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ESMAP
Energy Sector Management Assistance Program

Development of Local Supply Chain: The Missing Link for Concentrated Solar Power Projects in India

THE WORLD BANK

ESMAP MISSION

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Acronyms and Abbreviations

ADB	Asian Development Bank
BOP	Balance of plant
capex	Capital expenditure
CCD	Concessional customs duty
CDTI	Spanish Centre for Industrial Technological Development
CEA	Central Electricity Authority
CENER	Centro Nacional de Energías Renovables (National Renewable Energy Centre)
CERC	Central Electricity Regulatory Commission
CII	Confederation of Indian Industry
CR	Central receiver
CRS	Central receiver system
CSP	Concentrating solar power
CTA	Corporación Tecnológica de Andalucía
CUF	Capacity Utilization Factor
DNI	Direct normal irradiance
DSG	Direct steam generation
EEA	Egyptian Electric Authority
EPC	Engineering, procurement, and construction
EPCM	Engineering, procurement, construction management
ERM	ERM Power
EUR	Euro
FDI	Foreign direct investment

FIT	Feed-in tariff
GBI	Generation Based Incentive
GDP	Gross domestic product
GW	Gigawatt
HCE	Heat Collector Element
HTF	Heat Transfer Fluid
IBRD	International Bank for Reconstruction and Development
ISCCS	Integrated Solar Combined Cycle System
IDA	International Development Association (World Bank)
IDFC	Infrastructure Development Finance Company
IEA	International Energy Agency
IFCs	Infrastructure finance company
IMD	India Meteorological Department
INR	Indian Rupee
IP	Intellectual Property
IREDA	Indian Renewable Energy Development Agency
ISO	International Organization for Standardization
ITC	Investment Tax Credit
ITT	International Telephone & Telegraph
JNNSM	Jawaharlal Nehru National Solar Mission (National Solar Mission)
JV	Joint venture
kWh	Kilowatt-hour
LCOE	Levelized cost of energy
LF	Linear Fresnel
LFR	Linear Fresnel reflector
LIC	Life Insurance Corporation of India
L&T–MHI	Larsen & Toubro Limited Company
m	Meter
m2	Square meter
MEIL	Megha Engineering and Infrastructures Limited
MENA	Middle East and North Africa
MNRE	Ministry of New and Renewable Energy
MOF	Ministry of Finance
MOP	Ministry of Power
MOU	Memorandum of Understanding
Mton	Million tons
MW	Megawatt
NAL	National Aerospace Laboratories
NAPCC	National Action Plan on Climate Change
NREA	New and Renewable Energy Authority (Egypt)
NTPC	National Thermal Power Corporation
NVVN	Vidyut Vyapar Nigam Ltd
O&M	Operations and maintenance
pa	Per annum

PD	Parabolic dish
PFC	Power Finance Corporation Limited
PG	Power generation
PPA	Power purchase agreement
PPP	Public-private partnership
PT	Parabolic trough
PTC	Parabolic trough collector
PTD	Power transmission and distribution
PTR	Power tower receiver
PV	Photovoltaic(s)
RBI	Reserve Bank of India
REC	Renewable energy certificate
RM	Raw material
ROE	Return on Equity
RPO	Renewable Purchase Obligation
Rs	Indian rupee
SEC	Securities and Exchange Commission
SES	Stirling Energy Systems
SESI	Solar Energy Society of India
SEEZ	Solar energy enterprise zone
SIDBI	Small Industries Development Bank of India
SMAG	Solar Millennium AG
SSG	Solar steam generator
SWOT	Strengths, weaknesses, opportunities, and threats
TADM	Tracking and drive mechanism
TERI	The Energy and Resources Institute
TES	Thermal energy storage
UPES	University of Petroleum and Energy Studies
US$	U.S. Dollar
USDOE	US Department of Energy
WACC	Weighted average cost of capital

Executive Summary

The specific objective of the study is to assess the potential of India's industries to set up a manufacturing base for production of Concentrating Solar Power (CSP) technology components and equipment. The study assesses competitive positioning and potential of Indian companies in the manufacturing of key CSP components. It proposes an action plan to help develop this potential and evaluate the resulting economic benefits. This report includes the following activities:

- Assessment of the competitive position of industries in India to support the development of CSP technologies
- Evaluation of short-, medium-, and long-term economic benefits of the creation of a local manufacturing base
- Action plan to stimulate local manufacturing of CSP technology components and equipment

Need to Support CSP Projects

Amidst the success of solar PV projects in India, the CSP technology also provides a compelling case for support by the government because of the following technological reasons:

- Among Solar CSP is the only techno-economically viable option at present which has a storage option that can enable solar energy to become dispatchable, dependable, which can meet both the peak base load.
- The conversion of solar to steam is a relatively high-efficiency process (vs. the conversion efficiency of PV), and this can effectively supplement the fossil fuels/renewable fuel, such as biomass, thus contributing to overall energy security of the country.

Competitive Position of Industries in India to Support the Development of CSP Technologies

The two drivers considered in the cost evolution model are experience and technology breakthroughs. In addition, for each of these technologies, the main actors of the plants' and components' value chain have been identified in this report. In the medium term, India is expected to become a major CSP player worldwide. India's Jawaharlal Nehru National Solar Mission (JNNSM) includes measures for rapidly expanding the use of photovoltaic and solar thermal systems, in order to drive down costs and encourage domestic solar manufacturing. The plan also proposes scaling up centralized solar thermal power generation with the aim of achieving cost parity with conventional grid power by 2020 and the full necessary energy infrastructure by 2050. With the objective of 20 GW of solar power by 2022, and a first step of 1.3 GW of solar power by 2013, this is the most ambitious solar plan that any country has laid out so far.

For the solar plan to succeed, existing Indian industries have to identify the opportunities and react proactively to participate significantly in supplying CSP components and systems. Many traditional industries that could take an active part in CSP technology development are automotive, glass, metal, power and process heat, machine tools and robotics, technical supervising, electronics industry, oil and gas, and chemical industries. Many of them only need a modest effort to adapt their manufacturing processes to the demands of the CSP industry. Nonetheless the competition between CSP players will increase in future, enlarging the need for R&D activities to develop cheaper and more efficient components. That is why collaborative research between private companies and research laboratories is important to develop the components and systems that will help in reducing the cost of CSP technologies.

To perform an assessment of the competitive position of industries in India to support the development of CSP technologies, a detailed analysis of the local industrial capabilities was carried out for different key components of CSP, which included an assessment of the requirements of components, current industrial capacity in India, expected impacts on cost reduction as a result of local manufacturing, relative market growth, and market dynamics. A strengths, weaknesses, opportunities, and threats (SWOT) analysis for local manufacturing was also performed. A proposed timeline for indigenization of each key component was also developed as shown on page no. 3.

Under JNNSM Phase 1, a significant reduction of tariffs has been achieved because of the implementation of a reversed auction bidding mechanism, combined with the approach taken by the solar project developers which is a combination of both locally manufactured and imported components. For example, the developers went in for domestic structural, civil, and mechanical items, while limiting the imports to key components, such as mirrors, receiver tubes, heat transfer fluid (HTF), solar steam and turbine generators. In future further cost reductions could be expected from local manufacturing of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures (parabolic trough, PT). Local manufacturing has additional benefits like -developing indigenous operations and maintenance (O&M) industry supported by local subcontractors, better procurement lead time, and trained local manpower. This study, indicates that local manufacturing and local IP, could reduce the costs of mirrors, receiver tubes and structures for PT collectors up to 28 percent, 30 percent, and 40 percent, respectively. The potential involvement of international players in local manufacturing activities in India has been also considered.

COMPONENTS	PHASE I (1 to 3 years)	PHASE II (4 to 7 years)	PHASE III (8 to 12 years)
SOLAR FIELD			
Site Development	Local	Local	Local
Foundations & Pylons	Local	Local	Local
Mirrors PT and PD*	Import	Import	Local
Mirrors CR and LF*	Import	Local	Local
Frame and Support Structure	Local	Local	Local
Receiver tubes PT and LF	Import	Import	Local
Receivers for CR and PD	Import	Local	Local
HTF Synthetic Oil	Import	Import	Local
Drive and Track PT and LF	Local	Local	Local
Drive and Track CR and PD	Import	Import	Local
POWER BLOCK			
Solar Steam Generator	Local	Local	Local
Turbine	Import	Local	Local
Cooling System	Local	Local	Local
BOP	Local	Local	Local

Local   Import

Conclusion:
Solar Field:
- **Mirrors:** Partial Manufacturing is possible in phase I with full indigenization in phase II
- **Receiver Tubes, HTF, Drive & Track Mechanism:** Indigenization is estimated by phase III

Power Block:
- **Turbines:** Indigenization may happen in phase I itself, but is expected to get stabilized by phase II

*The technology for mirror manufacturing would be available at these phases provided that low iron sand is available in India. Otherwise low iron sand would have to be imported.

Short-, Medium-, and Long-Term Economic Benefits of the Creation of a Local Manufacturing Base

It has been seen that with appropriate incentives, some countries have reached a very high rate of local manufacturing for CSP components. For example, the Spanish Association of the Solar Thermal Electricity Industry claims that between 75 percent and 80 percent of the components used in the Spanish CSP plants come from national manufacturing or are developed with national technology. To reach this high level of domestic production, the Spanish industry benefited from incentives enabling the development of manufacturing plants, combined with other mechanisms focusing on job creation and promoting the development of innovative companies. Successful examples of CSP manufacturing plants that have also been built in Germany, Spain, and the United States which are reported in this document.

Local economic benefits resulting from industry development in India have been analysed using a dynamic economic model with market scenarios and reference plants with assumptions regarding the local share of a CSP deployment and manufacturing of components. The results are aggregated by average share of local manufacturing in India, economic impact on GDP, labour impact (that is, job creation), and foreign trade impact.

The projections indicate that the potential cost reductions in solar field components are large, which would be led by the savings resulting from local manufacturing, lower customs duties for equipment and raw or processed material, and the lower cost of logistics and labour. For other components, cost reductions could materialize because the increase in market size and the passage of time in years would result in economies of scale. In cases where the critical minimum market size is not reached, cost reductions resulting from local manufacturing have been suitably scaled down. A total reduction of approximately 10 percent has been projected for components taking into account the learning curves by 2022 if volume growth is ensured (Optimistic Scenario). This has been reduced to 3 percent in the other extreme where the volume growth is small (Pessimistic Scenario). A moderate scenario has also been projected.

Effects on direct and indirect economic values are calculated in absolute numbers for each scenario. In addition to local manufacturing of components and construction of the plant, it is also assumed that EPC and O&M will contribute to the economic impact of CSP plants. The economic impact is strongly related to the market demand for CSP technologies. The main results of this study are presented below.

SCENARIO	INSTALLED CAPACITY	LOCAL SHARE IN MANUFACTURING	COST REDUCTION	CREATED JOBS
Scenario A (pessimistic)	2,000 MW	76%	13%	19,000
Scenario B (moderate)	6,000 MW	83%	16%	58,000
Scenario C (optimistic)	10,000 MW	90%	20%	96,000

Foreign trade, in terms of generated exports, is estimated only for CSP solar field and thermal conversion specific components. It is assumed that there will be no additional exports for conventional elements, such as power blocks and electrical conversion blocks resulting from the projected growth of the solar thermal industry. Consideration has also been given to the expected learning curve and the lead time for stabilization that will be required for the manufacturing of components in India. Minimum market demand for manufacturing also plays an important role because this factor will be decisive for determining proper timing to start production in India. For this reason, in scenarios A and B, exports are not considered because with two technologies competing for the market—parabolic trough and central receiver—the demand will be just adequate to justify full-fledged production of some components for each technology, but not sufficient to start exports. In this report, exports have been considered mainly for the currently commercially mature PT technology. Assuming growth in exports from 400 MW per year in 2022 to 900 MW per year in 2030, the export market is estimated to be about Rs. 5,000 crores in 2022, Rs. 8,000 crores in 2025, and Rs. 11,500 crores in 2030, respectively.

Action Plan to Stimulate Local Manufacturing of CSP Components and Equipment

As part of the study, the two workshops were conducted that brought together representatives from industry and government, and the industry expectations to jump-start market development of CSP projects and plant components were discussed. These discussions are reflected in the report. To address the industry expectations, the report suggests a comprehensive action plan as shown on page no. 5.

SECTION	ACTION PLAN	SUPPORTIVE RESPONSIBILITY	Y1	Y2	Y3	Y4	Y5
Long term policy framework for CSP development	Year-wise allocation for CSP power projects	MNRE					
	Regulatory support & tariff mechanism for solar thermal hybrid projects	MNRE & CERC					
	Renewable Energy Certificate mechanism for Solar Thermal energy generation	CERC					
Planning for payment security	Adequate payment security mechanism (using the Coal cess Funds).	MOF/MNRE					
Low cost financing	Enablement of low cost financing for CSP from banks & separate exposure limits for CSP projects.	MOF					
Financial planning of subsidies and incentives	Time-bound and milestone-based CCD and zero excise duties for materials and components used for manufacturing of solar systems and development of projects	MOF					
	Fiscal incentives for sponsored research and in house R&D expenditure	MOF					
Mechanism for promotion of R&D and innovation	Development and maintenance of a public repository of knowledge	MNRE					
	Development of quality and specification standards	MNRE					
	Establishment of a R&D framework on a PPP basis	MNRE					
	Development of solar energy courses	MNRE					
	Sponsored research projects in educational institutions	MNRE					

The responsibilities are assigned within the current operating institutional framework of the central and state governments. The second and third phases of the JNNSM should provide clarity in the allocation of capacity for solar thermal technologies versus other solar technologies for the next 10 years.

To offset the high capital costs representing a large fraction of the levelized cost of energy (LCOE) in CSP plants, the government should focus its effort on establishing an adequate payment security mechanism coupled with low-cost financing for CSP. From the technology perspective, hybrid technologies – Biomass / coal including generation of pure steam and HVAC need to be made eligible to receive government incentives (in proportion to their solar components), along with those facilities that employ only solar technical options. Accelerated depreciation benefits and/or investment tax credit policy needs to be sustained for the long term. This also has to be accompanied by tax holidays and zero excise duties for components produced locally. For those components that are currently available in the Indian market, market growth should be promoted in order to reduce costs.

COMPONENT OR MATERIAL	PRESENT LOCAL MANUFACTURING CAPABILITY	RECOMMENDED ACTIONS
RECEIVER (PT)	low	■ Promote R&D for metal glass seal, and solar selective and anti-reflective coatings ■ Promote collaboration with global players
RECEIVER (CR)	low	■ Promote R&D for receivers able to work under high solar flux, for volumetric receivers using atmospheric air as HTF, and for durable pressurized air receivers
MIRROR (PT)	medium	■ Explore sources of low iron sand ■ Lower customs for bending equipment and low iron sand
MIRROR (CR)	medium/high	■ Zero customs for low iron sand ■ Explore sources of low iron sand
DRIVE/TRACKING (PT)	medium	■ Promote R&D for solar sensor and controller technology ■ Promote collaboration with global players
DRIVE/TRACKING (CR)	low	■ Promote R&D for solar sensor and controller technology ■ Promote collaboration with global players
HTF (Synthetic Oil) and MOLTEN SALTS)	medium	■ Ores not present in India. Lower customs for oil and salts. ■ Promote R&D in materials having high heat density, stability, thermal conductivity, and latent heat ■ Promote R&D in thermochemical and electrochemical storage
TURBINES	medium/high	■ Establish technical and quality standards for CSP turbines

Concluding Remarks

The JNNSM Phase I catalysed the growth of the solar sector in the country, with more than 1 GW of solar capacity being installed by October 2012, and contributed to the reduction of tariffs offered by project developers. To keep this momentum and to achieve further cost reductions for CSP technologies, the government needs to provide clarity regarding the capacity allocation for CSP sector, so that the industry is clear about the market size of CSP in the next 10 years.

In the long term, with reduction in the solar field costs, CSP will become more and more cost effective, specifically within the intermediate and base-load market segments because of the integrated storage options. CSP is the only solar technology presently that can incorporate thermal storage solution, making CSP solar power dispatchable and thus more cost effective to meet all segments of power demand.

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Realistic potential exists for solar thermal technologies to make an important contribution in meeting India's energy demand and diversifying the country's power generation profile. Global trends and actual price discovery indicate that the LCOE from renewable options will continue to go down, while the cost of fossil fuels will continue to rise and the demands for energy independence and the growing awareness of the real social and environmental costs of energy generation will ensure that this potential is realized.

Potential also exists for the subcomponents of solar thermal systems to be manufactured in India in the short, medium, and long terms. India has inherent competitive advantages that will facilitate the transition to becoming a major provider of solar thermal technologies. The factors that could contribute to this include highly trained engineering staff, low labour costs, and an emerging domestic market. These are some of the aspects that can be leveraged by the Indian industry to lower the capital costs for CSP plants, thereby decreasing the LCOE and driving the market penetration of solar technologies.

Government, developers, and industry need to work together to ensure a viable path for solar thermal technology development by

- creating a financial and regulatory environment that supports -- investment in R&D,
- establishment of financial and political incentives for sustainable development,
- lowering the effective financial risks for investors, while factoring in the positive impacts on the environment, improvements in health, the natural habitat, and the quality of life that are associated with renewable energy in general and solar thermal technologies in particular.

PART I

Assessment of CSP Project Prices and Costs in India

1. Introduction

In the following section, the four main Concentrated Solar Power (CSP)[1] technologies are presented, giving an insight into the value chain of systems and components, and into the commercial projects and pipeline.

The solar spectrum may be roughly approximated by the spectrum of a blackbody at approximately 5,778 K, which means that solar energy has a very high exergy. The solar flux density at the earth's mean distance (or "solar constant") is about 1,366 kW/m^2. Some of this is scattered and absorbed as it passes through the atmosphere, so only around 1 kW/m^2 is incident on the surface of the earth at noon on a cloudless day. This means that the solar radiation by itself would only heat a thermal fluid to a relatively low temperature; to achieve higher solar fluxes and higher temperatures, sunlight must be concentrated.

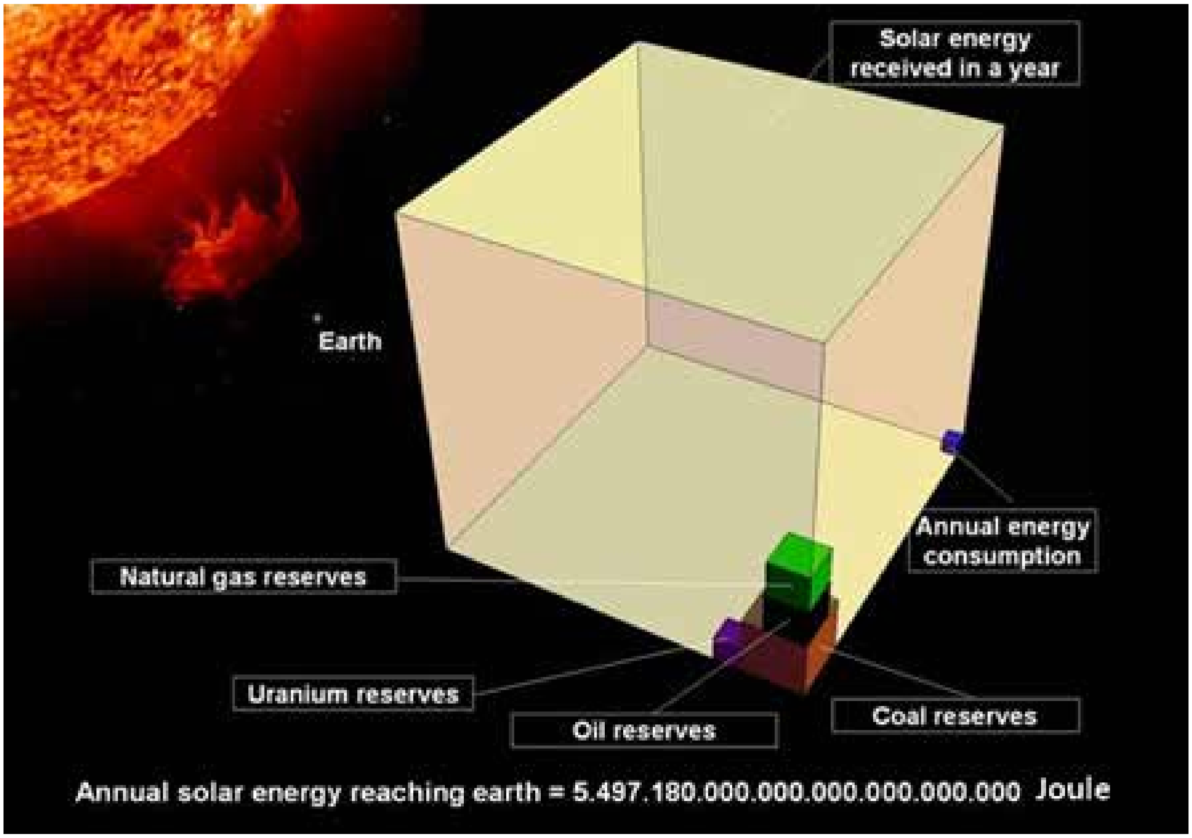
Figure 1 shows the high potential of the solar energy in comparison with other energy sources. Solar radiation received in the whole terrestrial surface in one year is represented in this figure, together with all the known fossil fuel reserves, including uranium. Annual energy consumption is also depicted in Figure 1.

This huge potential is distributed over the earth, having different incidence in specific locations, depending on the latitude and average cloudiness, for example. These values can vary from 675 kWh/m^2/year in the Arctic islands to 2,400 kWh/m^2/year in some locations such as the Sahara.

Solar energy thus has two main characteristics: it is highly diluted and highly variable.

