regulatory incentives in Morocco

Technology	Current LCOE	Incentive applied	LCOE after incentive	% Change in LCOE
Parabolic trough *(Air-cooled—with storage)*	**37.25**	Tax reduction	**36.80**	**–1.21**
		VAT exemption	**36.53**	**–1.93**
		Accelerated depreciation	**31.92**	**–14.31**
		Concessional loan terms	**34.49**	**–7.41**
		Concessional loan rates	**33.68**	**–9.58**
		Concessional loan terms + rates	**30.26**	**–18.77**
		AD + concessional loan terms + rates	**24.82**	**–33.37**
Power tower *(Air-cooled—with storage)*	**23.27**	Tax reduction	**22.99**	**–1.20**
		VAT exemption	**22.81**	**–1.98**
		Accelerated depreciation	**19.90**	**–14.48**
		Concessional loan terms	**21.52**	**–7.52**
		Concessional loan rates	**21.00**	**–9.76**
		Concessional loan terms + rates	**18.84**	**–19.04**
		AD + concessional loan terms + rates	**15.40**	**–33.82**
Parabolic trough *(Wet-cooled—with storage)*	**34.52**	Tax reduction	**34.11**	**–1.19**
		VAT exemption	**33.85**	**–1.94**
		Accelerated depreciation	**29.58**	**–14.31**
		Concessional loan terms	**31.96**	**–7.42**
		Concessional loan rates	**31.21**	**–9.59**
		Concessional loan terms + rates	**28.04**	**–18.77**
		AD + concessional loan terms + rates	**23.00**	**–33.37**
Power tower *(Wet-cooled—with storage)*	**22.11**	Tax reduction	**21.85**	**–1.18**
		VAT exemption	**21.68**	**–1.94**
		Accelerated depreciation	**18.91**	**–14.47**
		Concessional loan terms	**20.45**	**–7.51**
		Concessional loan rates	**19.96**	**–9.72**
		Concessional loan terms + rates	**17.91**	**–19.00**
		AD + concessional loan terms + rates	**14.64**	**–33.79**

Source: Authors' analysis.

Table B.14: Impact assessment of different regulatory incentives in South Africa

Technology	Current LCOE	Incentive applied	LCOE after incentive	% Change in LCOE
Parabolic trough *(Air-cooled—with storage)*	**42.32**	Tax reduction	**41.58**	**–1.75**
		VAT exemption	**41.47**	**–2.01**
		Accelerated depreciation	**37.07**	**–12.41**
		Concessional loan terms	**41.18**	**–2.69**
		Concessional loan rates	**38.78**	**–8.36**
		Concessional loan terms + rates	**37.23**	**–12.03**
		AD + concessional loan terms + rates	**31.91**	**–24.60**
Power tower *(Air-cooled—with storage)*	**24.92**	Tax reduction	**24.48**	**–1.77**
		VAT exemption	**24.41**	**–2.05**
		Accelerated depreciation	**21.78**	**–12.60**
		Concessional loan terms	**24.24**	**–2.73**
		Concessional loan rates	**22.80**	**–8.51**
		Concessional loan terms + rates	**21.87**	**–12.24**
		AD + concessional loan terms + rates	**18.69**	**–25.00**
Parabolic trough *(Wet-cooled—with storage)*	**38.90**	Tax reduction	**38.21**	**–1.77**
		VAT exemption	**38.11**	**–2.03**
		Accelerated depreciation	**34.07**	**–12.42**
		Concessional loan terms	**37.85**	**–2.70**
		Concessional loan rates	**35.64**	**–8.38**
		Concessional loan terms + rates	**34.22**	**–12.03**
		AD + concessional loan terms + rates	**29.33**	**–24.60**
Power tower *(Wet-cooled—with storage)*	**23.76**	Tax reduction	**23.34**	**–1.77**
		VAT exemption	**23.27**	**–2.06**
		Accelerated depreciation	**20.77**	**–12.58**
		Concessional loan terms	**23.11**	**–2.74**
		Concessional loan rates	**21.73**	**–8.54**
		Concessional loan terms + rates	**20.85**	**–12.25**
		AD + concessional loan terms + rates	**17.82**	**–25.00**

Source: Authors' analysis.