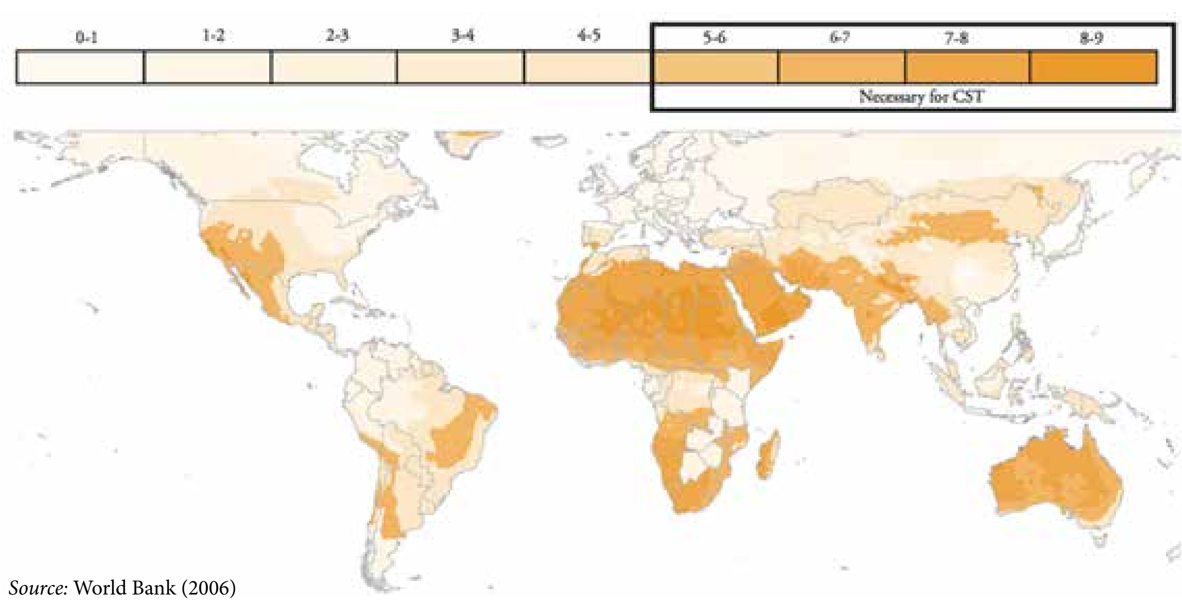
[1] In this report, CSP stands for Concentrating Solar Thermal Power and focuses only on the power generation aspect of solar power. The report discusses only a group of CSP technologies and excludes concentrating PV.

Figure 1:
Comparison of Different Energy Sources Worldwide



Source: CENER

Figure 2:
Solar Resources for CSP Technologies
(DNI in kWh/m²/day)



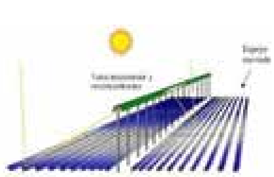
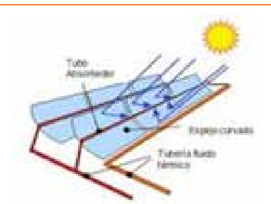
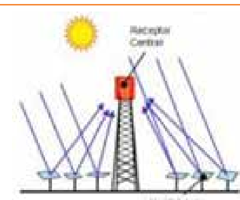
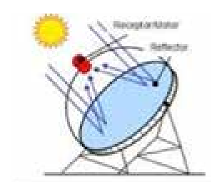
Source: World Bank (2006)

The benefits of solar power are compelling: environmental protection, economic growth, job creation, energy security, and rapid deployment, as well as the global potential for technology transfer and innovation. The underlying advantage of solar energy is that the fuel is free, abundant, and inexhaustible. Solar conversion technologies can be applied properly in regions with annual mean radiation values higher than 1,750 kWh/m^2 per year. Solar thermal power has an important advantage in comparison to other renewable energies technologies—and that is its potential dispatchability. For many solar thermal technologies, it is possible to include an effective thermal storage system or a hybrid scheme, with fossil fuels or biomass to avoid interruptions during transient conditions or after sundown.

Hybrid systems allow for reduction of polluting and greenhouse gas emissions in comparison to fossil plants, offset variations of the solar radiation by fossil fuel to avoid partial load operation of the turbine, improve the integration to the grid, and increase the capacity factor without incremental costs associated major additional investment costs. Solar thermal technology takes advantage of incident solar radiation, concentrating and collecting it in a specific system that heats a thermal fluid. This heat is then used to run a turbine or engine and produce electricity. This process can be carried out directly or indirectly, through an intermediate heat transfer fluid and the use of a heat exchanger.

As presented in Table 1, four CSP technologies are being currently developed and operated: linear Fresnel reflector (LF), parabolic trough (PT), power tower system or central receiver system (CRS), and parabolic dishengine (PD).

Table 1:
Main Characteristics of the Four Main CSP Technologies

LINEAR CONCENTRATION SYSTEMS		POINT FOCUS CONCENTRATION SYSTEMS	
LINEAR FRESNEL REFLECTOR	PARABOLIC TROUGH	POWER TOWER SYSTEM	PARABOLIC DISH OR ENGINE (STIRLING)
			
■ LF reflector concentrating systems use flat or slightly curved mirrors to focus solar radiation onto a linear receiver.	■ PT systems concentrate the solar radiation with a parabola-shaped mirror onto a linear receiver located at its focal length. ■ The PT system is the predominant linear system and is the most developed and commercially tested CSP technology.	■ A Central Reciever system uses mirrors called heliostats with two-axis sun-tracking to focus concentrated solar radiation on a receiver at the top of a tower. ■ Two main technical designs can be distinguished depending on the working fluid used: water/steam and molten salts.	■ PD systems consist of a mirrored dish that collect and concentrate 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 common type of heat engine used).

A detailed description of commercially available CSP technologies and their plant and components value chain is provided in Appendix 1.

2.
Assessment of Cost Reduction for CSP Projects under JNNSM

In the following section, the cost evolution and bid price assessment for the four main CSP technologies are presented in the context of the completed bidding for Phase-I of the JNNSM.

While Appendix 3 provides information on the cost evolution normally expected, the prices of CSP projects in India, quoted by the bidders, have evolved in a unique manner, and a reduction of about 37.5 percent over the reference project costs has-been seen in the very first round of 470 MW projects under Batch I of Phase I of the JNNSM. The contracts were awarded through a process of a reverse auction based on tariff-based competitive bidding. Steep reductions were observed in the offered CSP prices facilitated through a wide array of regulatory mechanisms, detailed in Appendix 4.

While the Central Electricity Regulatory Commission (CERC) had notified a benchmark capital cost of Rs 15 crores/MW of installed capacity translating to a benchmark (feed-in tariff) tariff of Rs 15.30/KWh, (based on petitions filed by project developers, public consultations, comparative studies of international project costs, and adjusting these costs to the local conditions where applicable). Because of an overwhelming response of solar project developers, which would have resulted in capacity oversupply, the Government of India had to resort to a competitive bidding process for the selection of project developers.

Sixty-five bidders were shortlisted, totaling an installed capacity of 2,811 MW. The Ministry of New and Renewable Energy (MNRE) set a ceiling for submitting bids at the 470 MW, planned for contract awards. Since the number of bidders far exceeded the project capacity to be awarded, the selection of the bidders was carried out through a reverse auction process wherein the bidders were asked to provide discounts against the CERC determined tariff of Rs 15.30/KWh. In order to prevent adventurous bidding, the discounts to be offered were linked to additional bank guarantees, depending on the quantum of the discounts offered.

The list of bidders and the discounts offered by the bidders are given in Table 2.

Table 2:
Bidders and Discounts Offered for a CSP Project in NSM Phase-I

Name of the Bidder	Capacity (MW)	Discount (P/KWh)
LANCO	100	482
KVK Energy	100	411
Megha Eng	50	400
Raj Sun-Tech	100	334
Aurum Renewable	20	312
Godavari	50	311
Corp Ispat	50	307
Indure	50	297
Welspun Renewables	50	285
Chennai Radha	5	281
Sai Sudheer	20	276
OM Metal	50	246
Wadhwan Solar	50	242
Sravanthi	75	235
Zamil Infra	100	234
Welspun	50	234
Birla corp	10	230
GAIL	50	219
Goyal MG Gases	50	213
Neel Metal	45	201
Coramondal	25	194
Abengoa	50	181
VA Friendship Solar	50	157
Sujana	10	154
Aravali	45	153
Essar Power	100	153
ACME	50	151
Cargo	50	140
Stellar Energy	50	132
Askit Power	50	125
ACME	50	123
Sheshraj	10	120
Prithvi info	100	108

Name of the Bidder	Capacity (MW)	Discount (P/KWh)
Askit Power	50	100
Dot Servises Ltd	5	92
VS lignite	50	82
Hetthrow	50	82
KG Solar	50	76
Knowledge	10	74
Gamnmon Renewable	50	64
Airmid Power	100	50
GRD	25	46
Shapoorji Pallonji	50	37
East India	20	34
BG Power	50	32
Abengoa	50	31
Sujana	10	31
Alstrom Capital Solar	5	16
MAHA GENCO	50	1
Cethar Energy	10	0
Surana Green	50	0
Intergra	30	0
Skill Infrastructure	36	0
VA Friendship Solar	50	0
Era T&D	50	0
Birla Urja	10	0
Madhav Power	5	0
Alex Spectrum	25	0
ILFS	10	0
Surya Vidyut	10	0
Hindustan Thermal	30	0
Green Energy Renewables	50	0
Stellar Energy	50	0
Surya Chakra	50	0
Surya Chakra	5	0
Elecor SA	100	0

Of the 65 shortlisted bidders, 16 did not offer any discount. Fourteen bidders offered discounts ranging from Rs 1.00 to Rs 2.00/kWh. Thirteen bidders offered discounts from Rs 2.00/kWh to Rs 3.00/KWh and the 7 successful bidders offered discounts from Rs 3.07/KWh to Rs 4.82/KWh. Seven companies, including Abhijeet, Lanco, and Reliance, were allocated projects at a weighted average price of Rs. 11.48/ KWh.

The bids quoted by the developers are an indication that the bidders gave consideration to the strategic importance of early entrance to the market and were able to leverage both internal and external resources to competitively lower offer prices. By contrast, the CERC prices might have also been on a higher side, since adjusting feed-in tariff close to real prices requires regular adjustments based on the experiences of implemented projects in a given country environment. As per the JNNSM timelines, the developers have to commission the plants by May 2013. Even though all the projects have achieved financia clouser, it has been reported that several projects are facing implementation challenges, ranging from financing, inaccurate DNI data (leading to reengineering the solar collector sizing), supply chain, etc.

2.1 Estimation of LCOE Based on Bid Analysis

The major parameters that go into determination of a rate of cost recovery are as follows:

- Project cost
- Interest rates
- Return on equity (ROE)
- Net generation
- Debt-to-equity ratio

As per the CERC norms for these parameters, cost of electricity tariff for a project with the investment cost of Rs. 15 crores/MW translates into Rs. 15.30/KWh. Considering the same CERC assumptions, the project costs for a successful bidder would translate into Rs. 10 to Rs. 12 crores/MW if the bidder accepts a lower ROE of 14 percent as against the CERC norm of 19 percent. In addition, the developers may have factored in on balance sheet financing a foreign loan or domestic loan at a lower interest rate, which would allow arriving at the acceptable internal rate of return at a project cost assumed by CERC. Considering these and other factors, it can be inferred that the developers would have estimated a project cost of between Rs. 13 crores/MW and Rs. 14 crores/MW.

The CSP projects in India are currently in the execution phase, and most of the projects have achieved financial closure and have commenced construction. There are reports that several developers are experiencing delays in project construction due to lack of experience. Further, the lack of availability of the HTF s also cited as one of the bottlenecks. Only upon commissioning the projects and assessing the lessons learned, including the re-evaluation of estimated costs, would it be possible to determine with a higher degree of accuracy the reasons for considerably low project prices offered by the bidders. In this respect, it is necessary to emphasize that the bid price of the project doesn't necessarily represents its cost. In markets, in which the developers are exploring the ways of early entrance, the prices can be intentionally lowered to secure first contracts and gain the needed project development and operational experience. It is quite plausible that some other factors contributed to lower bidding prices, including but not limited to the following:

- The global recession leading to competition among the global suppliers for key solar plant items resulting in an ability to negotiate a lower cost.

- Adopting an engineering, procurement, and construction (EPC) management route rather than the full EPC procurement method.[2] The latter assumes full functional and performance guarantees, thus increasing the overall project cost. The downside of the EPC management approach is the risk of not achieving the performance parameters provided in the bid, as well as slipping on project schedule milestones and commissioning dates.

2.2 CSP Plant Cost Estimates in India

Based on the analysis of project prices offered by the bidders, a comparison between the capital cost of the reference 50 MW CSP parabolic trough plant without storage and cost estimates of a similar plant in the Indian market conditions plant is presented in Table 3.

Table 3:
Cost Breakup of a Reference 50 MW CSP Parabolic Trough Plant

CONCEPT	COST (US$ M)	COST (Rs. Crores)	Typical India Cost Estimates (Rs. crores)
Solar collection system	106.7	471.4	**176.8**
Mirrors	17.3	76.6	49
Support structures	34.7	153.1	49
Drive mechanisms	3.8	16.7	4.8
Land leveling	10.4	45.9	15
Foundations	17.3	76.6	24
Assembly	23.3	102.8	35
Thermal conversion system	43.3	191.5	**130**
Thermal oil	3.2	14	22.5
Receiver tubes	18.4	81.2	60
Ball joints	0.6	2.6	2
Piping, valves and spare parts	1.9	8.5	5
Oil forwarding skid (filters, piping, pumps, tanks, assembly)	12.4	55	35
Oil purification system	0.5	2.4	1
Fire protection system	1.6	7.2	2
Inertization system	0.8	3.7	2.5
Natural Gas Boilers	3.8	16.7	0
Electrical conversion system	94.4	417.1	**195.5**
Oil/steam heat exchanger	17.2	75.8	30
Power block	37.2	164.3	65
Balance of plant (BOP)	25.7	113.8	75
Civil work	14.3	63.2	25.5
Project management and EPC	44	194.6	**55.73**
Project management	2.1	9.5	5
EPC (17%)	41.9	185.2	50.73
TOTAL	288.4	1274.6	**558.03**

[2] EPC Management is a consultancy contract where the consulting firm only manages the engineering, procurement and construction aspects with limited performance guarantees. The developer undertakes the project performance risk.

Based on the numbers in Table 3, an estimated plant cost, if the EPC is carried out on a package basis and not a turnkey basis, and negotiating system-wise prices and result in a plant cost of Rs. 558 crores for 50 MW CSP trough plant (without storage) or Rs. 11 crores/MW.

2.3 Reasons for Higher Capex of International CSP Projects

As seen in Table 3, the cost of a typical international CSP project is almost twice that of estimated prices of projects of the same size in India.

Major factors for this significant difference could be attributed to the following:

a. Premium pricing for recovery of sunk technology costs
b. Project cost commensurate with the feed-in tariff, which is a guaranteed payment mechanism
c. Execution of the projects through the full EPC method, which requires higher premiums, since the project risk is shifted from the project developer to an EPC company
d. A longer project preparation cycle time and higher costs of obtaining permits & clearances
e. Higher wage costs

2.4 LCOE Evolution Comparison

The JNNSM launched by Government of India has been successful in promoting solar projects and has kick-started the solar industry in India. The JNNSM has achieved the major objective of bringing solar onto the center stage.

Phase I of the JNNSM witnessed a massive response from all stakeholders resulting in the launch of a transformational process for the Indian solar industry during the last two years. When Phase-I program of the JNNSM started, the CERC determined that prices were at about Rs. 19 crores/MW and Rs. 15 crores/MW for photovoltaic (PV) and CSP projects, respectively. At that time, the cost evolution pattern was clear neither for PV nor CSP. The prevailing assumption at that time was that since the PV module manufacturing process was dependent on silicon and the silicon prices were high, the possibilities for PV cost reduction were considered slim. It was also felt that since the CSP was based on commonly manufactured products, such as steel and mirrors, the prospects of CSP costs coming down were considered to be more realistic. Therefore, the government-estimated project costs and corresponding ceiling rates reflected the then level of technology cost projection information.

Since then, the solar PV project costs have come down sharply to a level of Rs. 7.5 crores/MW, whereas despite the significant price lowering cost reduction proposed by the domestic developers vis-à-vis international project costs, CSP projects were still priced significantly higher at about Rs. 11–13 crores/MW.

2.5 Future CSP Cost Reduction Possibility

To address the issue of the level of cost reduction achievable in the second phase, one needs to examine the cost drivers in detail to see whether localization can drive down the costs or not. Currently, the components being imported in the case of the trough technology are mirrors, HTF, receiver tubes, steam generators and steam turbine generators. In the case of the direct steam generation process, viz. CLFR, the imports are limited to mirrors and steam turbines.

The current import policy and concessional customs duties and exemption from excise duty for the setting up of solar thermal project is a very favorable policy and which in fact makes the imported components almost at par with the domestically manufactured components. The import duties for solar thermal projects have been further reduced in the current budget. It seems that there is not too much scope for additional import duties lowering measures that the government can take. On the other hand, even if there is an assumption that these components can be manufactured locally, the issue is whether that would result in a significant reduction in costs or not.

The key components, such as mirrors, Heat Collector Element (HCE), Heat Transfer Fluid (HTF), and solar steam generators, constitute only 25 percent of the cost of the CSP project. The other key equipment, presently being imported, is the steam turbine generator, which adds up another 10 percent to the project cost. This 35 percent import value is for the parabolic trough technology. In the case of the tower or CLFR technology, the only component that may need to be imported is the flat mirror and steam turbine, which will translate to about 20 percent of the project cost. The manufacture of low-iron glass-based mirrors involves emptying the furnace of the earlier charge and replacing it with a new charge of low-iron sand. Emptying the furnace and achieving the quality needed for solar application takes around 10 days. Because the volumes are low, the mirror manufacturers typically schedule the manufacturing twice a year. Unless there is sufficient volume, the mirror manufacturers may find it more cost-effective to import the mirrors than to manufacture them locally. It is understood that Borosil has a dedicated low-iron glass manufacturing facility that can cater to about 600 MW in a year.

Assuming that local manufacturing would result at best in a 25 percent reduction of certain equipment costs, this would translate into a reduction of 5–9 percent of the project cost. Therefore in the next round of CSP solicitation, the project bid prices for solar thermal projects are likely to come down to about Rs. 9 crores/MW, in the best case scenario, which is very competitive in the CSP field in comparison with global CSP costs. The CSP plants based on the tower technology can come down even further to a level of Rs. 8.5 crores/MW, since in the case of the tower technology, except for the mirror, all other item can be fabricated locally.

However, even with this price level, the stand-alone CSP project could hardly be competitive with a solar PV project at the present rate of Rs. 7.5 crores/MW. This cost advantage of PV technology over the CSP one is based on the assumption that both projects intend to supply only the mid-day load, and the CSP project does not have storage. Under different supply conditions, a CSP plant might be a preferable choice, given the technological ability to accommodate storage and thus serve morning and evening peak loads. The project cost definition for both PV and CSP projects presently doesn't include the cost related to maintaining the reliability of an electric system through the sufficient provision of reserve and backup capacity. When such an aspect is incorporated into the cost (and respective bid prices) of PV and CSP projects, the competitive advantage of the CSP option becomes more distinct.

PART II

Competitive Positioning of Local Manufacturing in CSP Technologies

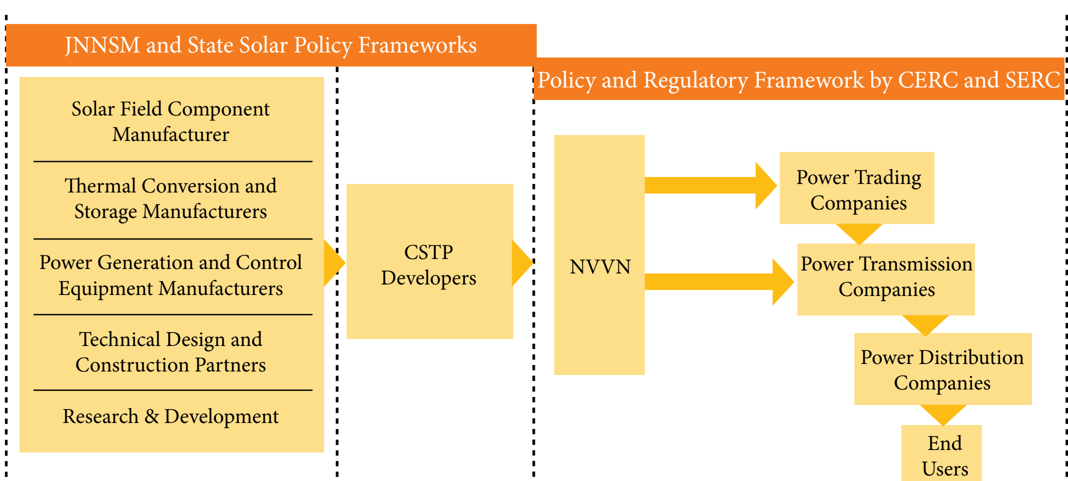
3. Present Scenario of CSP Local Manufacturing in India

The following section elaborates on the current scenario of local manufacturing in India.

3.1 CSP Value Chain

The Indian CSP value chain in Figure 3 depicts the players involved from the design stage to the end users. Currently the major part of activity in India is geared toward CSP plant developers who are collaborating with international CSP technology providers, EPC contractors, component manufacturers, and Indian power generation equipment manufacturers to set up CSP plants in Rajasthan and Gujarat.

Figure 3:
Illustration of CSP Stakeholders in India



Note: Presently the NSM is limited to CERC and NVVN
Source: AQUA MCG (2011)

Table 4:
Industry Groups and Other Organizations Identified as Key Stakeholders

INDUSTRY GROUPS	OTHER STAKEHOLDERS
DIRECT INDUSTRY GROUPS	■ Engineering institutes (IITs, Energy Institute India, TERI, ISP, UPES, EAI, Renewable Energy Institute, SEC) ■ Industry associations (FICCI, CII, FAST) ■ NGOs and societies (Indiasolar, SESI) ■ Government agencies and companies (IREDA, PFC, NVVN, CERC, MNRE, MOP, IM) ■ Banks and financial institutions (PSU banks, IDBI, SIDBI, NABRAD, World Bank, ADB, KfW/)
Developers; technology providers; glass and mirrors; electronic tracking, instrumentation and control systems; EPC or EPC management; support structures fabrication; heat exchangers & piping, electrical equipment; speciality industrial chemicals; speciality industrial equipment; CSP advisory	
INDIRECT INDUSTRY GROUPS	
Iron and steel; metals; wires and cables; cement; synthetic materials; automotive industry	

Identification of Key Players

The main equipment suppliers identified in India for each CSP technology are shown in Table 5, separated by different subsystems' components or functions: solar field, power block, and EPC.

Table 5:
Vendors for Solar Field Components Currently Identified in India

RECEIVER TUBE	MIRROR	SUPPORT STRUCTURES	PYLONS	SSGOR HEAT EXCHANGERS
■ Schott ■ Siemens ■ AREVA	■ Saint Gobain ■ Asahi ■ Guardian	■ Skyfuel (PT) ■ Abengoa (PT, CR) ■ Areva (LF) ■ Neo Structo Group ■ IOT Anwesha Eng ■ Flagsol (PT) ■ Siemens (PT) ■ KG Group (LF) ■ Larsen &Toubro ■ Solsys ■ Shrijee Tower and Solar Structures ■ Jyoti Structures ■ Associated Power Structures	■ Neo Structo Group ■ IOT Anwesha Eng& Cons. Ltd.	■ Thermax India ■ BHPV Ltd ■ Thermal Systems (Hyd) Ptv. Ltd. ■ GEI Power Ltd. ■ BHEL
DRIVE OR TRACKING	**BALL JOINTS**	**HTF**	**HTF PUMPS**	**PIPING**
■ Bosch Rexroth (India) Ltd. ■ Parker Hannifin (India) Ltd. ■ Vickers	■ Vardhman Bearings ■ Igus (India) Pvt. Ltd. ■ Carbon Rotofluid Pvt. Ltd.	■ Dow Chemicals ■ Solutia Chemicals ■ BASF ■ Bharat Petroleum ■ Hindustan Petroleum	■ Sulzer Pumps India ■ ITT India ■ KSB India ■ Flowserve India Controls Pvt. Ltd. ■ PPIL, Bangalore ■ KBL, Pune	■ BHEL

Table 6:
Vendors for Power Block Components and Concept Engineering/EPC Currently Identified in India

COMPONENTS	CONCEPT ENGINEERING OR EPC	
Siemens	Abengoa Solar	Infinia
GE Energy	Areva	Clique Developments Pvt. Limited
BHEL	Skyfuel	Sunborne Energy
Gammon India Limited	Acciona	Thermax
DF Power Systems Pvt. Limited	e-Solar	Suryachakra Power
TurboTech	Brightsource	LANCO
Maxwatt		
Triveni		

3.2 SWOT Analysis of CSP Component Manufacturing Industry

A SWOT analysis of the CSP component manufacturing industry is given below.

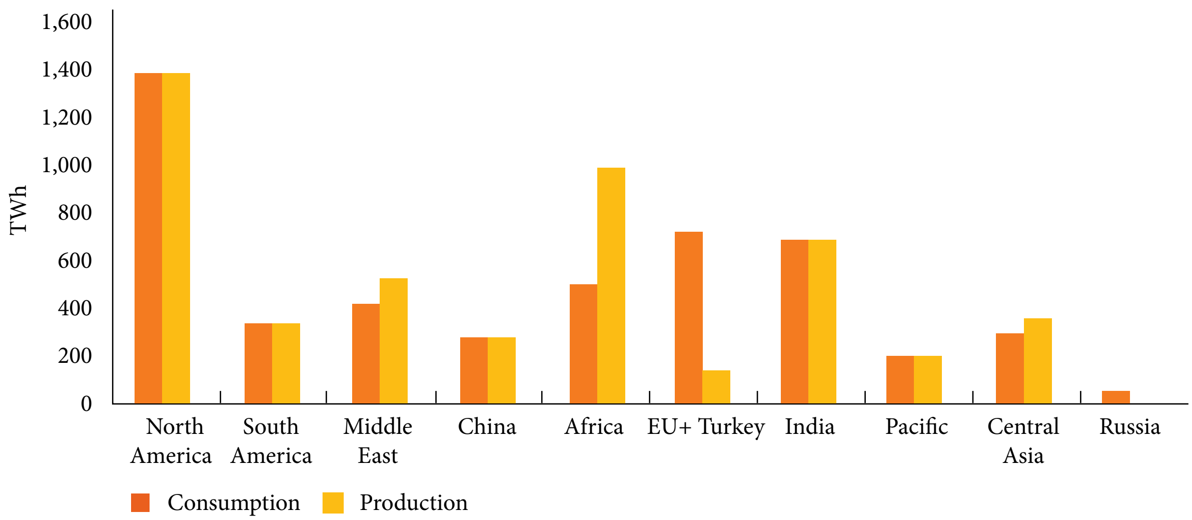
Table 7:
SWOT Analysis for Local Manufacturing for CSP Components

Strengths ■ Strong and established related industries in manufacturing in most of the components of the value chain—glass, precision equipment and turbines. ■ Prior experience in developing skilled manpower and resources through a large number of established technical and engineering institutes. ■ History of established models of success in other technology intensive industries, such as public-private partnerships (PPPs) and technology transfer through joint ventures (JVs). ■ Lower cost of unskilled labor resulting in lower costs of components manufacturing and EPC.	**Weaknesses** ■ Relative weaknesses in technologies for CSP plant development and component manufacturing. ■ Gaps in infrastructure and uncertain government support for performing local R&D for new and emerging technologies. ■ High financial cost of capital ranging from 11% to 11.5% from local sources of finance, leading to higher tariff rates, supplier financing and finance from overseas sources.
Opportunities ■ Strong indications by central and certain state governments of readiness to promote solar thermal power generation, such as many incentives in the form of customs duty, solar energy enterprises zones (SEEZs), exemption from electricity duty, establishment of solar parks in SEEZs, and tax holiday. ■ Expectation of increasing costs of other technologies as there is more demand for fossil fuels.	**Threats** ■ Lack of long term visibility and commitment from government on Phase II and onwards, in terms of pricing and policy framework. ■ Lack of clarity on long-term market penetration of any ■ One technology. ■ Core technology available only from two countries and only a select few global players. ■ Lack of knowledge of CSP technology among banks and financial Institutions. ■ Bureaucratic slow response in the provision of essentials such as water, power lines, roads, approvals and facilities. ■ Very tight project completion time lines (24 months) for such new technologies, with long lead time for supply of materials (for turbines, it is 18 months).

3.3 Participation of Related Existing Local Industries in Supplying CSP Components and Systems

In the medium time range, India is expected to become a major CSP player behind the United States and North Africa, and with a more prominent role than China, as depicted in the Figure 4 below.

Figure 4:
Production and Consumption of CSP Electricity by 2050 (TWh)



India's National Solar Mission includes measures aiming at driving down costs and encouraging domestic solar manufacturing in order to rapidly expand the use of PV and CSP systems. The plan also proposes scaling up centralized solar thermal power generation with the aim of achieving cost parity with conventional grid power by 2020 and the full necessary energy infrastructure by 2050. With the objective of 20 GW of solar power by 2022, and a first step of 1.3 GW of solar power by 2013 (1.1 GW grid-connected and 0.2 GW off-grid), this is the most ambitious solar plan that any country has laid out so far.

To bring this solar plan to success, existing Indian industries have to be incentivized to participate significantly in supplying CSP components and systems. Many traditional industries that could take an active part in CSP technology development have been identified. Most of them need only a modest effort to adapt their products and manufacturing processes to meet the demand of the CSP industry. Table 8 shows examples of traditional industries that are or could be successfully involved as component manufacturers for the CSP industry. In particular, the mass production processes used in the automotive industry could be implemented for CSP component manufacturing.

Besides the industries mentioned in Table 8, other traditional industries could also enter the CSP market:

- **Technical supervising** companies are able to achieve a high quality of control to reduce risks specifically in the scaling process by using advanced metrology techniques, such as artificial vision.

- **Electronics industry**, with several leading companies based in India, uses glass-to-metal seals in TV cathode ray tubes. These seals are of special importance in the manufacturing process of PT receiver tubes.
- Heat-trace system suppliers for **oil and gas industry** could provide such systems to trace molten salt piping for the thermal storage of CSP plants.
- **Chemical industry** could support the development of improved HTF or storage media. Furthermore, India's coating and paint industry is very active, with a considerable expertise in sol-gel and sputtering techniques, which are of special relevance in the manufacturing process of PT receiver tubes.

Table 8:
Traditional Industries Potentially Involved in CSP Industry and Components Manufactured in Future

EXISTING INDUSTRY	COMPONENTS	POTENTIAL SUCCESES
AUTOMOTIVE	■ Engines	Sener (SenerTrough) Ferrostaal (with Cleveland automotive industry) SES (with GM)
GLASS	■ Mirrors	Flabeg, Rioglass, Saint-Gobain, Guardian
METAL	■ Structures	Shuff Steel/SES, Gossamer/Acciona
POWER AND PROCESS HEAT	■ Power block ■ Balance of plant ■ Heat exchangers ■ Receivers	Siemens, Ormat Babcock & Wilcox, Victory Energy, GE, ALSTOM
MACHINE TOOLS AND ROBOTICS	■ Drive mechanisms	eSolar (navigation drives manufacturer)
CHEMISTRY	■ Heat Transfer Fluid ■ Storage fluid	Dow Chemicals, Solutia

To place the prospects in perspective, one may remember that five years ago only a small number of companies with specific expertise and a variety of research institutions were involved in R&D projects in this field. Today the number of private companies involved in this sector has strongly increased, and the newcomers are not only start-up companies, but also established corporations coming from traditional industries, such as automotive (processes for car glass manufacturing, metal stamping, and coating can be adapted to CSP components), glass, steel, power, or construction. With a moderate R&D effort, some of them were able to grab significant market shares. Nonetheless, the competition between CSP players will increase, enlarging the need for R&D activities to develop cheaper and more efficient components. That is why research collaborations between private companies and research laboratories are a key factor in developing the components and systems that will bring CSP technologies to success.

4.
Analysis of Manufacturing Capabilities of Specific Components

This chapter elaborates the manufacturing capabilities for specific CSP components.

4.1 Mirror Manufacturing Industry

The following section details out the mirror manufacturing industry in India.

Manufacturing Capability Requirements

Mirrors used in CSP plants are different from traditional mirrors in reflectivity, durability, and strength. The fabrication of the needed extra clear glass requires low-ferrous sand that is not easily available in India. Furthermore, this glass has no other application in India and therefore must be made specifically for solar CSPs.

Industry Structure

The glass industry in India has a production capacity of around 0.68 Mtons per year. Production of float glass is about 0.51 Mtons, which is nearly 75 percent of the total glass production in India. Sixty percent of the world's high-quality float glass is produced by four companies: Asahi, NSG Group (Pilkington), Saint Gobain, and Guardian. Using a metalized polymer film that can be laminated to an aluminium substrate, Skyfuel offers a competing technology with similar functionality.

Table 9:
Major Manufacturers of Mirrors in India

PLAYER	PROFILE
ST. GOBAIN	Has the capacity to manufacture 1,500 tons/day of float glass in Sriperumbudur plant. It is setting up additional facility for 950 tons/day in Bhiwadi (Rajasthan), which will be ready in 6 months. The existing facility can make extra clear float glass required as base glass for mirror manufacturing, but does not have the facility to make CSP quality mirrors.
ASAHI INDIA	AIS Float Glass has two manufacturing units located at Taloja and Roorkee with a combined capacity of 1,200 tons per day. The Roorkee float glass unit has an installed capacity of 700 tons/day. AIS Float Glass commands a nearly 29% share of the Indian float glass market.
GUJARAT GUARDIAN	Gujarat Guardian Limited is a joint venture company that has set up a float glass plant in India in technical and financial collaboration with Guardian Industries Corp., USA. The factory is set up in India at Village Kondh in Bharuch district of Gujarat. GGL currently makes float glass and mirror glass at a float line with 630 tons/day of pull tone capacity and 4.2 Mm2/year mirror production facility.
SKYFUEL	Using a metalized polymer film that can be laminated to an aluminum substrate, Skyfuel offers a competing technology with similar functionality. Skyfuel has signed a Memorandum of Understanding (MOU) with Megha Engineering and Infrastructures Limited (MEIL) regarding the use of its PT collector in CSP projects (MEIL has been awarded 50 MW in Phase I of the JNNSM scheme).
3M	3M also manufactures polymer film based mirrors.

Table 10:
Gaps in Local Manufacturing

GAPS	POSSIBLE SOLUTION
■ High-quality low-iron sand availability in India	■ Import low-iron sand or low flat float glass to make mirrors
■ Technology gap for some of the players (bending, mirroring)	■ JV/licensing from CSP mirror manufacturers

Cost Reduction Because of Local Manufacturing

Cost reduction because of local manufacturing is expected to be in the range of 10 percent, but this may require the development of local glass handling and logistics skills. Specialized tools, such as specialized trucks with air suspension and custom-tailored steel frames for mirror transportation, should be provided by the manufacturers. The reduction can be attributed to lower shipment costs, lower labor costs, and ease of handling.

Higher cost reductions (up to 30–40 percent) in the short term can be achieved by importing high-quality low-iron sand flat float glasses with the subsequent bending and mirroring processes being carried out locally with specialized equipment available in the market.

Some developers are also exploring the possibility of importing low iron flat float glass and using Glasstech's 3 roll computerized glass bending machine to manufacture the mirrors. This can result in 40% reduction in cost.

Relative Market Growth and Market Dynamics

As mentioned before, the sales of mirrors—assuming 300 MW/Year of CSP installation—would only constitute a small proportion of overall sales for mirrors (5–10 percent), but the local industry considers it a growth sector with important potential.

International players, such as Saint Gobain and Gujarat Guardian, which have the required technology and the manufacturing facility in India, will look to manufacture mirrors locally provided there is enough local demand. Players like Asahi Glass and some other local players may seek the licensing route. As of now, the entry of players like Flabeg and Rioglass in ventures on their own is not envisaged in the near future.

Table 11:
Minimum Investment Required for CSP Parabolic Mirror Manufacturing

PHASES	ADVANCE COMPONENT ASSEMBLY	COMPONENT COATING	INTEGRATED MIRROR MANUFACTURING
INVESTMENT (Rs. crores)	12–14	60	120

If the float glass manufacturing facility already exists, only the raw material has to be imported so that extra clear glass can be made. A SWOT analysis of the local manufacturing capability of mirrors is given below.

Table 12:
SWOT Analysis for Local Manufacturing of Mirrors

Strengths ▪ Existing set up of float glass manufacturing and company ▪ Availability of technology with international players who are doing local manufacturing ▪ Availability of skilled manpower to make extra clear glass	**Weaknesses** ▪ High capital cost. ▪ Skilled manpower required for bending and mirrors ▪ Minimum demand is large for achieving efficiencies ▪ Testing facility and industry standard is not available
Opportunities ▪ Mirrors can provide extra high margin revenue to established players ▪ Importing low iron Flat Float Glasses & Bending & subsequent mirroring has the potential to reduce cost substantially.	**Threats** ▪ Delivery gaps from suppliers for meeting quality requirements ▪ Insufficient clarity in the road map of CSTP as it is high capital investment business ▪ Skyfuel using a metalized polymer film on an aluminium substrate, which is a competing technology

4.2 Fabrication Industry for Support Structures

The following section details out the support structures manufacturing industry in India.

Manufacturing Capability Requirements for Parabolic Trough Collectors

Support structures include mirror support, pylons, central stem and support arms. The concentrator mirrors are installed on a rigid metal structure, which gives them the parabolic shape necessary to concentrate the radiation in their linear focus. Structures are manufactured by high-precision fabrication processes with galvanized steel or aluminium as the raw material. Because the structures are exposed to open air, specific grades of steel are required. Manufacturing process requirements are different even for different types of parabolic trough collector (PTC) technologies. The design and type of PTC structure and technology determine the layout and cost of the manufacturing line.

Industrial Capability

The fabrication industry in India is fairly mature. Fabricated components are made locally for several applications and industries. Companies in the automotive component industry are capable of manufacturing support structures. For CSP manufacturing, several manufacturers in India are entering the market using JVs or collaboration with foreign counterparts.

Prominent global players for support structures are Flagsol, Solargenix, Sener, Albiasa Solar, and SkyTrough. In India, Jyoti structures Ltd under license from SBP, and Megha Engineering under license from Albiasa have already commenced fabrication. Some more potentially interested players are Bharat Forge (automotive component manufacturer), Larsen & Toubro (manufacturing, engineering, and construction), and Kalpataru Power Transmissions (operating in EPC and manufacturing for the real estate and electrical transmission industries). Other potential players could be AMW Auto Component (automobile component manufacturing), Anand Motor Products (automobile component manufacturing), JCBL (automobile manufacturing), Tata Autocomp (automobile component manufacturing), and HEC (Engineering Fabrication).

Cost Reduction Because of Local Manufacturing

According to the feedback received from local manufacturers who have JVs with overseas players, the cost reductions caused by local manufacturing are around 15 percent, because of differences in labor costs and savings in logistics costs and custom duties.

Local manufacturers who claim to have the capability to manufacture the structures on their own are suggesting cost reductions of around 30–40 percent. However, at this time, it is difficult to know the precision and quality of products to be supplied by companies that are attempting to fabricate these components for the first time.

Relative Market Growth and Market Dynamics

Both domestic and export markets offer huge opportunities. Approximately 300 MW of PTC installations per year would lead to a market size of approximately Rs. 450 crores. The

Middle East and North Africa (MENA) could be a potential export market in the future. A SWOT analysis of the local manufacturing capability of support structures is given below.

Table 13:
SWOT Analysis for Local Manufacturing of Support Structures

Strengths	**Weaknesses**
■ Existing industrial base & huge market potential has lead local manufacturers to develop this component indigenously via Licensing/JV route	■ Testing facility is not available. ■ Structures have to be tested under Indian conditions.
Opportunities	**Threats**
■ Export markets ■ Huge Potential to reduce costs & still earn decent margins.	■ If large number of players enter the market, then profitability after 5-7 years (Phase 3) might be a concern.

4.3 Receiver Tubes Manufacturing Industry

The following section details out the receiver tubes manufacturing industry in India.

Manufacturing Capability Requirements for PTC

The receiver (power tower receiver, PTR) is a critical component for the performance of the PT solar power plant because it is in the receiver where much of the energy losses (optical and thermal) originate. The selective surfaces of the receivers must be highly absorbent and have low thermal emissivity at the operating temperature.

Industry Structure

Currently there are no players in the Indian market who are capable of manufacturing PTR. While there are four prominent players in the global market, licensing and JVs are one route to a profitable opportunity. Another is indigenous development of technical know-how. Local companies venturing into this area can expect a market not only from CSP, but also from industrial heat applications. Some of the global players may set up their own Greenfield ventures in India in Phase II or Phase III, since the minimum demand requirement for any one player is 200 MW.

Leading players include Siemens, Schott, Archimede Solar, and Huiyen. Siemens and Schott have a strong dominance in the PTR market, but given the high margins for the existing players, there is the potential for much activity in receiver tube development and marketing in the near future.

Current Status of Local Manufacturers

While India will be in a position to develop its own expertise for reflective coating in the near future (1–2 years), expertise in the metal-glass seal is still lacking, even if the Indian electronics industry has some experience in this field. If Indian companies develop the technology indigenously, a large number of patents for receiver tubes internationally will force them to work on new concepts, which will require extra efforts in R&D.

Table 14:
Gaps in Local Manufacturing

GAPS	POSSIBLE SOLUTION
■ Technical know-how for Solar Selective Coating & Anti-reflective coating	■ Expertise expected to be developed by 2014
■ Technical expertise for metal glass seal	■ R&D either by the government or in PPP mode is required

There are Indian players who are indigenously developing this technology, namely, NAL Bangalore, Milman Thinfilm Pvt Ltd Pune, KG Design Services, and Borosil. However, the technology is not fully developed, and it would take 3–5 years before this is ready for commercialization.

Cost Reduction Because of Local Manufacturing

Currently, receiver tubes must be imported. Local manufacturing by global players will reduce costs by approximately 10 percent. Large cost reductions (30–35 percent) may be possible.

Relative Market Growth and Market Dynamics

Only high-quality receiver tubes can be used for CSP applications. Receiver tubes can also be used for industrial heat applications (for example, the pulp and paper industry), thus providing added incentives for manufacturers. Assuming 300 MW/year of PT plant installation, the market size would be Rs 450 crore/year for CSP itself. For heat applications, the market size per year would also be substantial. A key growth driver would be high investment in the R&D space by the government or in a PPP model. A SWOT analysis of the local manufacturing capability of receiver tubes is given below.

Table 15:
SWOT Analysis for Local Manufacturing of Receiver Tubes

Strengths ■ Indian Institutions are in a position to develop this technology provided Govt. support is provided	**Weaknesses** ■ Technology Transfer from global players maynot come easily ■ A large part of the cost is estimated to be from Propriety knowledge. ■ Globalplayers may not have any major advantage in setting up manufacturing base in India
Opportunities ■ Local players who develop the necessary technological knowhow indigenously can reap rich rewards. ■ Large supplementary demand from Industrial Heat Processes ■ Large Cost reduction Possible if Indian Players are able to develop the technology	**Threats** ■ Lack of clarity in demand may deter investments in the R&D space by privateplayers ■ The Local companies who develop this technology may need 2-3 years to prove their technology under real conditions.

4.4 Tracking and Drive Mechanism Industry

The following section details out the tracking and drive mechanism manufacturing industry in India.

Manufacturing Capability Requirements

The purpose of the drive mechanism is to ensure that the reflectors are optimally positioned during the whole day to track the sun's position. Thus, these mechanisms are a decisive parameter to attain a high degree of efficiency.