Table B.15: Economic analysis—main cost assumptions

		Parabolic trough			Power tower		
Item	**Unit**	**India**	**Morocco**	**S. Africa**	**India**	**Morocco**	**S. Africa**
Capacity (gross)	MW	100	100	100	100	100	100
Generation net	gWh/a.	397	264	440	388	388	493
Degradation of generation	% p.a.	0.0	0.5	0.0	0.0	0.5	0.0
Capacity factor	%	50%	30%	56%	49%	31%	63%
CAPEX	US$Mn.	738	600	861	717	717	786
Cons. period	Years	6	3	6	6	6	6
Lifetime of plant	Years	25	25	25	20	20	20
Variable O&M costs							
Fuel	US$Mn.	0.2	0.30	0.30	0.3	0.3	0.3
Water	US$Mn.	0.12	0.12	0.12	0.11	0.08	0.08
Fixed O&M costs	US$Mn.	14.2	15.1	16.6	14.5	12.3	16.3
Personnel	US$Mn.	4.4	4.5	4.4	2.7	3.5	4.5
Non-personnel	US$Mn.	9.8	10.6	12.2	11.8	8.8	11.8
CO_2 Eq. saved	Kg/kWh	1.03	0.64	1.03	1.03	0.64	1.03
Local pollutants							
SO_2	Kg./kWh	n.a.	0.011	n.a.	n.a.	0.011	n.a.
NO_x	Kg./kWh	n.a.	0.003	n.a.	n.a.	0.003	n.a.
PM10	Kg./kWh	n.a.	0.001	n.a.	n.a.	0.001	n.a.
Escalation factors							
Value of electricity	% p.a.	3.64	2.15	0	3.64	2.15	0
O&M costs	% p.a.	1.0/5.0	2.15	1.0/5.0	1.0/5.0	2.15	1.0/5.0
CO_2 & other ext. values		0	2.15	0	0	2.15	0
Value of electricity	US¢/kWh	8.0	11.1	17.5	8.0	11.1	17.5
Value of CO_2 in 2014							
Original	US$/ton	—	31.3	29.0	—	31.3	29.0
Modified	US$/ton	40.5	40.5	40.5	40.5	40.5	40.5
Value local pollutants							
SO_2	US$/ton	n.a.	267	n.a.	n.a.	267	n.a.
NO_x	US$/ton	n.a.	1,156	n.a.	n.a.	1,156	n.a.
PM10	US$/ton	n.a.	711	n.a.	n.a.	711	n.a.

Source: Macroeconomica 2011.
Note: Escalation of O&M costs was 1% for nonpersonnel and 5% for personnel costs in S. Africa & India. The escalation of the value of CO_2 was only in the original case. n.a. = not available.

Table B.16: Global CST value chain analysis

<table>
<tr><th></th><th colspan="2">Industry structure</th><th colspan="2">Economics and costs</th></tr>
<tr><td>Project development</td><td colspan="2">□ Small group of companies with technological know-how
□ International actors have fully integrated activities of concept engineering; often with project development, engineering, financing.</td><td colspan="2">□ Mainly labor-intensive engineering activities and activities to obtain permits.</td></tr>
<tr><td>EPC contractors</td><td colspan="2">□ Strong market position for construction, energy, transport and infrastructure projects.</td><td colspan="2">□ Large infrastructure companies (high turnover)</td></tr>
<tr><td>Parabolic mirrors</td><td colspan="2">□ Few, large companies, often from the automotive sector
□ Large factory output</td><td colspan="2">□ Large turnover for a variety of mirror and glass products</td></tr>
<tr><td>Receivers</td><td colspan="2">□ Two large players
□ Factories also in CST markets in Spain and the United States</td><td colspan="2">□ Large investment in know-how and machines required</td></tr>
<tr><td>Metal support structure</td><td colspan="2">□ Steel supply can be provided locally
□ Local and international suppliers can produce the parts</td><td colspan="2">□ High share of costs for raw material, steel or aluminum</td></tr>
<tr><th></th><th colspan="2">Market structure and trends</th><th colspan="2">Key competiveness factor</th></tr>
<tr><td>Project development</td><td colspan="2">□ Strongly depending on growth/expectations of individual markets
□ Activities worldwide</td><td colspan="2">□ Central role for CST projects
□ Technology know-how
□ Access to finance</td></tr>
<tr><td>EPC contractors</td><td colspan="2">□ Maximum 20 companies
□ Most of the companies active on markets in Spain and the United States</td><td colspan="2">□ Existing supplier network</td></tr>
<tr><td>Parabolic mirrors</td><td colspan="2">□ A few companies share market, all have increased capacities
□ High mirror price might decline</td><td colspan="2">□ Bending glass
□ Manufacturing of long-term stable mirrors with high reflectance
□ Inclusion of upstream float glass process</td></tr>
<tr><td>Receivers</td><td colspan="2">□ Strongly depending on market growth
□ Low competition today; new players about to enter the market</td><td colspan="2">□ High-tech component with specialized production and manufacturing process</td></tr>
<tr><td>Metal support structure</td><td colspan="2">□ Increase on the international scale expected
□ Subcontractors for assembling and materials</td><td colspan="2">□ Price competition
□ Mass production / Automation</td></tr>
<tr><th></th><th>Strengths</th><th>Weaknesses</th><th>Opportunities</th><th>Threats</th></tr>
<tr><td>Project development</td><td>□ Reference projects
□ Technology know-how</td><td>□ Dependency on political support</td><td>□ Projects in pipeline</td><td>□ Price competition with other renewables</td></tr>
<tr><td>EPC contractors</td><td>□ Reference projects
□ Well-trained staff
□ Network of suppliers</td><td>□ High cost</td><td>□ Projects in pipeline
□ Achieve high cost reduction</td><td>□ Price competition with other renewables</td></tr>
<tr><td>Parabolic mirrors</td><td>□ Strong position of few players
□ High margins (high cost reduction potential)</td><td>□ Cost of factory
□ Continuous demand required</td><td>□ New CST markets
□ Barriers for market entry</td><td>□ Unstable CST market
□ Flat mirror technology (Fresnel/tower)</td></tr>
<tr><td>Receivers</td><td>□ High margins (high cost reduction potential)</td><td>□ Dependency on CST market
□ High entry barrier for new players (know-how/invest)</td><td>□ High cost reduction potential through competition</td><td>□ Unstable CST market
□ Low market demand
□ Strong market position of few players; hard for new players to become commercial</td></tr>
<tr><td>Metal support structure</td><td>□ Experience
□ New business opportunities for structural steel
□ Low entry barriers</td><td>□ High cost competition</td><td>□ Increase of efficiency and size</td><td>□ Volatile CST market</td></tr>
</table>

Source: Ernst & Young and Fraunhofer 2010.

Table B.17: Technical and economic barriers to manufacturing CST 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 their 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**
Receive	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 required to build production lines Parabolic mirrors can only be used for CST market	Supplier network not strongly required	**High**

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Table B.17: (continued)

Components	Technical barriers	Financial barriers	Quality	Market	Suppliers	Level of barriers
Mounting structure	Structure and assembly are usually proprietary 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 production. However, the oil is not highly specific	Very capital-intensive	Standard product, heat resistant	Large chemical companies 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 CST specific equipment; Equipment not produced for CST only	Not identified	Not identified	Market demand of other industries necessary	Often supplier networks because of division	**Low**

Source: Ernst & Young and Fraunhofer 2010.

Table B.18: Action plan for stimulation of production of CST products in MENA

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 superordinated 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 consorts 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	∆ ▲	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 bureaucracy and assistance	International players	∆	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	∆	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	Δ ▲ ♦	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	Δ ♦ ◊	Short to medium term
	Support of training activities for local workforce	Review of existing national training facilities, upgrade/creation of specific institutions if needed		Δ ▲	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	Δ ▲	Short to medium term

(Table continues on next page)

Table B.18: (continued)

Goals	Intermediate steps	Necessary processes/assistance	Target groups	Potential actors	Implementation timeframe
		Support the training of regional workforce by financial support if external training facilities are involved	Regional companies, international companies	Δ ▲	Short to medium term
		Promotion of financial incentives for 'train the trainers' programs	Regional companies, international companies	Δ ▲	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	Δ ▲	Short to medium term
		Creation of master programs at foreign universities and student exchange programs with regard to RE/CSP	Regional students	Δ ▲	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)	Δ ▲	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)	Δ ▲	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

Source: Ernst & Young and Fraunhofer 2010.
Actors/financers: Δ = national authorities, ▲ = international donors, ◊ = national CST players, ♦ = international CST players