Industry Structure and Market Assessment

Some players in India (such as L&T) have been supplying tracking solutions for military applications and may be in a position to develop the technology on their own in the future. For Phase I, the drive mechanisms for CSP applications (costing about Rs 2.8–3.5 lakh/unit) will mostly be imported. Nevertheless, with companies having the manufacturing base for certain parts that are also used in wind power application, those companies are currently considering the option of adding manufacturing lines for certain parts of tracking devices for CSP as well. Some components of tracking devices for PT technology may potentially be manufactured locally by international players.

Local Manufacturing Capability Assessment

Table 16:
Indian Manufacturing for Parabolic Trough, Current Status and Future Scenario (assuming at least 500 MW/year of CSP installation in India)

COMPONENTS	APPROXIMATE COST (%)	COMPLEXITY	CURRENT STATUS	FUTURE STATUS
HYDRAULIC POWER PACK	20%	Standardized	Imported	Local
CYLINDER	20–30%	Specialized	Imported	Local
SENSORS	20%	Specialized	Imported	Imported
CONTROLLER	30–40%	Specialized	Imported	Imported

Source: AQUA; CENER

For CRS technology, the percentage cost of each individual sub component will vary.

Table 17:
Gaps in Local Manufacturing

GAPS	POSSIBLE SOLUTION
Proprietary know-how for sensors & controller	Indigenous R&D by Private Players like L&T
25–30% of total cost is propriety know-how	Indigenous R&D can reduce cost by 35–43%

Relative Market Growth and Market Dynamics

Since the market for tracking devices will be dependent to a large extent on the CSP plant installation, the key growth driver for local manufacturing will be clarity on the demand side. Some of the components for tracking devices are similar to the ones being used for wind power. Hence, the capital expenditures (capex) required will mostly be incremental. Local manufacturing for tracking devices will require a minimum demand of 500 MW/ year of CSP plant installation to justify the incremental capex (for international players with an established manufacturing base in India). A SWOT analysis of the local manufacturing capability of tracking devices is given below.

Table 18:
SWOT Analysis for Tracking Device Manufacturing in India

Strengths ■ Similarity in some of the components with Wind Power implies that only incremental capex will be required ■ Low manpower costs can provide a competitive edge ■ Tracking devices are already being manufactured and used for solar power steam generation and military applications	**Weaknesses** ■ Technology Transfer from global players is required•A large part of the cost is estimated to be from Propriety knowledge. ■ Thus local manufacturing will provide only 5-10% cost reduction
Opportunities ■ Local players who develop the necessary technological knowhow indigenously can reap rich rewards. ■ If min share of local project costs increasesin phase 2, then TADM that requires only incremental capex gets a boost. ■ Irrespective of the technology, this sector is expected to have a market demand as per government plans.	**Threats** ■ Lack of clarity in demand may deter manufacturers from setting up even incremental local manufacturing base ■ Unclear incentivesmay deter global players from collaborating affectively with local players for mutual benefits

4.5 HTF (Synthetic Oil) Industry

The following section details out the HTF industry in India.

Manufacturing Capability Requirements

The role of the heat transfer fluid (HTF) that circulates through the solar field 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 loops in the solar field. The solar field outlet temperature is restricted by the HTF properties, which means that the fluids that can perform these functions are also limited. The commercially proven technology is limited to a temperature of around 400°C. High-purity propylene crude and ethylene crude are the main raw materials to produce these fluids; sulphonation and blending are the two major production processes.

Industry Structure

Dow and Solutia are currently present in India and are the leading players. Indian Oil and Reliance Petrochemicals are producing industrial oils and are some of the potential players that may manufacture it locally. However, with the demand being uncertain as of now, it appears less probable that Indian players will invest in R&D and manufacturing facilities.

Current Status of Local Manufacturers

Since there are currently no local players, global players are meeting the demand of Phase I. The main raw materials for the production of ethylene crude and high-purity propylene crude are the most important factors for setting up production facilities in any region. In India, ethylene crude is produced by Reliance; high-purity propylene crude is not manufactured locally. The required sulphonation and blending processes can be done in India.

Table 19:
Gaps in Local Manufacturing

GAPS	POSSIBLE SOLUTION
■ Availability of high purity propylene crude	■ Import in the short term
■ Technical expertise for sulphonation and blending	■ R&D collaborations with petrochemical players

Cost Reduction Because of Local Manufacturing

No cost reductions are expected in the short and medium term. In the long term, it is difficult to estimate the extent of cost reduction because of the high variability of crude prices. Possible reductions in cost can occur if global players setup manufacturing facilities in India.

Relative Market Growth and Market Dynamics

Supply-demand mismatch coupled with higher crude prices have led to substantial increases in prices in the past two years. Demand for synthetic oil for solar applications forms a substantial portion of the total industrial demand of synthetic oil. A demand of 300 MW/year from PTC installation would lead to a market size of Rs. 240 crores/year. If the demand from new PTC plants continues to rise (as is expected), additional manufacturing capacity would have to be added. A SWOT analysis of the local manufacturing capability for HTF is given below.

Table 20:
SWOT Analysis for Local HTF Manufacturing

Strengths ■ Existingpetrochemical refining companies in India can develop the required expertise or enter into licensing/JV with emerging players in this segment like Radco	**Weaknesses** ■ Highpurity propylene crude will have to be imported. ■ HTF fluid would need to be tested for extended period of time.
Opportunities ■ Indian demand base (Rajasthan/Gujarat) in close proximity to existing petrochemical refining capacities, thus reducing logistics costs substantially.	**Threats** ■ HTF for solar application has only limited use outside of the solar demand. If the demand from PTC were to fall drastically, the profitability might be severely impacted.

4.6 Turbine Manufacturing Industry

Manufacturing Capability Requirements

CSP turbines have slightly different operational requirements than conventional steam turbines. Indeed, they have to endure frequent load variations and numerous start-up and shut-down procedures, so transient and part load operations are critical. Besides, they usually have a relative small capacity (50–100 MW) compared to turbines for traditional fossil fuel power plants (200–1,000 MW). In order to justify the investment cost for a CSP plant, which will not run continuously for 24 hours per day, high demands for efficiency and increasing economic returns are imposed on the CSP steam turbine. Additionally, day and night cycling often requires a large number of starts and rapid start-up capabilities from CSP steam turbines. Considering the annual power production operations, the short start-up times of the turbines are of great value to the CSP plant owner as they decrease the down time of the plant.

Country Level Capacity and Production

The Indian turbine market grew at a rate of 44.1 percent between 2004–05 and 2008–09. The growth was the result of additional power generation capacity. The demand for turbines is primarily met by domestic production, which was valued at US$912 million for 2008–09, while turbine installation in India was valued at US$1,136 million. Both imports and exports of turbines have grown at over 35 percent over the last few years. However, total imports of turbines largely outpace exports. In recent years, turbine imports from China and Korea have increased.

Current Status of Local Manufacturers

Table 21:
Major Manufacturers of Turbines in India

PLAYER	PROFILE
BHEL	BHEL is the largest state-owned engineering and manufacturing company in India catering to the energy and other infrastructure sectors.
L&T–MHI	Larsen & Toubro Limited (L&T) is a technology, engineering, construction, and manufacturing company. It is one of the largest and most respected companies in India's private sector.
GE TRIVENI LTD (JV)	Triveni is an engineering company that supplies components for the sugar, power, and water industries. It is one of the largest suppliers of steam turbines in India and the first such company to get ISO 9001:2000 certification for turbine manufacturing.
SIEMENS INDIA	Siemens consolidates its innovative offerings in the energy sector by combining its full range expertise in the areas of power generation (PG) and power transmission & distribution (PTD). Utilizing advanced plant diagnostics and systems technologies, Siemens provides comprehensive services for complete power plants and for rotating machines, such as gas and steam turbines, generators, and compressors.

Leading players, such as BHEL, have the capability to supply CSP specific turbines in the short term. GE-Triveni may also look at >60 percent indigenization in the medium term to reduce costs. Some other players, such as Maxwatt, have already supplied smaller CSP turbines (2–5 MW) to some developers in India.

Table 22:
Gaps in Local Manufacturing

GAPS	POSSIBLE SOLUTION
Know-how for meeting complete specifications	Expertise expected to be developed by 2012
Tight schedules due to demands on capacity	Successful implementation of Phase 2 and certainty in demand by 2013

Cost Reduction Because of Local Manufacturing

Cost reduction because of the local manufacturing of CSP turbines is expected to be in the range of 12–17 percent for global players. With BHEL and other local players coming into the picture, a cost reduction of 22–32 percent is envisaged.

Relative Market Growth and Market Dynamics

The key growth driver for turbine manufacturing in India will be the strong demand from the power sector. The expected addition is 100,000 MW in 2017 in terms of demand of power generation installations. However, CSP is expected to contribute to less than 3 percent of the energy generated via thermal power cycles.

Competitive Factors

An important parameter for solar thermal power generation is the efficiency of the turbine. At present, local manufacturers are developing the expertise to make CSP turbines meeting high efficiency requirements. The second important parameter is the lead time for supplying the customized CSP turbines. Current turbine manufacturers take 16–24 months to supply turbines once the order is placed. This is primarily because of the strong demand for turbines from the coal and gas power generation segment, which competes with the CSP segment, given the limited capacity for local manufacturing. Long lead times pose a challenge, given the tight deadlines for Phase I JNNSM projects, especially under the current dynamic growth of the gas thermal generation market driven by falling natural gas prices. A SWOT analysis of the local manufacturing capability of turbines is given below.

Table 23:
SWOT Analysis for Local Manufacturing of Turbines

Strengths ■ Technological know how already available withsomeInternationalcompanies with Indian presence& with Leading Indian players like BHEL ■ Highly mature Turbine industry implies that very little incremental	**Weaknesses** ■ Low demand from CSTP segment as compared to coal and gas based thermal power generation segment ■ CSTP Turbine demand will be much less than conventional ones like Coal and/or Gas based in theforeseeable future ■ Indian Manufacturers have yet to execute the first 50MW or greater work order of CSTP Turbine
Opportunities ■ Collaboration with CSTPTechnology providersis an option for localturbine manufacturers. Some steps have already been taken in this direction. For e.g. BHEL has signed an agreement with Abengoa. ■ In the future, export market especially in the MENA region may form a substantial portion of sales.	**Threats** ■ Lack of clarity in demand may deter manufacturers from developingCSTP specificmanufacturing expertise. ■ Unclear incentivesmay deter CSTP Technology providers from collaborating affectively with local players for mutual benefits

4.7 Solar Steam Generator Manufacturing Industry

The following section details out the solar steam generator manufacturing industry in India.

Manufacturing Requirement

The solar steam generators are a special type of heat exchangers that help in the transfer of heat from HTF/molten salts to water/steam.

Leading Players

Main potential solar steam generators in India are presented in Table 24.

Table 24:
Potential Lead Players in Solar Steam Generator Manufacturing

PLAYER	PROFILE
THERMAX (INDIA)	Has the technological know-how and the manufacturing capability to manufacture SSG for both HTF and molten salts use in PT, LF, and CR technologies.
BK AALBORG	Denmark-based company with manufacturing facilities in Denmark and China.
BHEL (INDIA)	Largest state-owned engineering and manufacturing company in India catering to the energy and other infrastructure sectors.
HOLTEC TERNATIONAL	Designs and fabricates a broad spectrum of solar power plant equipment, such as steam generators, superheaters, reheaters, water-cooled or air-cooled condensers, low-pressure feedwater heaters, and high-pressure feedwater heaters.
CETHAR VESSELS	For more than 25 years has been manufacturing all types of combustion and recovery boilers, heat recovery steam generators, power plant piping systems, water treatment plants, and cooling towers for thermal power plants.
VESPL	More than 25 years of experience in the design, manufacture, and supply of various types of sophisticated boilers and boiler components.
INDUSTRIAL BOILERS LTD	Manufactures oil-or gas-fired boilers, high-pressure power-generating water tube bi-drum boilers, heat recovery boilers for diesel generator and gas turbine applications, heat recovery equipments, and water treatment plants.
ISGEC JOHN THOMSON	Leading manufacturer of wide range of boilers and pressure vessels.
GODAVARI ENGINEERING LTD.	GEL is already supplying heat exchangers for some of the solar thermal projects under Phase-I.

As mentioned already, solar steam generators are a special variety of heat exchangers. Hence, only incremental capex is required for the companies already manufacturing boilers and heat exchangers. However, for international companies such as BK Aalborg that do not have a manufacturing base in India, the licensing or JV route might be more appropriate, since they may be more willing to provide technological know-how. For local manufacturers, participation will require incremental capex. Companies like BHEL are in a position to develop the required technological know-how on their own and have the required manufacturing facilities to produce solar steam generators.

Relative Market Growth and Market Dynamics

The key growth driver for solar steam generator manufacturing in India will be the demand from local CSP installations. However, Indian companies like Thermax and other local players may be in a position to supply this component to meet demand from MENA countries. The key competitive advantage for local manufacturing will be the low staffing costs, coupled with the required technological know-how already present with Indian companies. The minimum requirement in MW to catalyze local manufacturing is very low, since some Indian companies today are in a position to fulfil even small orders. A SWOT analysis of the local manufacturing capability of solar steam generators is given below.

Table 25:
SWOT Analysis for Solar Steam Generator Manufacturing in India

Strengths ■ Technological know already available with some local companies ■ Highly mature boiler/heat exchanger industry implies that only incremental investment will be required for the leading players	**Weaknesses** ■ Opportunities for year on year cost reductions expected based on economies of scale will be small
Opportunities ■ Collaboration with global players is an option for companies not havingknow-how ■ In the future, export market especially in the MENA region may form a substantial portion of sales. ■ If the local component in the total project cost is further increased, it will boost local manufacturing	**Threats** ■ Lack of clarity in demand may deter manufacturers from setting up even incremental local manufacturing base ■ Unclear incentivesmay deter global players from collaborating affectively with local players for mutual benefits

4.8 HTF Pumps Manufacturing Industry

The following section details out the Heat Transfer fluid (HTF) pumps manufacturing industry in India.

Manufacturing Capability Requirements

The HTF pumps used in CSP plants are used to transport thermal fluids to heat exchangers and are similar to the ones being used for refineries. They must be fully compliant with ISO 13709/API 610. Some solar installations have a primary and auxiliary HTF pump, both built to meet the plant conditions. Their design should keep in mind the wide fluctuations in operating conditions expected in CSP power plants.

Current Status of Local Manufacturers

Table 26:
Players in HTF Pump Manufacturing in India

PLAYER	PROFILE
ITT INDIA	They have the capacity to meet the demand of up to 1,000 MW/year of CSP installation (HTF–thermal oil). They have a plant in Baroda that can make complete pumps. They have local sources for raw material, and they estimate their pumps would cost 40–50% less than imported pumps.
KSB INDIA	Can provide auxiliary pumps from a local manufacturing base. HTF main pumps need to be sourced from their parent company in Germany. Molten salt pumps will need to be sourced from Rehintoor Germany.
FLOWSERVE PUMPS INDIA LIMITED	Can provide HTF pumps for CSP plants with less than 50 MW capacity from their local manufacturing base. For higher capacities, they need to be sourced from their parent company.

Cost Reduction Because of Local Manufacturing

Cost reduction because of local manufacturing is expected to be in the range of 30–50 percent. The reduction in manufacturing costs can be attributed to lower labor costs in India than in developed countries. This will result in lower tooling and lower component costs to be used in manufacturing. Since a local manufacturing base already exists for HTF pumps in India, any further cost reduction in the immediate future is not envisioned.

Relative Market Growth and Market Dynamics

The local HTF pump industry is not fully reliant on CSP industry, but sees it as important potential market. As mentioned before, although the sales of HTF pumps, assuming 4,000 MW of CSP installations by 2017, would constitute a small proportion of overall sales for HTF pumps (5–10 percent), the industry sees it as a growth sector.

Since the industry is at a stage where it can fulfil the demand originating from CSP power plants installations with ease, it is not expected to be a constraining factor to the growth of CSP power plants in India. In addition, the HTF pump technology is relatively mature, and not much reduction in cost is expected from technological breakthroughs in the near future (<10 years). Once the industry size becomes very large, further innovations specific to solar CSP might be possible.

The growth rate for HTF market in India for CSP power plants would be directly linked to the underlying requirement from CSP power plant installation. Since the cost will be lower by 15–20 percent, HTF can be exported as the manufacturers here gain experience in the CSP market. A SWOT analysis of the local manufacturing capability for HTF pumps is given below.

Table 27:
SWOT Analysis for Local Manufacturing for HTF Pump

Strengths ■ Low Manufacturing Cost ■ Availability of highly skilled labour at relatively lower costs. ■ Mature industries for Refineries & Thermal Power Plants ■ Availability of technology with international players who are doing local manufacturing	**Weaknesses** ■ Opportunities for year on year cost reductions expected based on economies of scale will be small
Opportunities ■ Can provide additional source of high growth revenues toexisting players ■ In the future, export market especially in the MENA region may form a substantial portion of sales.	**Threats** ■ Compromise on API 610 quality standards due to aggressive price bidding by players

5. Summary of CSP Local Manufacturing Potential and Cost Reduction

The following chapter provides the CSP local manufacturing and cost reduction potential.

5.1 Local Manufacturing Capability Assessment and Export Potential

Interactions with players in the CSP field have resulted in the assessment summarized in Table 28 of the local manufacturing capability for CSP specific components and the potential for export to regions, such as Middle East and North Africa (MENA) and South Africa.

Table 28:
Preliminary Local Manufacturing Capability and Export Potential to MENA

Subsystem	Component Ormaterial	Local Manufacturing Capability	Export Potential to Mena
Solar Field	Receiver Tube	1	1
	Mirror (PT)	2	1
	Mirror (CR)	3	1
	Structures or Pylons	4	3
	Solar Steam Generators	4	4
	Drive/Tracking (PT)	2	3
	Drive/Tracking (CR)	1	2
	Ball Joints	4	3
	Htf (Oil or Molten Salts)	1	1
	Htf Pumps or Piping	4	3
Thermal Storage	Molten Salts	1	1
	Other Components	4	3
Power Block	Turbines	3	4
	Other Components	4	4

**Ranking is from 1 (low) to 4 (high)*

Indeed, MENA could be a potential export market in the future, but only if India becomes a competitive manufacturing base for equipment as the MENA region is also looking to growing domestic industries for local manufacturing of CSP components. The table below analyses the export potential to MENA particularly. All projections concerning export options to MENA need to be considered with caution, since such opportunities might not be realized—at least in the near- and medium-term future.

Future investments in development of local manufacturing units (especially for specialized equipment) will depend on several factors:

- Successful implementation of solar thermal projects for the Phase 1 participants.
- Firm government commitment for the development of solar thermal power plants.
- R&D help from Indian institutions or JVs/Licensee arrangements with international companies.
- Easy availability of financing options for investment in a new and rapidly developing technology

5.2 Timeline for Indigenization

Interactions with players in the CSP field have resulted in the assessment of the timelines for manufacturing summarized in Table 29.

Table 29:
Timeline for Indigenization

COMPONENTS	PHASE I (1 to 3 years)	PHASE II (4 to 7 years)	PHASE III (8 to 12 years)
SOLAR FIELD			
Site Development	Local	Local	Local
Foundations & Pylons	Local	Local	Local
Mirrors PT and PD[3]	Import	Import	Local
Mirrors CR and LF	Import	Local	Local
Frame and Support Structure	Local	Local	Local
Receiver tubes PT and LF	Import	Import	Local
Receivers for CR and PD	Import	Local	Local
HTF Synthetic Oil	Import	Import	Local
Drive and Track PT and LF	Local	Local	Local
Drive and Track CR and PD	Import	Import	Local
POWER BLOCK			
Solar Steam Generator	Local	Local	Local
Turbine	Import	Local	Local
Cooling System	Local	Local	Local
BOP	Local	Local	Local

Local Import

Source: AQUA MCG, CENER

Conclusion:
Solar Field:
- **Mirrors:** Partial Manufacturing is possible in phase I with full indigenization in phase II
- **Receiver Tubes, HTF, Drive & Track Mechanism:** Indigenization is estimated by phase III

Power Block:
- **Turbines:** Indigenization may happen in phase I itself, but is expected to get stabilized by phase II

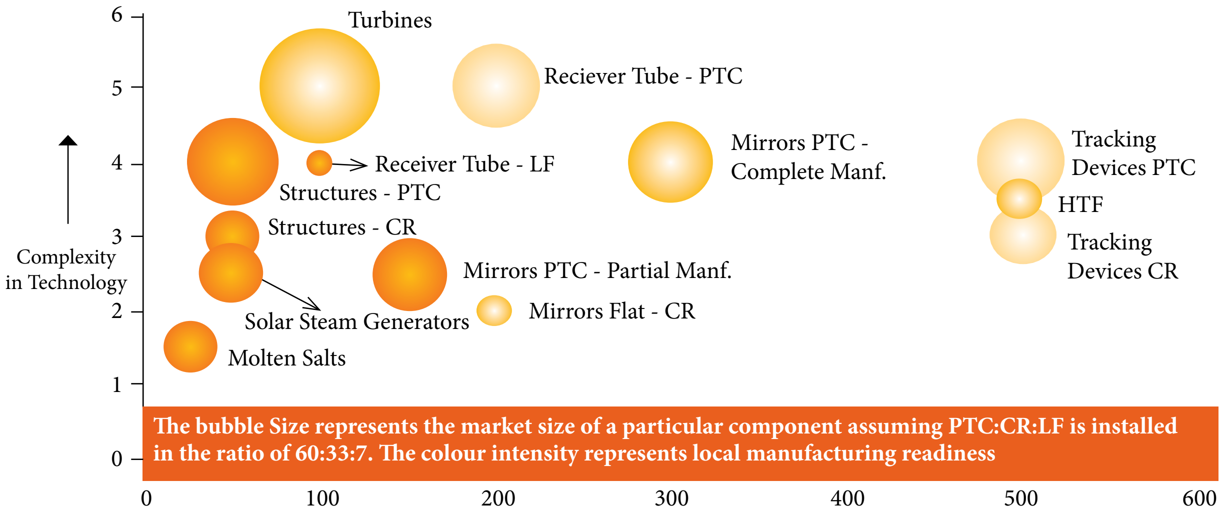
[3] The technology for mirror manufacturing would be available at these phases provided that low-iron sand is available in India. Otherwise low-iron sand would have to be imported. Also valid for Mirrors CR and LF

5.3 Minimum Demand Requirements

As depicted in Figure 5 below, local manufacturing for all CSP-specific components will require less than 500 MW/year of demand. For receiver tube (PTC) and tracking devices manufacturing to happen in India, significant R&D is required within India or a JV/ Licensing from international players.