Table B.19: Component-specific local manufacturing prospects in South Africa

CST system/component	Potential for manufacture within South Africa	Remarks
Structural steel	High	Up to 100% of steel required can be provided locally.
Concrete	High	Up to 100% of concrete required can be provided locally.
Steel piping	High	Up to 80% of all the steel piping can be provided locally.
CST-shaped glass	Medium in the short to medium term High in the long term	
Electrical and Control cabling and accessories	High	Up to 100% of all cabling can be manufactured locally.
Pressure vessels and storage tanks	High	All pressure vessels and storage tanks and vessels can be manufactured locally.
Shaped steel sections	High	All shaped steel sections can be provided locally.
Medium voltage and low voltage electric motors	High	All MV and LV motors can be manufactured locally.
DC motors	High	All DC motors can be manufactured locally.
Valves and actuators	High	Valves and actuators can be manufactured locally.
Distribution and power transformers (Oil-filled and dry type)	High	All transformers can be manufactured locally.
Lead Acid and nickel cadmium batteries	High	All batteries can be manufactured locally.
Battery chargers, UPSs and inverters	High	This equipment can be manufactured locally.
Variable speed drives (low voltage)	High	VSDs for LV motors can be manufactured locally.
Variable speed drives (medium voltage)	Low	MV drives will be imported into the long term.
Steam turbines	Low	
Heat exchangers	High	All heat exchangers can be manufactured locally.
Instruments	High	All instruments can be manufactured locally.
Programmable logic controllers, plant information systems and DCS equipment	Low	
Nitrogen systems	Low	Most of the Nitrogen gas will need to be imported.
Aluminum conductor for overhead lines	High	All Aluminum conductors for overhead lines can be manufactured locally.
Molten salts	Low	
Oil-based HTF	Low	
Diesel generator sets	Low	Diesel generator sets can be assembled in South Africa, but alternators and diesel engines, as well as the controls, will be imported into the long term.
Pumps	High	Most of the pumps can be manufactured locally. It is very likely that HTF pumps can be supplied locally in the medium term since there are existing suppliers of large pumps for the petrochemical industry.

(Table continues on next page)

Table B.19: (continued)

CST system/component	Potential for manufacture within South Africa	Remarks
Water treatment plants	High	All water treatment plants can be designed and assembled locally.
Chemicals for water treatment	High	All chemicals can be manufactured locally.
Heaters	High	
Heating, ventilation and air conditioning equipment (HVAC)	Medium	
Fencing material	High	All fencing material can be provided locally.
Firefighting equipment	High	
CST steel structures	Medium	Low in the short term. High in the medium to long term.
Tracking systems	Medium	Low in the short to medium term. High in the long term. Automotive component manufacturers have got the machining equipment to manufacture high-precision structures. The machining equipment can be used to manufacture tracking systems in the long term.
Weather measurement equipment	High	
Telecommunications and telecontrol equipment	Medium	
MV and LV switchgear	Medium	

Source: Fichtner 2011.

Table B.20: Capacity to manufacture CST components and provide CST-related services in South Africa

Sector	Financial strength	Research & development potential	Potential of entry by international firms into sector	Remarks
Steel manufacturing	High Large local firms Arcelor Mittal and Evraz Highveld Steel dominate this sector	High Both Arcelor Mittal and Evraz have got large R&D divisions and also benefit from the R&D capabilities of parent companies.	Medium.	The 2 firms have a dominant role in the steel sector in South Africa. South Africa's Industrial Policy Action Plan (IPAP) is proposing incentives for foreign investors into South Africa
Automotive component manufacturers	High	Low	High	Most firms have small R&D capabilities and rely on industry bodies to coordinate R&D efforts. Capacity to manufacture CST steel structures and components low in the short term, but there is potential for increase in the long term.
Glass manufacturing sector	High	Medium	High	The capacity to manufacture CST glass in the short to medium term is limited for PG Glass Industries.
Electrical equipment	High	High	High	This sector is dominated by the Big 5 multinational firms: GE, ABB, Siemens, Alstom and Groupe Schneider. Potential exists for other international players to enter this market for specific electrical equipment, such as MV Variable Speed Drives, which are currently being imported, as well as for large transformers and DCS equipment for power plants.
Electronics equipment	Medium	Medium	High	Most of the local electronics components manufacturing firms are small. This market is dominated by Siemens, Alstom and ABB.
EPC firms	High For the big 3 firms (Murray & Roberts, Group 5 and Grinaker LTA)	Medium	High	The local EPC firms do not have experience in doing EPC on CST projects. There is scope for them to work as subcontractors to large international EPC CST plant developers such as Abengoa.
Professional services (engineering consulting and project management)	High	Medium	High	Local engineering consulting and project management firms do not have experience in executing CST projects. There is scope for entry of international consulting firms in this area and subcontract work to local firms.
Cement and concrete	High	High	Low	This sector is dominated by a few large companies with a large market share. The oligopolistic nature of the industry presents significant entry barriers to new entrants.

Source: Fichtner 2011.

Table B.21: G20 and select nonmembers' producer price inflation (% over previous year)

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average	Std Dev
Argentina	. .	. .	0.4	4.3	2.9	–1.1	–3.4	–4.0	3.7	–2.0	78.3	19.6	7.7	8.4	11.0	11.8	14.5	4.8	16.5	10.2	18.9
Australia	1.5	2.0	0.8	4.2	0.3	1.2	–4.0	–0.9	7.1	3.1	0.2	0.5	4.0	6.0	7.9	2.3	8.3	–5.4	2.2	2.2	3.6
Brazil	987.8	2050.1	2311.6	57.5	6.3	10.1	3.5	16.6	18.1	12.6	16.7	27.6	10.5	5.6	0.8	5.6	13.7	–0.2	5.7	292.6	703.2
Canada	0.5	3.6	6.1	7.4	0.4	0.7	0.4	1.8	4.3	1.0	0.1	–1.2	3.2	1.6	2.3	1.5	4.3	–3.5	1.0	1.9	2.5
China	. .	. .	. .	. .	. .	. .	. .	. .	2.8	–4.0	0.4	3.0	7.1	3.2	3.1	3.1	6.9	–5.4	5.5	2.3	4.0
Hong Kong, SAR, China	1.8	0.7	2.1	2.8	–0.1	–0.3	–1.8	–1.6	0.2	–1.6	–2.7	–0.3	2.3	–7.9	2.2	3.0	5.6	–1.7	6.0	0.5	3.2
Euro Area	1.5	1.5	2.0	4.1	0.3	1.0	–0.7	–0.5	5.1	2.2	–0.2	1.4	2.3	4.3	5.4	2.7	6.3	–5.2	2.8	1.9	2.6
France	–1.5	–1.5	1.1	6.1	–2.6	–0.6	–0.9	. .	4.4	1.2	–0.2	0.9	2.1	3.1	2.9	2.3	4.8	–5.6	3.0	1.0	2.9
Germany	. .	0.2	0.6	1.7	–1.2	1.2	–0.4	–1.0	3.3	3.0	–0.6	1.7	1.6	4.3	5.4	1.3	5.5	–4.2	1.6	1.3	2.4
India	11.9	7.5	10.5	9.3	4.5	4.5	5.9	3.5	6.6	4.8	2.5	5.4	6.6	4.7	4.7	4.8	8.7	2.1	9.4	6.2	2.7
Indonesia	5.2	3.7	5.4	11.4	7.9	9.0	101.8	10.5	12.5	13.0	4.4	3.4	7.4	15.3	13.7	14.7	21.5	4.6	3.1	14.1	21.8
Italy	1.9	3.8	3.7	7.9	1.9	1.3	0.1	–0.3	6.0	1.9	–0.2	1.6	2.7	4.0	5.6	3.5	4.8	–4.7	3.0	2.6	2.8
Japan	–0.9	–1.6	–1.6	–0.8	–1.7	0.7	–1.5	–1.5	0.0	–2.3	–2.1	–0.8	1.3	1.7	2.2	1.7	4.6	–5.3	–0.2	–0.4	2.1
Korea, Republic of	2.2	1.5	2.7	4.7	3.2	3.9	12.2	–2.1	2.0	–0.4	–0.3	2.2	6.1	2.1	0.9	1.4	8.6	–0.2	3.8	2.9	3.3
Mexico	12.3	7.4	6.1	38.6	33.9	17.5	16.0	14.2	7.8	5.0	5.1	7.5	9.3	4.2	6.6	3.6	6.5	5.9	3.3	11.1	9.8
Netherlands	1.8	0.1	0.5	1.5	2.0	1.8	–0.2	1.0	4.8	3.0	0.8	1.7	2.8	3.2	3.6	4.5	5.1	–3.8	2.6	1.9	2.1
Russian Federation	. .	943.8	337.0	236.5	50.8	15.0	7.0	58.9	46.5	18.2	10.4	16.4	23.4	20.6	12.4	14.1	21.4	–7.2	12.2	102.1	228.0
Saudi Arabia	1.3	0.6	1.8	7.3	–0.3	0.0	–1.9	0.4	0.4	–0.1	0.0	0.9	3.1	2.9	1.2	5.7	9.0	–3.0	4.3	1.8	3.0
Singapore	–4.4	–4.4	–0.4	0.0	0.1	–1.2	–3.0	2.1	10.1	–1.6	–1.5	2.0	5.1	9.7	5.0	0.3	7.5	–13.9	4.8	0.9	5.6
South Africa	9.2	7.0	8.8	9.9	7.1	8.1	4.4	4.9	6.7	7.6	13.5	2.2	2.3	3.6	7.7	10.9	14.3	0.0	6.0	7.1	3.7
Spain	1.3	2.5	4.3	6.4	1.7	1.0	–0.7	0.7	5.4	1.7	0.6	1.4	3.4	4.7	5.4	3.6	6.5	–3.4	3.2	2.6	2.5
Switzerland	0.7	0.4	–0.5	–0.1	–1.8	–0.7	–1.2	–1.0	0.9	0.5	–0.5	0.0	1.2	0.8	2.1	2.4	3.4	–2.1	–0.1	0.2	1.4
Turkey	62.1	58.0	121.3	86.0	75.9	81.8	71.8	53.1	51.4	61.6	50.1	25.6	14.6	5.9	9.3	6.3	12.7	1.2	8.5	45.1	34.4
United Kingdom	3.1	4.0	2.5	4.0	2.6	1.0	0.0	0.6	1.4	–0.3	–0.1	0.6	1.0	2.0	2.0	2.3	6.8	1.6	4.2	2.1	1.8
United States	0.6	1.5	1.3	3.6	2.3	–0.1	–2.5	0.8	5.8	1.1	–2.3	5.3	6.2	7.3	4.7	4.8	9.8	–8.8	6.8	2.5	4.3