Figure 5:

Minimum Demand Requirements (MW/year)



Source: AQUA MCG

5.4 Expected Cost Reduction

Interactions with players in the CSP field have resulted in the assessment of expected cost reductions summarized in Table 30.

Table 30:

Assessment of Cost Reductions (in percent) due to Local Design and Production

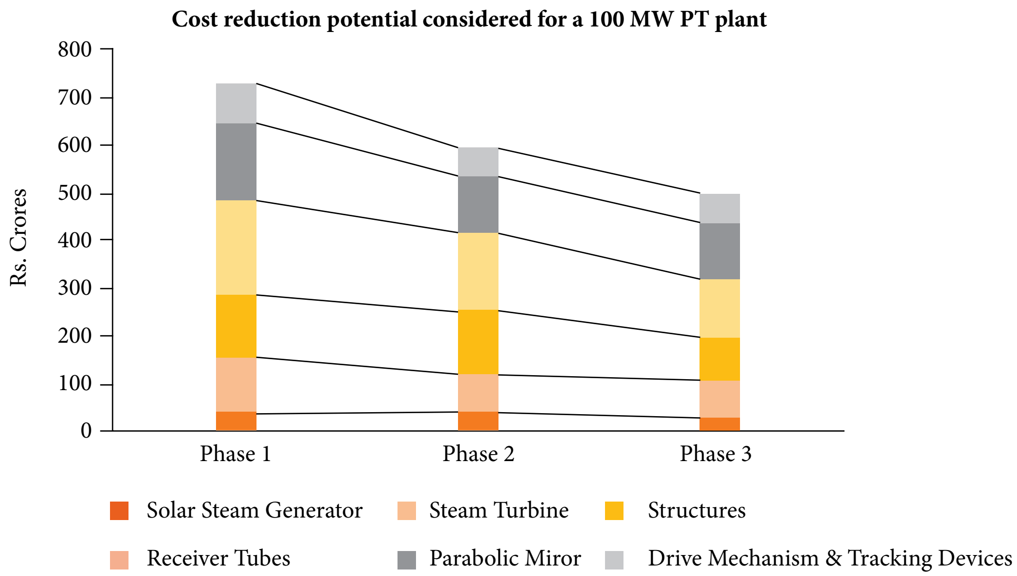
COMPONENTS	REDUCED LOGISTICS	LOCAL MANUFACTURING	TOTAL (EXISTING IP)	IP IN LOCAL DESIGN	TOTAL (LOCAL IP)
MIRRORS PARABOLIC	5	3	8	10–20	18–28
MIRRORS FLAT	3	3	6	—	6
TRACKING DEVICES DRIVE MECHANISM	2–5	3	5–8	25–30	30–38
RECEIVER TUBE-PTC	2	3	5	20–25	25–30
HTF PUMPS	3	8–10	11–13	—	11–13
TURBINES	2	5–10	7–12	10–15	17–27
STRUCTURE-PTC	3	4–7	7–10	20–30	27–40
SOLAR STEAM GENERATOR	2	3–5	5–7	15–20	20-27

— Not applicable

Cost reductions because of technological breakthroughs, higher volumes in domestic and International markets, and learning curve gains would have effects over and above the figures shown here.

A significant cost reduction is expected from local manufacturing of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures (PTC). Developers would also find local manufacturing very attractive because of value-added services, such as the local presence of many O&M options, better procurement lead times, and trained local work force.

Figure 6:
Cost Reduction Potential Due to Local Manufacturing for Components Considered for 100 MW PTC Plant without Thermal Storage



Source: AQUA MCG

The cumulative cost of the components illustrated above in 2011 is Rs. 723 crores, which is estimated to be 45% of the total project cost. With local manufacturing, we see a net decrease of Rs. 135 crores, a 19% decrease by Phase III and a decrease of Rs. 232 crores or 32% by Phase III for the above components (Phase II and Phase III prices are at 2011 prices).

5.5 Potential Involvement with International Players

The following section explains the potential involvement of Indian manufacturing industry with international players in the CSP market.

Expertise on CSP Technology

India currently lacks the necessary expertise and commercial scale experience for solar thermal power plants. In the short term, it is expected that the majority of the developers would depend on international players for their expertise. The following alliances for obtaining overseas expertise are currently known:

- Reliance Power has partnered with Areva

- Lauren Engineers has partnered with Jyoti Structures Ltd., who are locally fabricating the solar collectors of SBP design.
- Acme has entered into a licensing agreement with e-solar
- Dalmia Solar Power has decided to partner with Infinia
- Suryachakra Power Venture and Solar Millennium AG (SMAG), Germany, have formed a JV
- Megha Engg has signed up with Albiasa Solar for local manufacturing of solar collectors
- BHEL has signed an MOU with Abengoa.
- Ingemetal of Spain has established a subsidiary in Pune for manufacture of solar collectors.

Components Requiring Special Manufacturing Processes

With regard to critical components, such as receiver tubes or mirrors, indications from the industry are that in the short term international players will import them (in the case of PTR) or set up manufacturing facilities themselves (Saint-Gobain). It is highly unlikely that international companies will give license to local players to manufacture technology-specific components, such as receivers, given their concerns about IP protection.

Components with Modifications or Variations

As far as support structures are concerned, they will most likely be manufactured locally with the required expertise to be provided by the international players. Jigs, fixtures, and molds, for example, are expected to be different, but indigenously manufactured.

With respect to the turbines, it will take a while for local manufacturers, such as BHEL, to adapt their technology to what is required for solar power plants. Most of the turbines are likely to be imported for the Phase I of the JNNSM; however, local turbine manufacturers are expected to be fully ready by Phase II to become suppliers for solar power plants by 2013–17. Examples for governments providing incentives for local manufacturing of CSP components have been provided in the box below.

Box 1:
Examples of Incentives for Local Manufacturing of CSP Components

The Spanish Association of the Solar Thermal Electricity Industry (PROTERMOSOLAR) claims that between 75 percent and 80 percent of the components used in the Spanish CSP plants come from national manufacturing or are developed with national technology. To reach this high level of domestic production, Spanish industry benefited from subsidies enabling the development of manufacturing plants, with many mechanisms to promote the development of innovative companies and focused on job creations, such as national or regional or funds, for example, CDTI and CTA.

In Spain, subventions from the European Council were distributed to the Autonomous Communities by the Technological Fund, giving priority to those regions that have low per capita income. Thus, from the EUR 2,000 million received by the Spanish regional funds, more than 40 percent was directed to Andalusia. The managing organism for most of the budget of the newly created regional agencies for business strategy (mostly development project in consortium) is the Spanish Centre for Industrial Technological Development (CDTI), in collaboration with local institutions.

Cont...

The CDTI is a public entity funded by the Ministry of Science and Innovation whose mission is to promote innovation and technological development of Spanish companies. It supports R&D projects by direct subsidies and helps them access financial support from national and international third parties to improve the technological level of the Spanish industry. In 2009, CDTI was supporting at least five R&D projects for the CSP industry led by the main Spanish players of this sector.

At the regional level, private foundations, such as the CTA in Andalusia, promote collaborations between scientific and productive sectors to answer to the local needs in terms of innovation and development by subsidizing R&D projects and technology transfer. The CTA is currently supporting six R&D projects for the CSP industry.

Successful examples of CSP manufacturing plants that have been built in Germany, Spain, and the United States are shown in Table 31.

Table 31:
Successful Incentives for Local Manufacturing of CSP Components in Spain, Germany, and the United States

PLANT	RIOGLASS SOLAR I	RIOGLASS SOLAR II	RIOGLASS SOLAR INC	SCHOTT	TOTAL (LOCAL IP)
Component	PT mirrors			PT receiver tubes	
Country	Spain	Spain	USA	Spain	Germany
Investment	EUR 23 M	EUR 11 M	US$100 million	EUR 40 M	EUR 15 M
Subsidies	regional funds EUR 8 M	regional funds EUR 2.2 M	local subsidies	reg. & nat. funds EUR 9 M	NA
Job creation	120		200	109	109
Production	1.3 M mirrors/yr		NA	100 000 units/ yr (400 MW PT)	NA

6. Analysis of Potential Economic Benefits from the Development of a Local Manufacturing Base

The development of renewable energy sources is an important goal in its own right, for the reasons listed earlier in this report. When solar energy begins to replace fossil fuels for power generation in a nation or region that is a net importer of those fuels, there is an impact on imports that depends on the market penetration of the new technologies, and this has important consequences for the economy and for security. However, it cannot be assumed that measures taken to further the development of CSP systems will, by themselves, spur the growth of a domestic industry to meet the needs of that development. In some cases, if the industry does not develop at the same rate as the expansion of the renewable source or is incapable of competing in the global market in terms of costs of production or product quality, the development is likely to depend on imports from low-cost producing countries. This is already happening in industrial but high-cost countries, such as the United States, where stimuli intended to support solar technologies have failed to strengthen domestic industries due to competitive international markets. In some cases, and notably in the case of PV systems, domestic manufacturers have been put out of business by competition from cheaper imports. Free trade is supposed to make it possible for all nations to take advantage of the competitiveness of each, but the ideal model fails to take into account market imperfections. For CSP technologies, the highest contribution to the cost of power is the capital cost of systems and subsystems. Therefore, decision makers should take reasonable measures to further the development of an effective domestic manufacturing industry for solar systems and subsystems, related to but in addition to any measures taken to expand the market penetration of renewable energy. One set may assist entrepreneurs, investors, and even the utility industry. Another is needed to promote domestic manufacturing and competitiveness.

This section analyzes the local economic benefits resulting from industry development in India using a dynamic economic model with market scenarios and reference plants with assumptions regarding the local share of a CSP deployment and manufacturing of components. The results are aggregated by average share of local manufacturing in India, economic impact on GDP, and labor impact: job creation and foreign trade impact.

6.1 Description of Economic Model

The JNNSM plan and targets are being considered as a reference for this analysis, so the maximum market size for CSP technologies will be 10 GW by 2022. The other 10 GW of solar power production capacity would be based on PV technologies. The mechanism of a reverse auction is applied to all the three phases of JNNSM.

Besides this, state-level incentives are being offered in Gujarat and Rajasthan. In Gujarat, the market size is not specified, but the feed-in tariff (FIT) has been fixed for the next 25 years. In this mechanism, the lowest tariff is obviously not achieved, but the future market uncertainty is reduced considerably, which provides a good incentive for developers to setup CSP plants in the state. However, for the purposes of this analysis, the JNNSM has been assumed to be successful in the optimistic scenario. It is assumed here that the export markets will be supplied only when the domestic demand is met and they are hence considered separately. Considering the global trends in technology development, CR technology has also been considered in combination with the current dominant PT technology. Three scenarios have been considered for analysis in 2022 (see Appendix 8, as shown in Table 32).

Table 32:
Considered Scenarios for Installed Capacity in India and Export Market

SCENARIO	INSTALLED CAPACITY IN 2022	EXPORT MARKET DEMAND IN 2022
Scenario A (pessimistic)	2,000 MW	0 MW
Scenario B (moderate)	6,000 MW	0 MW
Scenario C (JNNSM, optimistic)	10,000 MW	2,000 MW

Source: AQUA MCG
Assumptions: Scenario B=60% of Optimistic, Scenario A=20% of Optimistic, Export Demand=20% of Optimistic

In order to estimate the total economic impact, costing for a reference plant has been chosen of 100 MW capacity and 8 hours of thermal storage. CR technology has been incorporated because it is generally considered the more advanced and promising technology. However, since there is only one CR plant being setup in India, which is of a small size (10 MW), the cost estimates given for the 100 MW reference plant are approximate, based on similar plants in other parts of the world and adapted to local prices.

Cost reductions in solar field components are primarily due to local manufacturing, and lower customs, logistics, and labor costs. For other components, cost reductions because of learning curves have been considered, taking into account the increase in market size and the passage of time in years. In cases where the critical minimum market size is not reached, only a percentage of cost reductions due to local manufacturing has been considered.

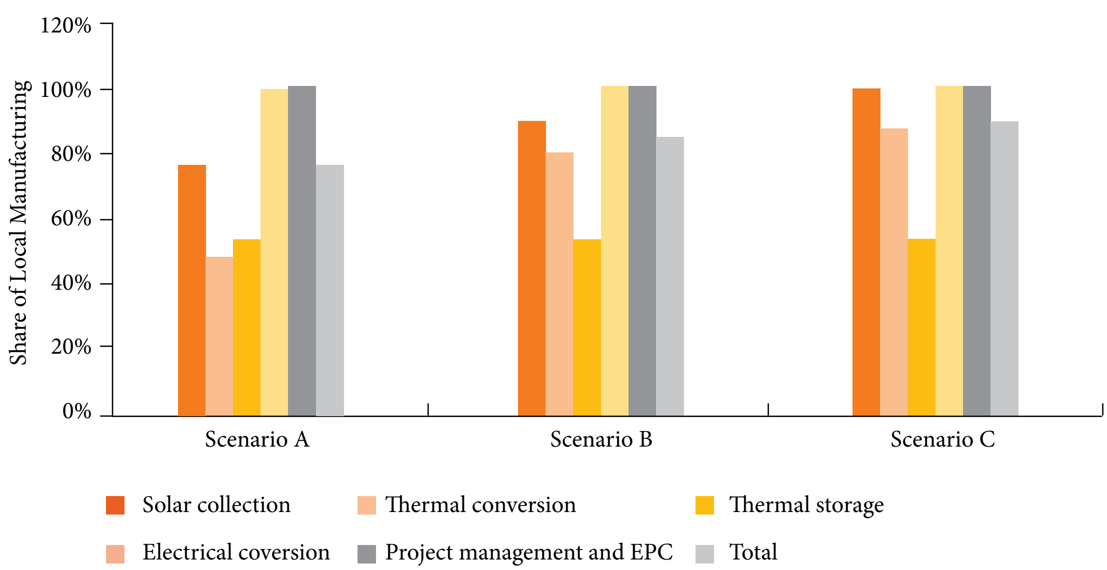
A total reduction of approximately 10 percent in component costs has been considered because of learning curves by 2022 if volume growth of installed capacity materializes. However, if the volume growth is small, these cost reductions are reduced to 3 percent.

6.2 Projected Share of Local Manufacturing

A share of local manufacturing has been showed separately for each of the PT and CR technologies. In both technologies, electrical conversion, thermal storage, and EPC are assumed to be manufactured or supplied locally except for molten salts. In solar collection and thermal conversion, the specific solar technology components, such as mirrors, tracking and drive mechanism (TADM), and receiver tubes, have been considered to be manufactured in the country partially depending on the volumes projected in the respective scenarios. In the first case (Scenario A), TADM and receiver tubes are considered to be imported because of insufficient volumes. In the CR technology, components are simpler and hence easily made locally. However, in scenario A and B, because of insufficient volumes, mirrors and TADM will continue to be imported.

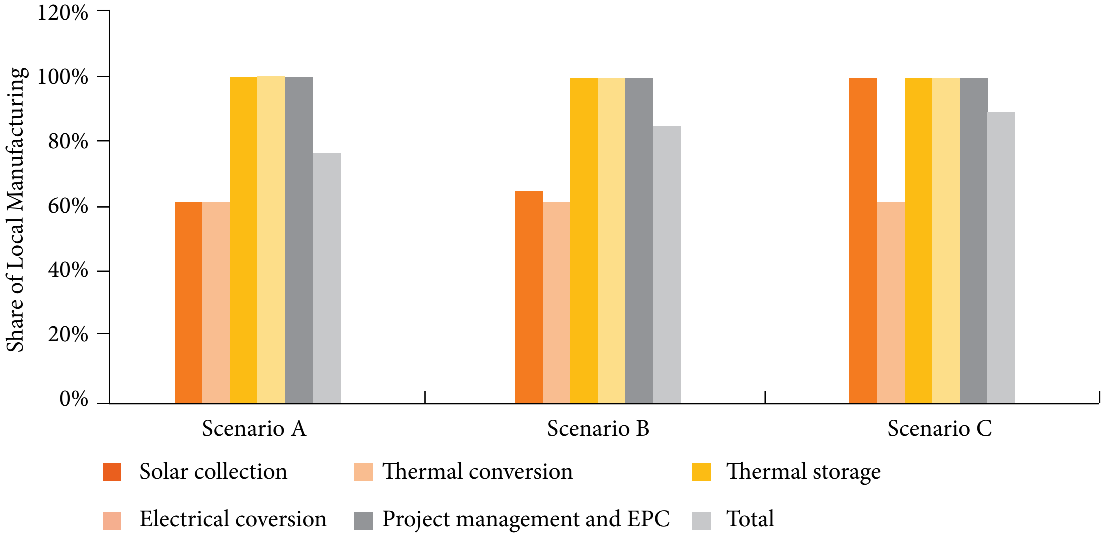
The results of this analysis are gathered in Figures 7 and 8.

Figure 7:
Share of Local Manufacturing in PT Technology



Source: AQUA

Figure 8:
Share of Local Manufacturing in CR Technology



Source: AQUA

6.3 Direct and Indirect Economic Impact

Effects on direct and indirect economic values are calculated in absolute numbers for each scenario. In addition to local manufacturing of components and construction of the plant, O&M will also contribute to the economic impact of CSP plants. The economic impact is strongly related to the market size of CSP.

Table 33:
Estimated Direct and Indirect Economic Impact (in Rs. Crores per Year) for Scenarios A, B, and C

SCENARIO	ECONOMIC IMPACT	PHASE I (2010–13)	PHASE II (2013–17)	PHASE III (2017–22)	LOCAL SHARE BY 2022	COST REDUCTION BY 2022
A	Direct	1,097	2,084	8,400	76%	13%
	Indirect	437	1,020	4,168		
B	Direct	3,233	6,114	24,132	83%	16%
	Indirect	1,288	2,983	12,961		
C	Direct	5,369	10,027	49,170	90%	20%
	Indirect	2,370	5,434	28,725		

Source: AQUA MCG

6.4 Labor Impact in Terms of Job Creation

The results of the labor impact assessment give the numbers of direct job creation during CSP plant construction, as well as the indirect job creation in local manufacturing plants.

The workforce needed during construction and ongoing operations has been estimated for the reference plant based on interactions with developers on the skills, resources, and staffing required. A local factor that needs to be taken into consideration is the way labor is deployed in India. In power plant construction, the core staff is limited and a large part of the work is subcontracted and carried out by contract labor. It is also a fact that higher technology may not be as extensively deployed as in some of the developed countries, since labor in India is relatively cheaper and businesses very often prefer to deploy more staff rather than go in for expensive technology.

Thus the O&M of the plant will also create long-term employment in the solar sector. Jobs in construction and O&M will also have an impact on induced jobs in the region. The number of indirect jobs for construction and O&M will increase other induced jobs. Thus, this will lead to a cascading effect, which will lead to greater wealth and income when new services and products for their private consumption are demanded. It is difficult to quantify the total number of all induced and indirect jobs. It is assumed that the indirect jobs created because of local manufacturing will increase proportionately with the extent of local manufacturing.

The results of job creation for each considered scenario are gathered in Table 34.

Table 34:
Jobs Created for Each of the Scenarios A, B, and C in India

	TYPE OF JOB	CONSTRUCTION			LOCAL MANUFACTURING			OPERATION		
		PH. I	PH. II	PH. III	PH. I	PH. II	Ph. III	Ph. I	Ph. II	Ph. III
A	Managerial staff	33	75	400	30	67	360	17	37	200
	Skilled labor	83	187	1,000	75	169	900	33	75	400
	Unskilled labor	665	1,500	8,000	600	1,350	7,200	67	150	800
B	Managerial staff	100	225	1,200	90	200	1,080	50	110	600
	Skilled labor	250	562	3,000	225	505	2,700	100	225	1,200
	Unskilled labor	2,000	4,497	24,000	1,800	4,050	21,600	200	450	2,400
C	Managerial staff	167	375	2,000	150	338	1,800	83	190	1,000
	Skilled labor	417	938	5,000	375	845	4,500	165	375	2,000
	Unskilled labor	3,333	7,500	40,000	3,000	6,750	36,000	333	750	4,000

Source: AQUA MCG

6.5 Impact of Foreign Trade

Foreign trade in terms of exports generated is estimated only for CSP specific components related to solar fields and thermal conversion. It is assumed that there will be no additional exports for the traditional power block, electrical conversion block, and EPC block components because of growth in the solar thermal industry.

Consideration has also been given to the fact that some of the components will take time to stabilize once manufacturing starts in India. Minimum market demand for manufacturing also plays a factor because this will decide the time at which manufacturing will start in India. For this reason, in scenarios A and B, exports are not considered because with two technologies, sharing the market pie, the market demand is just sufficient for each technology to justify full-fledged production of some components, but not enough for production to stabilize and start exports. Exports have been considered primarily for the more stable PT technology.

Assuming growth in exports of from 400 MW per year in 2022 to 900 MW per year in 2030, the export market is estimated to be about Rs 5,000 crores in 2022, Rs 8,000 crores in 2025, and Rs 11,500 crores in 2030.

PART III

Preparation of an Action Plan to Stimulate Local CSP Technologies in India

7. Present Scenario and Future Needs

There have been some cases where government intervention has been successful in furthering the market penetration of CSP technologies. Spain is a notable example, where a government policy has created what is probably the most mature solar thermal electricity generation infrastructure in the world, promoting domestic manufacturing, the service industries, and energy independence. In a certain way, however, there may be a negative side to even this success story. Indeed, by implicitly neglecting to reward risk-taking and innovation, the infrastructure might turn obsolete very fast.

Conversely, a policy based simply on rewarding the lowest bids may attract non-mature players that may not be in a position to deliver what is expected. A policy that requires a large domestic input in parts and systems where the domestic capacity to produce those parts and systems is non-existent may unduly delay market penetration or may require ad hoc adjustments to show early wins. A policy that completely shields investors from risk may generate complacency and inefficiencies.

There are other ways in which government intervention may be ineffective. A policy that requires a large domestic input in parts and systems where the domestic capacity to produce them is non-existent may delay market penetration unduly. Timing is one of the most common sources for failure. An immediate positive outcome may not be realistic if it depends on an activity whose implementation may take years. Fortunately, in this case, there are tools that may help, such as the so-called critical path method, a project modeling technique extensively used for effective management of all forms of projects. Although this model has not been adopted here formally, it has implicitly informed the recommendations for the implementation of the actions along different stages.

Any of these possibilities may slow rather than promote market penetration (Covell Hansen, and Martin1996). Any time lost in the achievement of what is an urgent goal is time that we all can ill afford. That is why the action plan of the Indian government and industries should be carefully elaborated.

7.1 Current Situation

From the perspective of all the stakeholders, be it the government, the investor, the developer, or the banks, the solar PV projects today are looking attractive because of low capex; low risks; proven technology; simpler installation, operation and maintenance; faster gestation time; not requiring highly skilled operators; not requiring large amount of water; not getting affected much from cloud transients; and having a very low auxiliary power consumption. However, as it was stressed earlier, the CSP advantage becomes more profound when the load serving is needed during the morning and evening peak hours and, in the midterm future, the baseload. The evaluated cost CSP would also be further reduced if the cost related to maintaining the system reliability was incorporated into a solar project costs (for both PV and CSP). From a utility of any entity that has to meet the RPO obligations at the lowest possible cost, presently, the PV technology is clearly the technology of choice within the for mid-day load service segment. In fact, some of the CSP project developers, specifically those who had been developing projects of less than 20 MW capacity, have been exploring the possibility of shifting to solar PV technology option, since the CSP technology was not working out to be economically viable, especially at lower capacities. In case of Gujarat, only one CSP developer of a 25 MW facility is still involved in the construction of the plant, although the project has not made much progress.

One of the ways to reduce the cost difference between CSP and PV is through hybridization of CSP plants, which will significantly improve their economic viability. In the medium term, that storage option should be incorporated into the plant design to further reduce CSP project costs.

7.2 Need to Support CSP Projects

In view of the above, the CSP projects need long-term support from the government to keep the developers interested in the projects and the industry. It is critical that the CSP development in India does not fall through the cracks. Amidst the success of solar PV projects in India, the CSP technology also provides a compelling case for support by the government because of the following reasons technological reasons:

- Firstly, the conversion of solar to steam is a relatively high-efficiency process (vs. the conversion efficiency of PV), and this can effectively supplement the fossil fuels/renewable fuel, such as biomass, thus contributing to overall energy security of the country
- Secondly, CSP technology is the only techno-economically viable technology at present for a storage option that can enable solar energy to become dispatchable, dependable, and for meeting the peak power shortages, as well as serve the base load

8. Action Plan

The JNNSM has plans to increase the contribution of solar thermal power in the country's overall production of power significantly. Hence, going forward, this needs to prominently feature in the country's energy policy and energy planning for the next 10 years. Similarly, the CSP industry associated with solar thermal energy is expected to also grow along with the Solar Thermal Generation. Hence, CSP Industry growth needs to factor in the country's industrial growth plans.

A specific action plan for the government in India has been divided into four parts—policy framework, low-cost financing, subsidies and incentives planning, and a mechanism for promoting innovation and R&D. Specific action items under each government body are provided in Table 35.

Besides all the actions mentioned in the above matrix, the solar policy based on JNNSM guidelines needs to cover the following issues on a long-term basis under the responsibility of the MNRE:

- R&D and innovation framework: Funding mechanism and government support for R&D projects, and mechanisms for PPPs for R&D projects.
- Framework for demonstration plants: Objective of the plants. Parties involved and responsible for results. Funding mechanism. Role of private sector. Knowledge sharing mechanism. Recognition and awards.
- Framework for solar industrial parks: Objective of getting economies of scale from large volumes in a single location. Guidelines for initiation, private sector involvement, incentives, and infrastructure planning.
- Guidelines for states to setup solar policies: Norms to ensure consistency in policies of center and states in terms of aspects like eligibility criteria, land acquisition, environmental

clearances, quality standards, performance standards, costs, and incentives, so that there is a united action and more credibility for the industry. Mechanisms rewarding production at peak time should be encouraged.

- Framework for synergies and sharing knowledge: Synergies in action, such as shared institutions giving certifications and training. Knowledge-sharing mechanism, so that there is a shared list of recognized, as well as failed technologies, equipment, companies, and methodologies.

Table 35:
Key Responsibilities and Timelines for the Action Plan

For all these actions, the key responsibility should be attributed to the MNRE / SECI

SECTION	ACTION PLAN	SUPPORTIVE RESPONSIBILITY	Y1	Y2	Y3	Y4	Y5
Long-term policy framework for CSP development	Year-wise allocation for CSP power projects	MNRE					
	Regulatory support and tariff mechanism for solar thermal hybrid projects	MNRE & CERC					
	Renewable energy certificate mechanism for solar thermal energy generation	CERC					
Planning for payment security	Adequate payment security mechanism using the coal cess funds	MOF/MNRE					
Low-cost financing	Enabling of low-cost financing for CSP from banks and separate exposure limits for CSP projects	MOF					
Financial planning of subsidies and incentives	CCD and zero excise duties for materials and components used for manufacturing of solar systems	MOF					
	Fiscal incentives for sponsored research and in house R&D expenditure	MOF					
Mechanism for promotion of R&D and innovation	Development and maintenance of a public repository of knowledge	MNRE					
	Development of quality and specification standards	MNRE					
	Establishment of a R&D framework on a PPP basis	MNRE					
	Development of solar energy courses	MNRE					
	Sponsored research projects in educational institutions	MNRE					

8.1 Long-Term Policy Framework from the Government

Given the present situation, the question is what the government's stand would be with respect to supporting the CSP projects. The government can go ahead with the same policy of equal capacity allocation for both PV and CSP, which would imply a differential tariff regime for the same energy source, or the government can stay technology agnostic and leave the choice of technology to the developer and allocate capacities purely based on tariff just as the choice between thin film and crystalline was left to the developers.

If the government has to allocate equal capacity for CSP technology in Phase II, there has to be a compelling economic case for doing so. Question that needs to be answered are what levels of bid prices can be achieved in CSP projects in the second phase, specifically in light of the present level of reduction already achieved in Phase-I.

Given the present trend in solar PV prices, the government may well decide to leave the choice of technology to the developers and invite a bid without any quota for solar thermal. If that happens, the chances of any developer opting for solar thermal project are slim. The downside of this decision is that the market will quickly be saturated, leaving no option for further cost reductions and potential increases in utility operating costs (with potentially new firm capacity additions) because of the need to back up a significant influx of intermittent capacity.

In the immediate future, what is necessary is a support mechanism for enabling solar hybrid projects. The support mechanism can either be via subsidy provided for the solar block or a generic tariff recognizing solar thermal contribution or a renewable energy certificate (REC) modality, giving credit for the solar thermal energy harvested. Once the steam generation from solar is given due credit, the hybrid CST projects will find lots of favor from the large number of biomass projects that are not able to operate at full capacity because of biomass availability constraints. Augmentation with solar steam would lead to biomass conservation by 23 percent. This would then give an impetus for CST projects. With some more decreases in CST project costs through experience and localization, CST can also substitute for imported coal, after which the CST projects will proliferate. The tariff from such a solar thermal—biomass hybrid plant—comes out to be Rs 6.68 per unit. The tariff calculation for this hybrid plant is provided in Appendix 5, Solar Hybrid Systems.

Once the CSP projects in hybrid mode becomes commonplace, storage solutions will also develop in parallel. In case of storage solution, because of the supply of power during the peak period, these projects will merit a higher tariff that can then sustain the CSP project with storage option.

A hybrid CSP option or a storage option would enable use of domestically available steam turbines as well and thus not only be cost competitive to that of PV power, but CSP power will be dispatchable and dependable. In addition, the quality of power from the CSP plant will be much better compared to that of the PV plant.

The major action needed from the government is clear policy guidelines concerning the CSP projects. More clarity is needed regarding the following:

- The quantum of CSP projects that would be supported in Phase-II and Phase-III of the national Solar Mission
- Whether the CSP projects would be limited to stand-alone CSP projects or also recognize the hybrid projects.
- Generic tariff guidelines for solar biomass hybrid projects and CSP projects with storage.

On the REC mechanism, the government can recognize solar thermal technology and update the REC certification mechanism to make steam production from solar energy sources eligible for REC credits.

Another major area in which the government needs to address is an alternative to the accelerated depreciation benefit that is expected to be removed with the direct tax code being introduced. A possible option could be to adopt the 30 percent investment tax credit policy prevailing in the United States. In fact, the Investment Tax Credit policy is much better than the accelerated depreciation concept, since it is the end use that is important and not the user. ITC policy similar to the U.S. policy will give a huge boost to the renewable energy sector and specifically the solar sector.

Policies need to be detailed out at both central and state levels for elaborating on government Intentions for the long term because the life of a solar plant is estimated to be approximately 25 years. Industry needs a long-term vision, as well as a clear indication of commitment and expected benefits to induce them to make investments over such a long range of time.

8.2 Availability of Low-cost Financing

This section is about what the government needs to do in order to make available low-cost financing for the CSP industry, which is essential because much of the energy cost is the result of the interest on the initial capital cost of setting up the plant. Specific action items under each government body are as shown in Table 36.

8.3 Financial Planning of Subsidies and Incentives

The government has plans to grow the CSP industry in a big way. However, the initial growth is going to depend heavily on subsidy and tax incentives. Since the subsidies are going to be large, it is very essential to plan for these in terms of arranging for the sources of funds. It is also essential plan for tax incentives carefully, have a time-sound milestone-based exit strategy for this public finance, so as to maximize the impetus for growth. Specific action items are shown in Table 37.

Table 36:
Action Plan on Low-cost Financing

ACTION PLAN	SUPPORTIVE RESPONSIBILITY	DESCRIPTION
Enabling of low-cost financing for CSP from banks	MOF	One factor that has come out of the workshops is that interest rates are going to be critical in determining the cost of energy. This is especially relevant in India because of the high interest rates prevailing in the country, whereas developers overseas do not face this problem and enjoy low debt interest rates. Since there is no operating fuel for the plant, the operational costs of a CSP plant are very low and the entire cost of power is a result of the interest rate on the capital investment involved. In order to make CSP competitive, it is important that the government ensures that low-cost financing is available to developers and people setting up local manufacturing capabilities. This can be done by facilitating banks and financial institutions to make investments in CSP through the following: ■ Supporting knowledge by updating banks on CSP industry developments through SEC and CEA. ■ Mandating a certain percentage of investments in CSP technologies, ■ Obviating the risk concerns of banks by giving certain CSP technologies technical approvals and validity. ■ Subsidizing interest rates by a certain amount, say, 1–2. ■ Facilitating funding through International bodies, such as World Bank, KFW, and ADB. ■ Owning significant equity stake in the CSP plants and thus sharing some of the risks associated with the project.
Low-interest rate green loans	IREDA	Solar sector could have source to low-cost debt funds facilitated by the RBI, which could announce special lending rates for this sector as a priority sector, with funds mainly sourced from international bodies (ADB, KFW, IDA, and IBRD) and tax-free solar bonds.
Creation of DNI measurement centers across India	IMD	This has already commenced and a number of monitoring stations have been set up. ■ MNRE needs to make it mandatory for all developers to share their locally measured DNI data at their project sites.

Table 37:
Action Plan on Financial Planning of Subsidies and Incentives

ACTION PLAN	SUPPORTIVE RESPONSIBILITY	DESCRIPTION
Enabling of low-cost financing for CSP from banks	MOF	Currently there is an exemption of CCD of 5 percent on items imported for solar thermal and photovoltaic power generation projects. This is sufficient for developers of solar power projects to avail themselves of the benefits, but it is not clear whether local manufacturers in CSP industry importing raw materials (RMs) and local components for supplying components to solar power projects can obtain excise exemptions for their materials. This needs to be extended as follows: ■ CCD should extend for the above not only for the initial setting up of the plant but for the maintenance requirements also for the next 8 years. ■ Quality and specification standards should be developed and integrated with the subsidies ■ For local solar thermal component manufacturers, CCD should be applicable to imported components and RMs used for manufacture of the CSP components. For example, for manufacturing TADMs, some of the key high-cost components, such as controllers and sensors would need to be imported in the short and medium term. A lower CCD will result in lower overall cost of CSP power. ■ Help will have to be taken from CEA in making a list of RMs and components where CCD benefit can be applied to right away. ■ CCD needs to be effective only for the next 8 years which is the approximate time required to develop local capabilities. This is also the time required for ramping up of the local volumes as per the JNNSM. This will give a cut-off date for overseas players to setup local plants in the country in anticipation of the market opportunity. ■ CCD should be applicable even if the RMs or components are not directly used for CSP component manufacturing, but other goods manufacturing in other areas of the business for the following reasons: - There would be and indirect cross-subsidy for CSP as well because of the lower costs of running the business. - More companies will go for CSP component manufacturing and thus increase volumes in order to take advantage of the benefits. - There will be less bureaucracy, less paper work, and faster processing when cross-checking of RM utilization and RM waste is avoided by the government. - This will also require less time spent in dispute resolution.

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ACTION PLAN	SUPPORTIVE RESPONSIBILITY	DESCRIPTION
Favorable tax benefits for CSP developers and manufacturers	MOF	Currently, there is an accelerated depreciation benefit of 80% of the capital costs for power developers for solar thermal and photovoltaic power generation projects for the first year. However, this benefit is likely to be discontinued with the direct tax code policy being implemented. Should that happen, the Government of India needs to evolve an alternate tax policy, such as the investment credit policy in the United States. Additionally, similar benefits may be extended to local manufacturers in CSP industry. . The subsidies need to be extended to the CSP industry which includes manufacturers of CSP components: ■ tax holidays on all CSP power projects. ■ Accelerated depreciation for all local CSP component manufacturers. ■ tax holidays for service industries in the CSP industry, such as those doing EPC, EPCM, business and technical consultancy, and R&D as their only core business. ■ Service tax exemption for services provided in the CSP Industry for companies providing services to developers, as well as vendors of CSP.
Fiscal incentives for sponsored research and in-house R&D expenditures	MOF	It will help companies invest more in research activities that will improve long-term competitiveness of individual players in the industry, at the same time improve the overall technological maturity of the ecosystem and reduce overall investment, cost of production, and maintenance.
List of components and services in CSP for excise duty and CCD exemptions	CBEC	For easier implementation, a list of all components and materials that need to have excise duty exemption and CCD needs to be prepared and maintained. This needs to be prepared and approved by the CEA, the Technical Authority in consultation with the SEC taking feedback from the Industry which is represented by FAST for solar power.
Source funds from the public at lower interest rates for CSP plants	MOF	To stimulate public investment in infrastructure, the government and RBI have encouraged IFCI, IDFC, LIC, and NBFCs designated as infrastructure finance companies (IFCs) to issue government-guaranteed tax saving and tax free long term infrastructure bonds for providing long-term financial assistance to infrastructure projects. The concessional financing provided for infrastructure projects can be extended specifically to solar thermal plants. ■ Tax-saving solar bonds over a horizon of several years that are backed by the government and that have tax-free returns. ■ For proven technologies (PT, CRS) where there are existing plants in operation in the world, the government can provide backing for financing of projects so that banks can lend funds at lower-risk interest rates. ■ Consequently, reverse auctions need to be setup with developers in combination with the lowered rate of interest.

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ACTION PLAN	SUPPORTIVE RESPONSIBILITY	DESCRIPTION
Funds for CSP from the Clean Energy Fund	MOF	Currently, there is an accelerated depreciation benefit of 80% Currently Rs 50 per ton is being levied as coal cess for the purpose of funding the Clean Energy Fund. Since the purpose of this fund is to sponsor research and invest in clean energy technology, a part of this fund needs to be allocated for promoting technological innovation in CSP and financing subsidies in CSP component manufacturing setup. To avoid inappropriate use, allocation needs to be done specifically for high-technology component development and manufacture, which will reduce cost of power and enable faster grid parity. ■ Total of Rs 400 crores can be allocated specifically to TADM technology development for PT, LF, and CR technologies. ■ Total of Rs 400 crores can be allocated specifically to receiver tubes technology development for PT and LF technologies, ■ Total of Rs 100 crores can be allocated to specifically setup DNI measurement centers across the country.

8.4 Mechanism for Promotion of R&D and Innovation

Government funds can be channelled into one of two areas—subsidies on tariffs or on R&D to lower the tariffs. Subsidizing tariffs is a very costly proposition in the long term, since the industry is expected to grow very large. This also tends to protect the industry and make it less competitive. Promotion of R&D and Innovation has long-term benefits in terms of a reduced cost structure and is also less expensive. This section is about possible action steps in having a mechanism to promote R&D and innovation. Specific action items are shown in Table 38.

Table 38:
Action Plan for Promotion of R&D and Innovation

ACTION PLAN	SUPPORTIVE RESPONSIBILITY	DESCRIPTION
Development and maintenance of a public repository of knowledge	SEC	There needs to be a central Institution that maintains a repository of knowledge regarding solar energy. SEC is in a position to take up that role. Information that needs to be public domain is DNI data across various locations in the country, and technology-wise costing models showing a relationship with various parameters, such as mirror area, modularity, efficiencies.
Development of quality and specification standards		CEA, the technical authority in the country on quality and standards in power, needs to develop and establish quality and specification standards for components. A separate division in CEA can be setup for the Solar Block, which is the new factor in the industry. These standards need to be setup with participation from the industry, especially where there are issues relating to standardization in design of various components.

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ACTION PLAN	SUPPORTIVE RESPONSIBILITY	DESCRIPTION
Establishment of an R&D framework on a PPP basis	CEA, SEC	Investment in R&D is one of the key feedbacks from the workshop. Industry is also looking to the government in actively promoting this. Hence, recommendation from the consortium in developing an R&D framework with government and industry participation on the following lines of thought: ■ Establish 'Reform Champions' within the ministries ■ Establishment of a separate R&D setup as a public limited company with private participation. ■ The government would own a controlling stake with the rest being auctioned to interested industry players. A minimum ownership of the company would entitle the company to own commercial license rights to the IP developed by the company, and to have corresponding voting rights on the projects taken up and the distribution of R&D funds. ■ Company would have specific R&D objectives in order to achieve which R&D projects should be taken up. Each project would have resources required in terms of equipment and people, projection of funds that would be required for the project year on year, and time-based expected results in terms of IP produced. ■ Specific sectors that require targeting by the government are the development of TADMs, and the development of receiver tubes.
Development of solar energy courses for educational institutions	SEC, CEA, IIT Jodhpur	SEC as a central Institution for promoting solar energy needs to take up the responsibility of developing course materials for a solar energy–related field of specialization. It can then specify guidelines for developing courses for qualifications in CSP for graduate and post graduate levels for developing technical professional and managerial talent.
Sponsored research projects in educational institutions	SEC, MOF, IREDA	Specific research projects on CSP can be announced by the SEC for taking up by educational institutions. These can be sponsored by the government, which can be another source of getting R&D work done in solar energy. This could help to change the mindset of the young, and to attract and recruit the best talent.
Fast-track technology demonstration projects	SEC	Specific research projects on solar thermal called technology demonstration projects are already announced by the SEC for taking up by private players. These need to be fast-tracked.
Develop a mechanism to promote innovation	SEC	An institutional mechanism to promote networking and JVs is needed. The government should start CSP workshops with specific agendas on component manufacturing for promoting collaboration among various players in the industry.

Based on the feedback received from the two workshops conducted, below is tabulated an insight in what the industry expects from the government. It should be noted that this list reflects the demand from the industry and is not the opinion of the World Bank.

Box 2:

Expectations from the Government

Technology	■ Increased market size. ■ Development of a body of knowledge to tailor the technology to Indian conditions. ■ Funding of R&D projects in CSP in order to reap benefits of cost reduction by local technology development. ■ R&D framework, including the participation of the industry. ■ Test lab for CSP components to ensure quality and specification standards in solar component manufacturing. ■ Standardization committee for CSP components. ■ Benchmarking and calibration centers for CSP components involving private players. ■ Institutional mechanism to promote networking and JVs. ■ Acceleration of technology demonstration projects with stricter qualification criteria to avoid unrealistic projects. ■ Promotion of innovation and diversity of technology. ■ Setting up reliable sources of DNI and making them accessible to the market.
Policies	■ Stable solar policy with clear guidelines for CSP to reduce variability in the financial models of the developers and also create a more stable market for CSP. ■ Clear land acquisition, water and environmental policies supportive of CSP projects. ■ Clearer long-term RPO and REC policies extending up to 10 years. The floor price needs to be fixed for these for the next 10 years. ■ Aligned state and central government policies. ■ Strengthened RPO enforcement considering penalties if not followed.
Incentives for Financing	■ Incentive mechanisms for developers and manufacturers funded from the CESS collected from coal, as subsidies to reduce interest rates for CSP industry and the capital cost of the projects to international borrowing rates. ■ Availability of nonrecourse funding for CSP as for the wind energy sector. ■ Lending enabled for a period of 15–20 years rather than 10 years. ■ Implementation of futures market for interest rates.
Industry Growth	■ Increased visibility for developers about the policy road map of the central government for Phase II and Phase III. ■ Increased localization target to promote local manufacturing. ■ Revision of the bidding mechanism to avoid usage of less efficient established technologies compromising innovation and long-term success. ■ Stricter bidding criteria for the selection of developers in Phase II, with qualification requirements. ■ Government-owned IP.
Human Resource Development	■ Setup of education and certification programs for people to be trained in solar energy. ■ Promotion of institutes providing the requisite training and education for CSP industry.