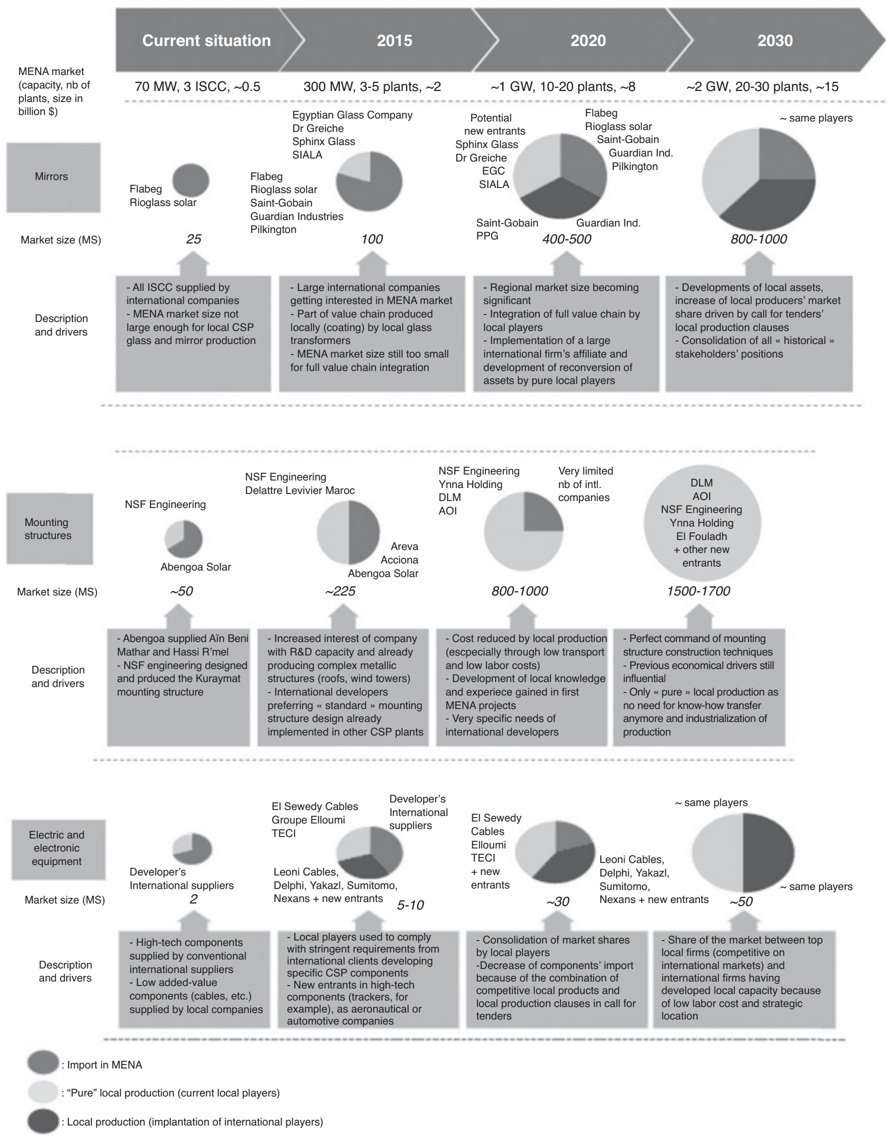
Source: Bureau of Labor Statistics 2010.