9. Roadmap for Specific Industries

For all the specific industries mentioned in Table 39, the government needs to set up quality specification standards as an action in the short term, and accelerated depreciation needs to be provided for in the long term. This also has to be accompanied by tax holidays and zero excise duties for components produced locally. A summary of the Industry specific actions is shown in Table 39. For the other components considered to be currently available in the Indian market, market growth should be promoted in order to reduce costs.

The action plan is further divided into short term, medium term, and long term. Short term consists of actions that can be accomplished in the next six months. Medium term is what can be accomplished from then on from seven months to two years. Short- and medium-term actions are those that are associated with policies and planning. Long-term actions are actions that are mainly execution oriented in nature and that need to be sustained over several years from the third year onward.

Table 39:
Industry-Specific Actions to Promote CSP Technologies

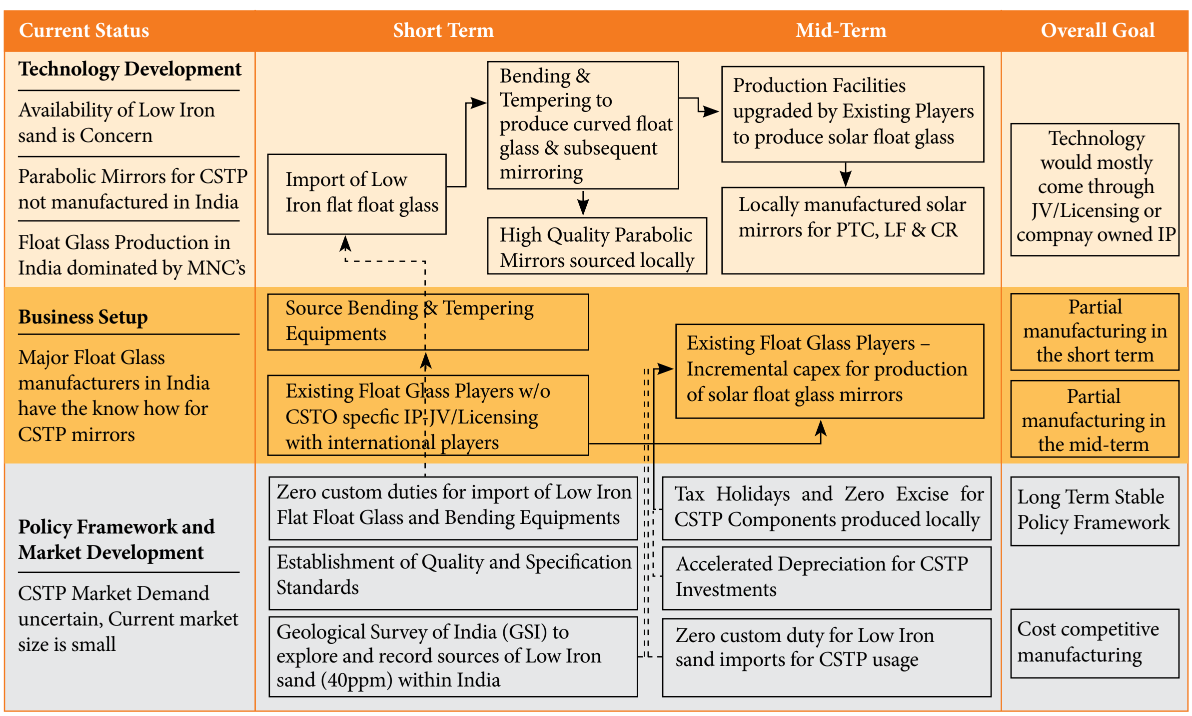
Component Ormaterial	Local Manufacturing Capability	Recommended Actions
RECEIVER (PT)	1	Promote R&D in solar selective and anti-reflective coatings. Promote R&D for metal glass seal. Promote collaboration with global players.
RECEIVER (CR)	1	Promote R&D for receivers able to work under high solar flux. Promote R&D for volumetric receivers using atmospheric air as HTF. Promote R&D for durable pressurized air receivers.
MIRROR (PT)	2	Zero customs for low-iron sand. Explore sources of low-iron sand. Lower customs for bending equipment.

Cont...

Component Ormaterial	Local Manufacturing Capability	Recommended Actions
MIRROR (CR)	3	Zero customs for low-iron sand. Explore sources of low-iron sand.
DRIVE/ TRACKING (PT)	2	Promote R&D for solar sensor and controller technology. Promote collaboration with global players.
DRIVE/ TRACKING (CR)	1	Promote R&D for solar sensor and controller technology. Promote collaboration with global players.
HTF (OIL OR MOLTEN SALTS)	2	Ores not present in India. Lower customs for oil and salts. Promote research in materials having high heat density, stability, thermal conductivity, and latent heat. Promote research in thermochemical and electrochemical storage.
TURBINES	3	Establish technical and quality standards for CSP turbines.
BALL JOINTS	4	Promote market growth for reducing cost.
HTF PUMPS/ PIPING	4	Promote market growth for reducing cost.
SUPPORT STRUCTURES/ PYLONS	4	Promote market growth for reducing cost. Promote technology to reduce labor and the cost of manufacturing and assembly.
SOLAR STEAM GENERATORS	4	Promote market growth for reducing cost.

9.1 Mirror Manufacturers

Figure 9:
Roadmap for Mirror Manufacturers



The main concerns for mirror manufacturing in India revolve around the certainty of demand, availability of low-iron sand, and incremental capex costs of investments. Mirror manufacturers need to start some production operations locally first by importing low-iron float glass and then bending and tempering it locally to produce curved glass. This can then be further processed in terms of mirroring.

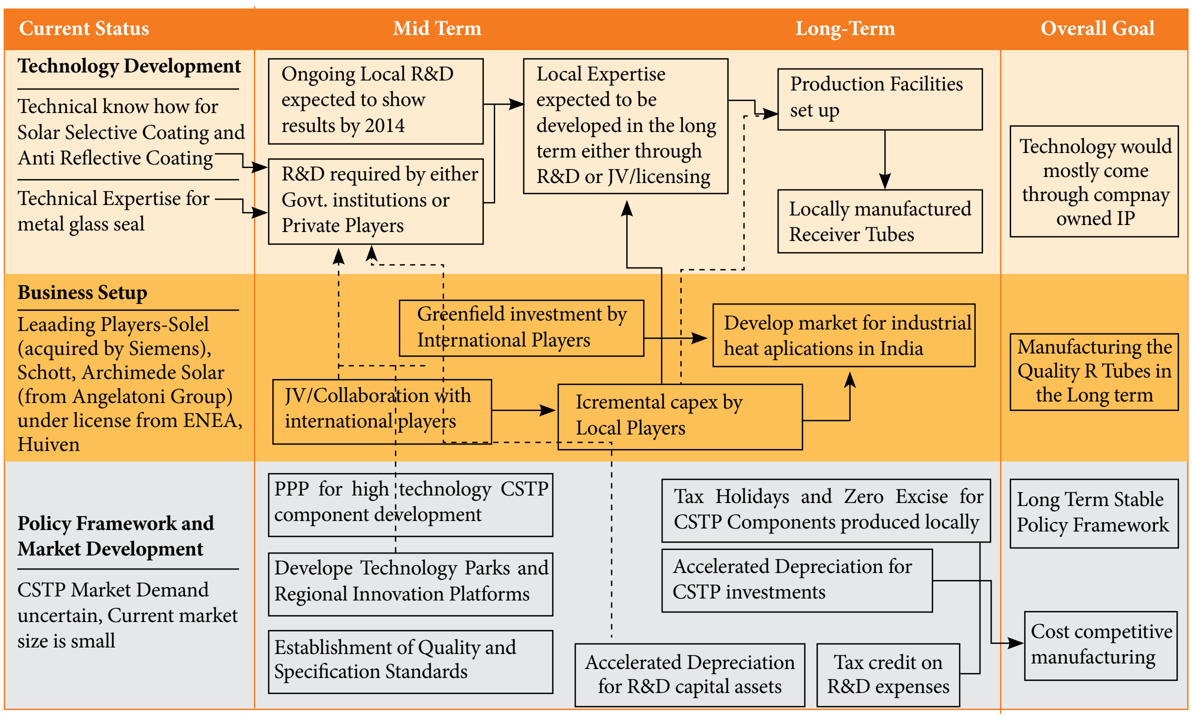
Global players who have the technology can then upgrade their facilities to produce float glass. Investment will be required in bending and tempering equipment and line upgrades. For local players, the cost of licensing will also need to be factored in.

Government support of an action plan is required for the waiving of import duties and customs on low-iron float glass and bending equipment in the short term. In the long term, a waiver on the import of low-iron sand and customs is required.

9.2 Receiver Tube PTC Manufacturers

Figure 10:

Roadmap for Receiver Tube PTC Manufacturers



The main concerns for receiver tube manufacturing in India are the lack of technology and know-how. The action plan is therefore tailored accordingly for promoting technology, collaboration, and innovation.

Currently, there are no manufacturers of receiver tubes in India. Manufacturers in related industries need to first complete R&D and experimentation for the solar selective coating and antireflective coating. Simultaneously R&D work needs to start on the metal glass seal.

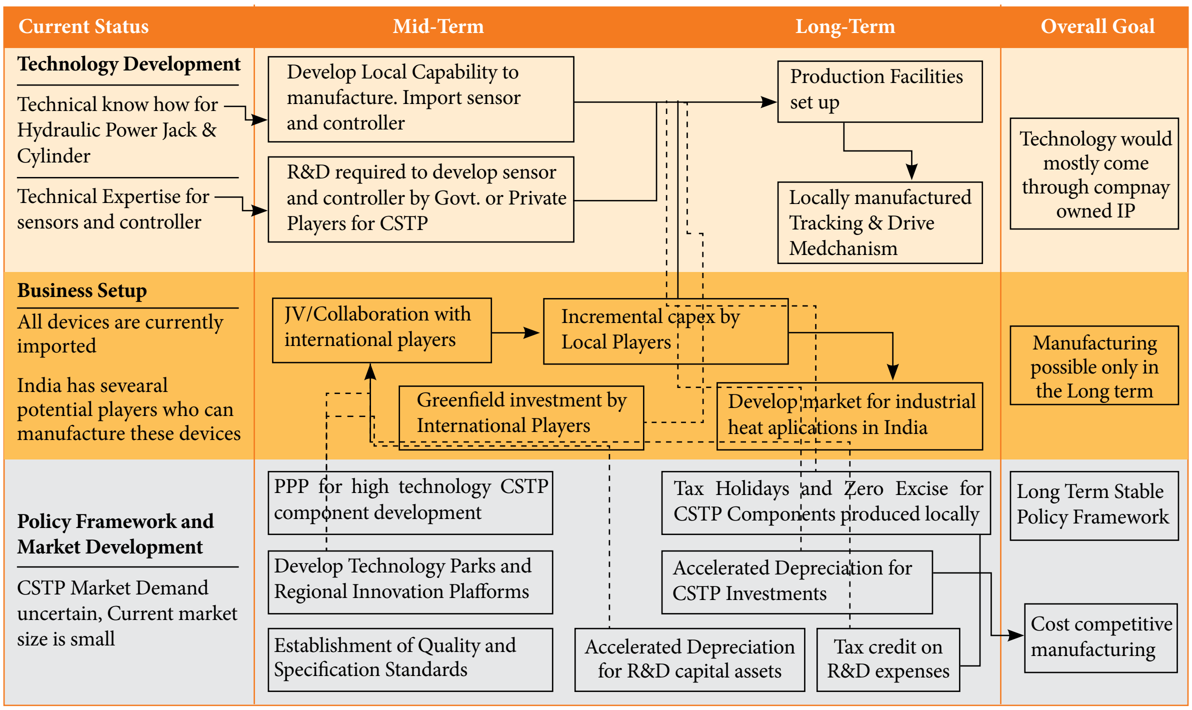
Global players who have the technology can collaborate with local players to enter the Indian market. Alternatively, they can setup a greenfield venture in India. A better route, however, will be to upgrade existing facilities in India—their own or a partner's—and then just provide the technical know-how. Players would then need to look at JVs and other collaborative mechanisms to work jointly and share benefits.

Government support in terms of the action plan is required for promoting innovation and R&D in terms of technology parks and regional innovation platforms. The government also needs to come up with a format to develop technology using PPP models.

In the medium term and long term, tax credits on R&D expenses are required, and accelerated depreciation on R&D capital assets is strongly recommended.

9.3 Tracking and Drive Mechanism (TADM) Manufacturers

Figure 11:
Roadmap for TADM Manufacturers



The main concerns for TADM manufacturing in India are the lack of technology and know-how. The action plan is therefore tailored accordingly to promote technology, collaboration, and innovation.

Currently, there are no manufacturers of TADM components in India. Manufacturers in related industries need to first complete R&D and experimentation for solar tracking devices, which are currently being used in military applications, and come up with a component that is accurate enough to be used for CSP applications. This technology gap should be overcome easily, in particular for PT.

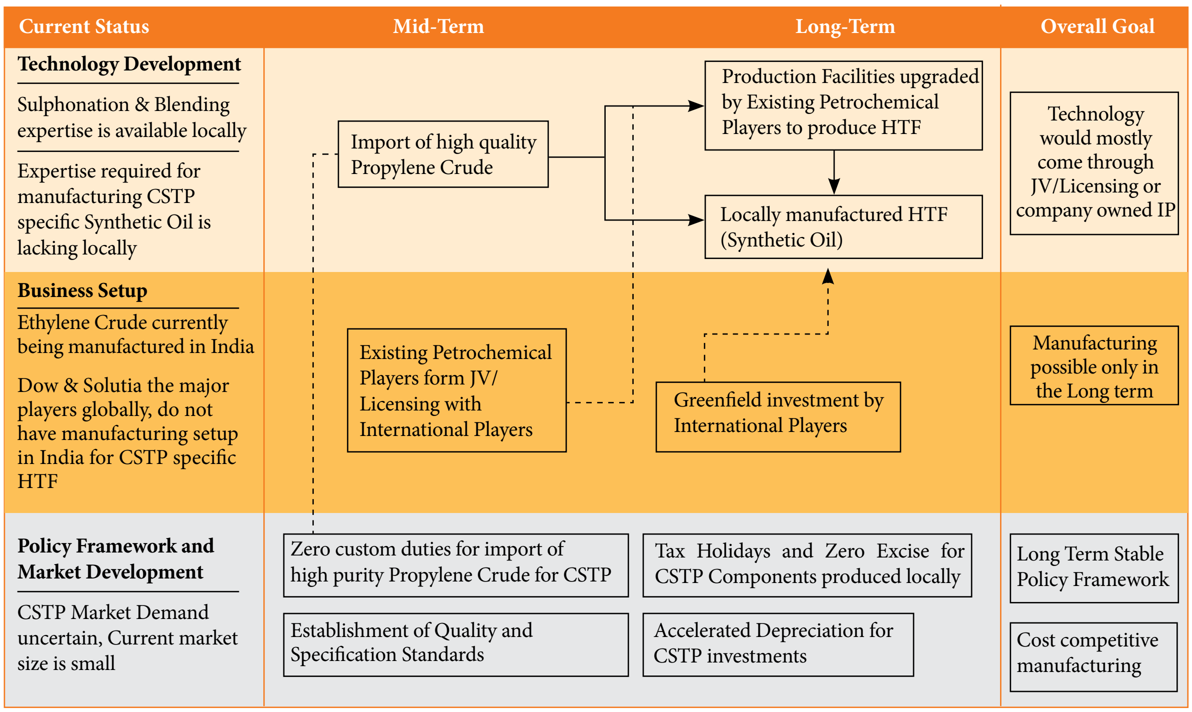
Global players who have the technology can collaborate with local players for entering the Indian market. Alternatively, they can setup a greenfield venture in India. A better route, however, would be to upgrade existing facilities in India—their own or a partner's—and then just provide the technical know-how. Players would then need to look at JVs and other collaborative mechanisms to work jointly and share benefits. In this case, some of the components, such as the hydraulic jack and cylinder, can be made locally. The sensor and controller can be imported from overseas.

Government support of an action plan is required for promoting innovation and R&D in technology parks and regional innovation platforms. The government also needs to come up with a format to develop technology using PPP models.

In the medium and long term, tax credits on R&D expenses are required, as well as accelerated depreciation on R&D capital assets.

9.4 HTF Manufacturers

Figure 12:
Roadmap for HTF Manufacturers



The main concerns for HTF manufacturing in India revolve around the certainty of demand and the availability of raw materials (ethylene crude and propylene crude.)

HTF manufacturers need to first start production operations locally by importing high quality propylene crude. The number of manufacturers of ethylene crude—the other RM—in India is also limited. Then, existing facilities can be upgraded to produce HTF by introducing the processes of sulphonation and blending.
Global players who have the technology can then upgrade their facilities to produce HTF. Investment will be required will for equipment and line upgrades. For local players, the cost of licensing will also need to be factored in.

Government support in terms of an action plan is required for waiving import duties and customs on high quality propylene crude in the short term. Also, a waiver on the customs duties for the sulphonation and blending equipment is required.

10. Conclusions

The JNNSM Phase I catalyzed the growth of the solar sector in the country and contributed to the reduction of prices offered by the project developers. To keep up this momentum and to achieve further cost reductions for CSP technologies, the government needs to provide clarity on the following:

- Capacity allocation for CSP sector
- Hybrid CST projects
- CSP projects with thermal storage, so that the industry is clear about the market size of CSP in the next 10 years

CSP technologies incorporating thermal storage solution will make solar power dispatchable and thus more cost effective to meet all segments of power demand. There is a realistic potential for solar thermal technologies to make an important contribution to meeting India's capacity and energy demand and diversify the country generation profile.

There is also potential for the subcomponents of solar thermal systems to be manufactured in India in the short, medium, and long terms. India has inherent competitive advantages that will facilitate the transition to becoming a major provider of solar thermal technologies. The factors that could contribute to this include highly trained engineering staff, low labor costs, and a large domestic market. These are only a few aspects that can be leveraged by the Indian industry to lower the capital costs for CSP plants, subsequently decreasing the LCOE and driving the market penetration of solar thermal technologies.

To bring the solar plan to success, existing Indian industries have to identify and introduce changes to participate significantly in supplying CSP components and systems. Many traditional industries that could take an active part in CSP technology development have been identified (automotive, glass, metal, power and process heat, machine tools and robotics, technical supervising, electronics industry, oil and gas, and chemical industries). Most of them only need a modest effort to adapt their products and manufacturing processes to the demands of the CSP industry. Nonetheless, the competition between CSP players will increase, enlarging the need for R&D activities to develop cheaper and more efficient components. That is why research collaborations between private companies and research laboratories are a key factor in developing the components and systems that will bring CSP technologies to success.

Cost reductions are also expected from local manufacturing of tracking devices, receiver tubes, parabolic mirrors, turbines, and structures (PT). Developers would find local manufacturing very attractive also because of value-added services, such as the local presence of many O&M options, better procurement lead time, and trained local workforce. The rapid reduction of solar PV price has made it mandatory for solar thermal technologies to accelerate the cost reduction process for their survival. Having achieved significant cost reductions in Phase I, India has the potential to make the solar thermal technology competitive to solar PV. For this, however, there must be a critical mass of investment, dedicated human resources, and educational efforts, and criticality will be achieved when there is alignment of convergent forces with national and regional policy and the right financial environment.

In the short term (within the next year), India's readiness to manufacture or produce some critical components, such as receiver tubes and mirrors, that make up solar thermal plants is questionable, in spite of the huge manufacturing capacity of the country and the skills of its labor force. In some cases, such as in the manufacture of reflecting surfaces, the lack of a natural resource (in this case low-iron sand) poses an impediment to indigenization. In other cases, such as in the manufacture of vacuum tubes, the obstacle to overcome is the lack of a relevant technical know-how that is proprietary technology owned by others. Sometimes, in a fast-growing economy, the high demand for some industrial products might lengthen the delivery time for certain components.

Government, promoters and industry need to work together to ensure a viable path for solar thermal technology development, creating a financial and regulatory environment that supports investment in R&D, establishing financial and political incentives for sustainable development and lowering the effective financial risks for investors while factoring in the positive impacts on the environment, improvements in health, the natural habitat and the quality of life that are associated with renewable energy in general and solar thermal technologies in particular.

A review of what that cooperation entails has been presented in this report in terms of the actions the governments need to take (through taxation, subsidies financing, special tariffs, for example) and the steps industry must take if it is to become an important player in developing market for CSP components. The key factors that will enable India to emerge as competitive base for manufacturing CSP components are as follows:

- Supportive regulatory and fiscal environment to promote indigenization and technology transfers, and create a favorable and viable business environment for all stakeholders involved in CSP projects
- Favorable government policies to create market growth for all stakeholders of CSP projects
- Development of CSP-related R&D capabilities in the country
- Availability of low-cost and adequate financing for CSP component manufacturers

Uncertainty in whatever form is a probably the greatest disincentive for domestic and external investors and providers to make the commitments necessary to pave the way for electrification based on renewable technologies. One of the forms that uncertainty takes is about the scale of the domestic and global demand for subsystems and eliminating or at least alleviating this risk depends on a clear road to commitment by governmental and financial agencies.

PART I V
Appendixes

Appendix 1
CSP Technologies

In the following section, the four main concentrated solar power (CSP) technologies are presented, giving an insight into the value chain of systems and components, and into the commercial projects and pipeline.