Table B.22: Select MENA wholesale price inflation (% over previous year)

Country	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average	Std Dev
Algeria	. .	. .	. .	. .	. .	. .	3.9	2.5	2.5	4.8	2.3	4.5	4.3	3.1	2.0	3.9	8.5	3.5	. .	3.8	1.7
Egypt, Arab Rep.	. .	6.4	6.0	5.7	8.9	3.3	1.6	1.6	1.5	1.5	6.0	14.1	17.3	5.3	7.0	10.3	21.2	(5.6)	. .	6.6	6.5
Jordan	. .	. .	. .	. .	. .	. .	0.0	(2.2)	(3.3)	(1.1)	(3.4)	2.4	5.8	9.9	16.0	8.6	56.3	(16.8)	. .	6.0	17.9
Morocco	. .	4.9	2.4	5.7	5.4	(2.1)	3.2	(2.0)	4.2	0.0	2.0	(4.9)	. .	. .	. .	. .	. .	. .	. .	1.7	3.5
Tunisia	. .	6.1	2.9	5.6	3.9	2.5	2.5	1.2	2.4	2.3	3.4	2.2	3.2	4.2	7.0	3.7	11.7	2.4	. .	4.0	2.5

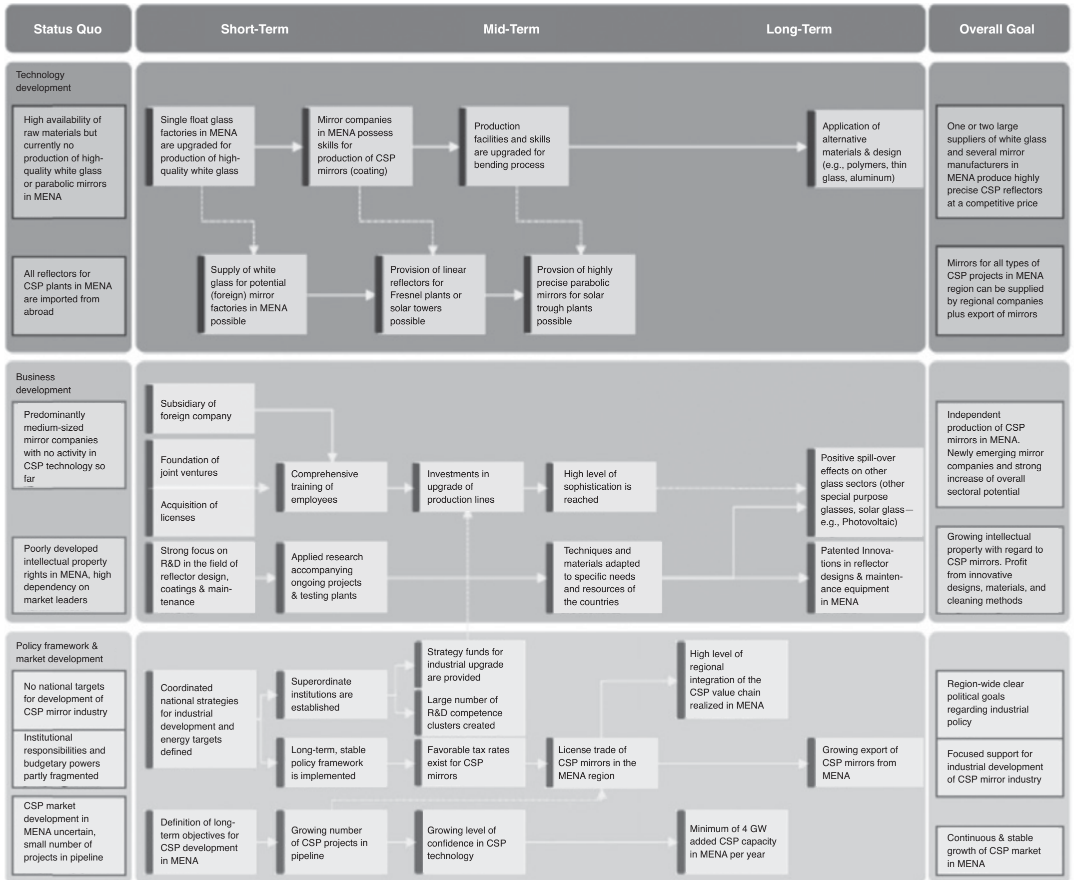
Source: Bureau of Labor Statistics 2010.

Figure B.1: Possible evolutions of local CST industries for key components in MENA



Source: Ernst & Young and Fraunhofer 2010.

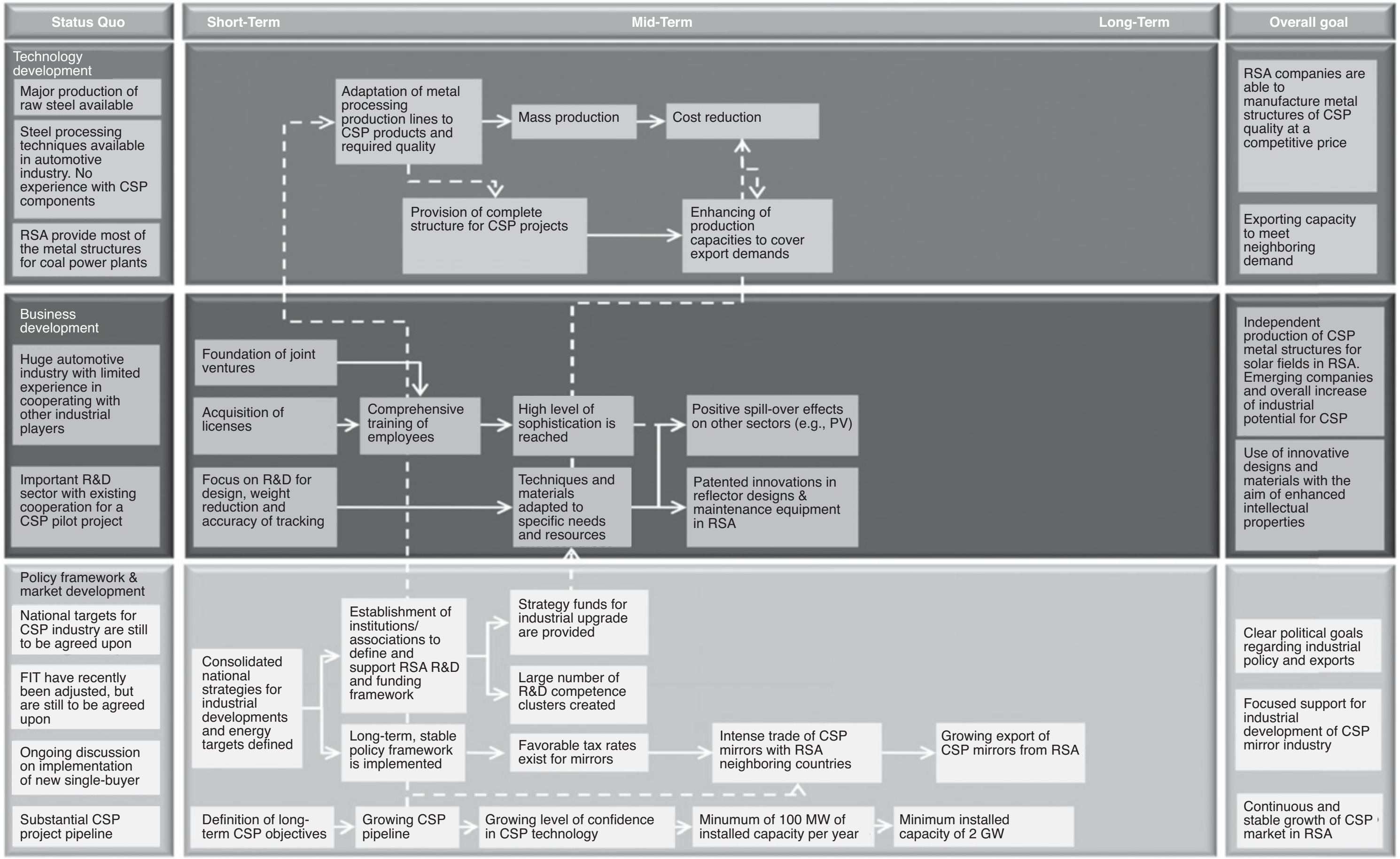
Figure B.2: Potential roadmap for the production of CST mirrors in the MENA Region



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

Source: Ernst & Young and Fraunhofer 2010.

Figure B.3: Potential roadmap for the production of metal structures for CST in RSA



Source: Fichtner 2011.

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At present, different concentrating solar thermal (CST) technologies have reached varying degrees of commercial availability. This emerging nature of CST technology means that there are market and technical impediments to accelerating its acceptance, including cost competitiveness, intermittency, and an understanding of technology capability, limitations, and the benefits of electricity storage. Many developed and some developing countries are currently working to address these barriers to scale up CST-based power generation.

Given the considerable growth of CST technology development in several World Bank Group partner countries, there is a need to assess the recent experience of developed countries in designing and implementing regulatory frameworks to draw lessons that may facilitate the deployment of CST technologies in developing countries. Merely replicating developed countries' schemes in the context of a developing country may not generate the desired outcomes.

Against this background, this report (a) analyzes and draws lessons from the efforts of some developed countries and adapts them to the characteristics of developing economies; (b) assesses the cost reduction potential and economic and financial affordability of various CST technologies in emerging markets; (c) evaluates the potential for cost reduction and associated economic benefits derived from local manufacturing; and (d) suggests ways to tailor bidding models and practices, bid selection criteria, and structures for power purchase agreements for CST projects in developing market conditions.

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