A. Linear Fresnel Reflector Technology

General description

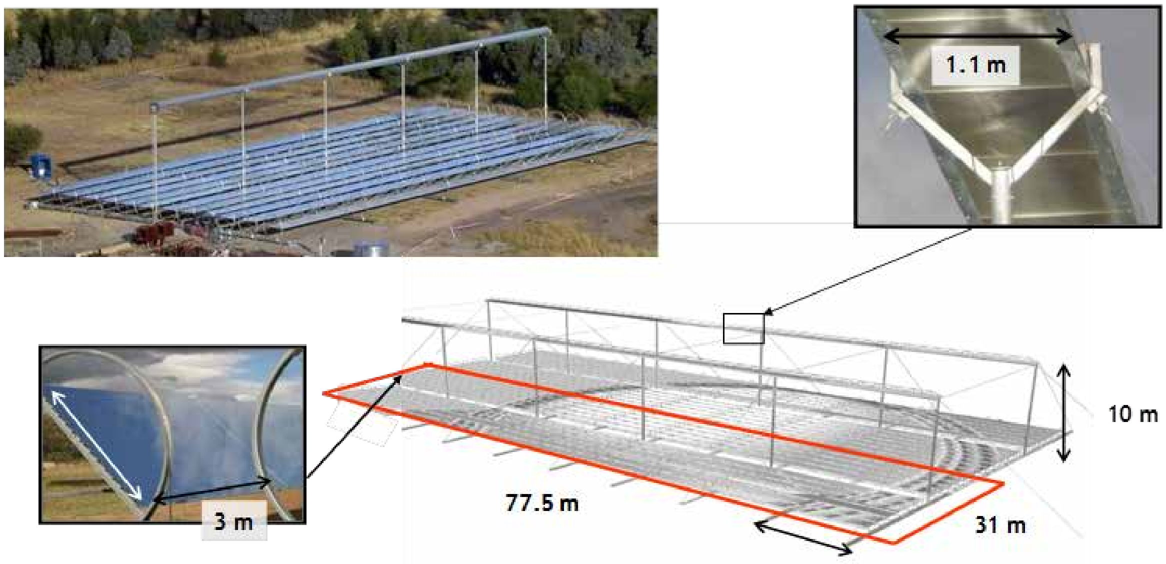
According to its developers and promoters, linear Fresnel reflector (LF) systems have lower costs and are less sensitive to accidents than other alternatives by virtue of the off-the-shelf components chosen for its construction and the use of low-curvature mirrors. Besides, they make better use of the land than other technologies for the same power output.

However, LF systems work at low operating temperatures and low solar field efficiencies and therefore they tend to be less efficient than other technologies. Furthermore, there is no technically developed storage system available for LF systems.

Plant configurations in LF technology are similar to those for parabolic troughs. However, low temperatures systems also offer better opportunities for implementation in innovative cycles like organic Rankine cycles, solar preheating, integrated solar combined cycle systems, and other low temperature applications, such as solar air conditioning systems.

The most common configuration of linear Fresnel plants is direct steam generation (DSG). This innovative concept consists in using water/steam, not only as working fluid in the power block, but also as heat transfer fluid in the solar field. It can be implemented in many plants and in particular in strongly hybridized systems.

Figure 13 :
Views of Linear Fresnel Reflector Arrays



Source: Morrison 2006

Plant and Components Value Chain

Table 40 shows the main stakeholders of the LF plants value chain. Having added in 2010 Ausra´s technology to its package of thermal system offerings to provide turnkey solutions, Areva can be now considered a leader in this technology. However, the company does not have any new plants under construction, whereas Novatec Biosol is now building its 30 MWe Puerto Errado II solar plant in Calasparra, Spain.

Table 40:
Linear Fresnel Reflector Value Chain

TECHNOLOGY PROVIDER & INTEGRATOR	Areva, MENA Cleantech AG, Novatec Biosol
PROJECT DEVELOPMENT	Areva, MENA Cleantech AG, Novatec Biosol
EPC	Solar Heat& Power, Areva, Prointec S.A.
OPERATION	Macquarie Generation, Novatec Biosol
PROJECT OWNERSHIP	Macquarie Generation, Novatec Biosol

Source: Emerging Energy Research 2010

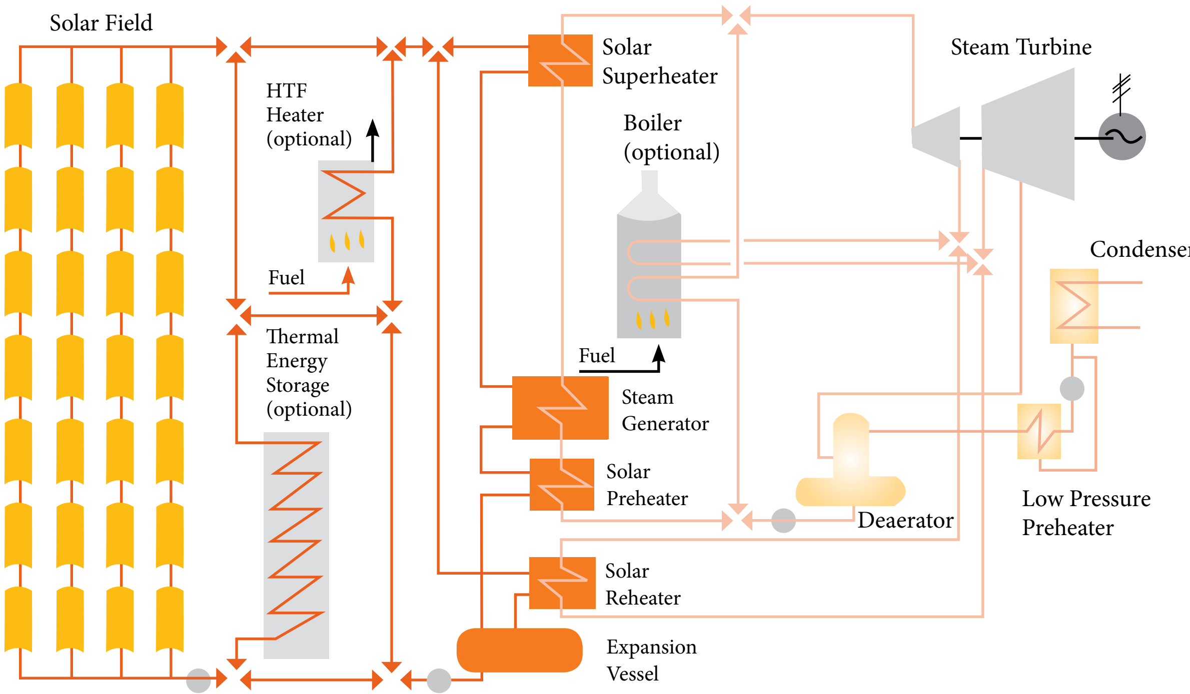
Major LF technology promoters, such as Areva and Novatec Biosol, develop and manufacture their own specific components with proprietary designs. Regarding mirror assemblies, LF technologies have fewer customized requirements, allowing technology integrators to rely on the more than 65 flat glass suppliers worldwide.

B. Parabolic Trough Technology

General Description

Parabolic trough (PT) technology is the most mature concentrated solar thermal technology today. Commercial PT plants have been operating satisfactorily for more than 20 years, giving valuable information and providing opportunities for improvements in design, as well as O&M. Thus, they have a leadership position in power generation among CSP plants.

Figure 14 :
Basic Scheme of a PT Power Plant



Source: Pitz-Paal, Dersch, and Milos 2005

PT solar fields are modular: they can be implemented at any capacity, providing great versatility. Even so, the optimal capacity for current technology is estimated to be about 150–200 MWe.

PT technology is expected to compete with conventional thermal power plants in the midterm.

Plant and Components Value Chain

Table 41 and Table 42 list the main stakeholders of the parabolic trough plants and components value chain. These are players with a track record of built projects, that is to say, projects that have been involved in at least one demonstration or commercial CSP installation.

Figure 15:
Aerial View of Andasol Power Station

Source: Solar Millennium AG

Table 41:
Parabolic Trough Plant Value Chain, Playerswith a Track Record of Built Projects

TECHNOLOGY PROVIDER & INTEGRATOR	Flagsol, Solar Millennium, Siemens CSP Ltd., Solare XXI, ENEA, Abengoa Solar, Aries Solar Termoeléctrica, Ingemetal or SAMCA, Sener, Acciona Energía, Solel, Iberdrola, SkyFuel
PROJECT DEVELOPMENT	Solar Millennium, ERM Power, Inner Mongolia Luneng New Energy, Suryachakra Power, Entegra Ltd., Enel, NEAL, World Bank, NREA, Abengoa, Total, Dioxipe Solar, SAMCA, Flagsol, Sener, ACS Cobra, Acciona Energía, Fotowatio, NextEra Energy, Iberdrola, Ibereólica, FCC, Abantia, Enerstar, Magtel, Epuron, Conergy, Siemens, SkyFuel, Cogentrix Energy, NextEra, FPL
EPC	Leighton Contractors Pty, Inner Mongolia Luneng New Energy, Techint, Orascom, Ferrostaal, Abener, Teyma, Aries or Elecnor, GEA21, TSK Energía, Ferrostaal, Duro Felguera S.A, ACS Cobra, Acciona Infraestructuras, OHL, Iberinco, Inveravante, FCC, Técnicas Reunidas, Magtel, Abengoa Solar, Siemens, MAN Ferrostaal, Cogentrix Energy, Iberdrola Renovables, Worley Parsons, Lauren
OPERATION	ERM Power, Inner Mongolia Luneng New Energy, Suryachakra Power, Entegra Ltd., Sonatrach. Cofides, ONE, Egyptian Electric Authority (EEA), Abengoa, Total, Masdar, Dioxipe Solar, Grupo SAMCA, Solar Millennium, Sener, Acciona Energía, Fotowatio, NextEra Energy, Iberdrola, Ibereólica, FCC, Abantia, Enerstar, Magtel, Epuron, Siemens, Solar Trust America, Chevron Energy Solutions, Cogentrix Energy, Worley Parsons, NextEra, Lauren, FPL
PROJECT OWNERSHIP	Inner Mongolia Luneng New Energy, Suryachakra Power, Entegra Ltd., Enel, Sonatrach. Cofides, ONE, Egyptian Electric Authority (EEA), Abengoa, Total, Masdar, EON, Hyperion, Dioxipe, ACS Cobra, Acciona Energía, Fotowatio, OHL, NextEra Energy, Iberdrola, Ibereólica, Inveravante, FCC, Abantia, Enerstar, Magtel, Epuron, Solar Trust America, Chevron Energy Solutions, Cogentrix Energy, NextEra, FPL, Acciona Energía

Source: Emerging Energy Research 2010; CENER

Table 42:
Parabolic Trough Components Value Chain

HEAT TRANSFER FLUIDS	Dow Chemical, Solutia, Radco
HEAT COLLECTION ELEMENT	SOLEL, Schott, Enertol Santana, Archimede Solar
MIRROR ASSEMBLY	Flabeg, Rioglass, Saint-Gobain, Guardian, Ronda Reflex, Glaston, ReflecTech
SUPPORT STRUCTURE	Acciona Power, Flabeg Solar, Abengoa Solar, Sener, Samca, Albiasa Solar, ENEA, SkyFuel, Sopogy, Sapa

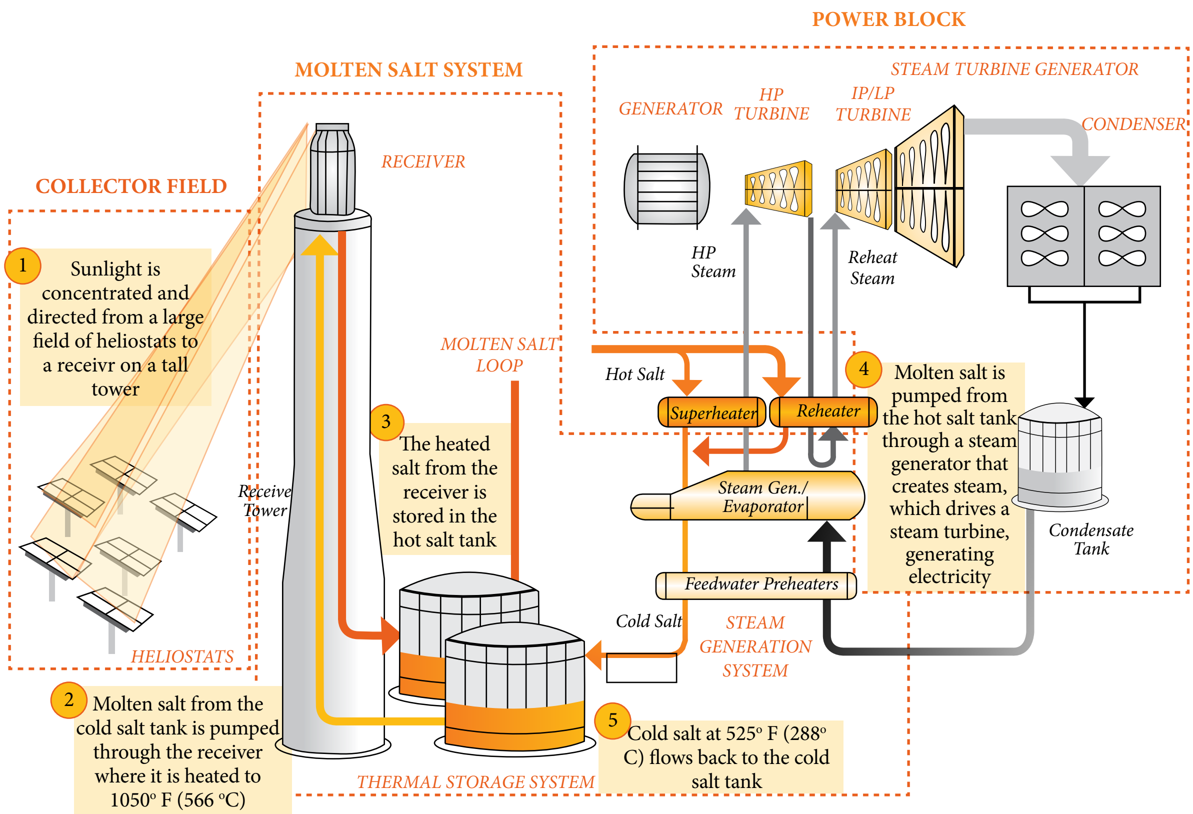
Source: Emerging Energy Research 2010; CENER

C. Power Tower Technology

General Description

A power tower system or central receiver system (CRS) uses mirrors called heliostats with two-axis sun-tracking to focus concentrated solar radiation on a receiver at the top of a tower. The receiver absorbs the concentrated radiation and transforms it into thermal energy of a working fluid.

Figure 16:
Scheme of a Molten Salt Power Tower



Source: Solar Reserve

An advantage of central power towers over most other concentrating solar power (CSP) technologies is that the solar collection occurs at one receiver atop a central tower, so piping is not required throughout the solar field.

Because of high radiation fluxes reached in the receiver, it is possible to work at very high temperatures without significant thermal losses, which makes it possible to integrate this module in more efficient thermodynamic cycles.

Plant and Components Value Chain

Table 43 and Table 44 show the main stakeholders of the power tower value chain. These are players with a track record of built projects—that is to say, those that have been involved in at least one demonstration or commercial CSP installation.

Table 43:
Power Tower Plant Value Chain

TECHNOLOGY PROVIDER & INTEGRATOR	Lloyd Energy Storage, Worley Parsons, Chinese Academy of Sciences or National High-Tech Research, eSolar, Penglai Electric, Acme Energy Solutions, Millennium Energy Industries, Aora, Clean Energy Systems, SolarReserve, Abengoa Solar, Sener, BrightSource Industries Israel, United Technologies, Lockheed Martin
PROJECT DEVELOPMENT	Penglai Electric, Acme Energy Solutions, Millennium Energy Industries, Clean Energy Systems, Eskom, Abengoa Solar, Torresol Energy, BrightSource, eSolar, NRG, SolarReserve
EPC	SMEC, China Huadian Engineering, Abener, Sener, Amsa, Bechtel, Fluor
OPERATION	China Shaanxi Yulin Huayang New Energy, Acme Energy Solutions, Abengoa Solar, Torresol Energy, Bechtel, BrightSource
PROJECT OWNERSHIP	China Shaanxi Yulin Huayang New Energy, Acme Energy Solutions, Eskom, Abengoa Solar, EON, Sener or Masdar, Bright Source Energy, NRG, US Renewables

Source: Emerging Energy Research 2010; CENER

Table 44:
Power Tower Components Value Chain

HELIOSTAT MIRROR ASSEMBLY	Guardian, FLABEG, Saint Gobain
HELIOSTAT METALLIC STRUCTURE	Art Precision, China Manufacturing, Inabensa
TOWER RECEIVER	Abengoa Solar NT, Sener, Brightsource Energy, SolarReserve, Pratt & Whitney, Babcock Power, Victory Energy, Babcock & Wilcox
TOWER CIVIL WORKS	ALTAC

Source: Emerging Energy Research 2010; CENER

D. Dish Engine Technology

General Description

The dish/engine is unique among CSP systems in that it uses mechanical energy rather than a working fluid in order 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.

Figure 17:
SES SunCatcher Dish Stirling Design

Source: SES

Compared to the other CSP technologies, dish-engine systems have higher investment costs and do not have the potential for effective thermal storage and hybridization solutions.

On the other hand, the Stirling engine technology has three major advantages over other thermal steam technologies: water usage is limited to O&M activities (for example, mirror washing), efficiencies as high as 30 percent have been attained (at Sandia Laboratories), and its modularity allows for a range of system sizes, from cumulative several MW to hundreds of MW. Indeed, unlike other CSP technologies, dish-engines do not need water for cooling, and they do not need the proximity of grid connection.

Plant and Components Value Chain

Table 45 and Table 46 show the three main players of the dish engine plants value chain. Up to now, they are only active in Spain and the United States (2).

Table 45:
Dish Engine Solar Plant Value Chain

TECHNOLOGY PROVIDER & INTEGRATOR	Abengoa Solar, Stirling Energy Systems, Infinia
PROJECT DEVELOPMENT	Abengoa Solar, Tessera Solar
EPC	Abener, RMT Mortensen
OPERATION	Abengoa Solar, Stirling Energy Systems
PROJECT OWNERSHIP	Abengoa Solar, Stirling Energy Systems, NTR

Source: Emerging Energy Research 2010; CENER

Table 46:
Dish Engine Solar Components Value Chain

STIRLING ENGINE	Guardian, FLABEG, Saint Gobain
DISH MIRROR ASSEMBLY	Paneltec, Tower Automotive
DISH STRUCTURE	Schuff Steel

Source: Emerging Energy Research 2010; CENER

E. Power Island

General Description

The power island is common to the first three solar thermal technologies explained in this document (LF, PT, and CRS). The heat exchangers and fire protection system specific to thermal oil are not included in the DSG technology. According to their functional characteristics, components in the power island can be divided into the power block (including every component which closes the thermodynamic cycle, operating at high pressures and temperatures, and the balance of plant (BOP, including every auxiliary additional element necessary to the correct operation of the power block).

Component Value Chain

Table 47:
Power Island Components Value Chain

STEAM TURBINE AND GENERATOR	Siemens, Alstom, General Electric Co., Ormat Technologies, MAN Turbo
HEAT EXCHANGERS	Foster, Wheeler, GEA Group, Stork, SPIG, Atepisa, Talleres MAC, SPX Cooling Technologies, B.A.C. (MOVISAF), Soljet (Thermax), Hamon (Esindus), Alfa Laval, Graver, Holtec International, Mecet, Sedical, Viessmann
BOILERS	GTS Energy, PolyComp, Standard Sky, Cerney, Teyvi, Aalborg Industries
ELECTRICAL EQUIPMENTS	Caterpillar, Koncar, Circutor, Ansaldo, Landis & Gyr, Schneider Electric
INSTRUMENTATION AND CONTROL	Honeywell, Campbell Scientific Spain, WIKA, Krohne, Emerson Electric, Meisa, ATC-Control, Endress+Hauser, Crespo y Blasco, Sirsa
PUMPS AND FILTERS	Friatec, Emica, Ruhrpumpen GmbH, Imo Pump, Varisco, Sulzer, Grundfos, Sterling, SPP Pumps, Weir, KSB, PFS Pumps, Hidrafilter
TANK AND PRESSURIZED EQUIPMENTS	Calprisa, Koch Heat, Cremasco, Talleres, Talleres Lombo
UTILITY SYSTEMS	Oinse, Comin, Compair, Sugimat, Wedeco, Ondeo, Regasa, Praxair, Eurowater, Aquafrisch, Cryonorm, Chart Ferox, Spirax Sarco, Adiquímica, ProMinent, Pastech, Nalco, Idagua, Deisa, KEU

Source: Emerging Energy Research 2010; CENER

F. Thermal Energy Storage System

General Description

The implementation of thermal energy storage (TES) in CSP plants is intended to reduce the cost of electricity by increasing their capacity factor and their ability to meet peak demand and thus to command a higher rate in markets with varying prices along the day.

Storage capabilities must be proven at a large scale before widespread adoption takes place. This is the key factor that differentiates CSP from wind and PV technologies and that must be delivered in the medium term for the CSP market to grow. With increasing intermittent renewable alternatives added to the grid, TES technology is expected to play an even greater role.

Components Value Chain

Table 48:
Components Value Chain for Thermal Energy Storage

TES INTEGRATOR	Solar Millennium (Flagsol), ACS Cobra, Sener, SolarReserve, Solare XXI, Entegra, Abengoa, Abener
TES SUPPLIER	Bertrams Heatec, Friatec, GEA
TES INVESTIGATION	Lloyd Energy Storage, Ibereólica
MOLTEN SALT PRODUCER	Haifa Chemicals, Sociedad Quimica y Minera de Chile SA, Coastal Chemical

Source: Emerging Energy Research 2010; CENER

Appendix 2. Commercial Projects and Pipeline Worldwide

Table 49 shows the total installed capacity worldwide up to now, including the main promoters of these projects already in operation. The pipeline of each technology is also shown.

Table 49:
Total Installed Capacity and Project Pipeline Worldwide

TECHNOLOGY	MAIN PROMOTERS	TOTAL CAPACITY WORLDWIDE (MW)	PROJECT PIPELINE WORLDWIDE (MW)
LINEAR FRESNEL REFLECTOR	AREVA, Solar Power Group, Man Ferrostaal, Novatec Biosol	11	367
PARABOLIC TROUGH	Luz, ACCIONA, ACS, FPL, Abengoa, Solar Millennium, Iberdrola, ACS Cobra, SAMCA	1,172	3,905
CENTRAL RECEIVER	Abengoa, eSolar, Torresol, Alpine SunTower, SolarReserve, BrightSource, NRG Energy	53	1,967
PARABOLIC DISH	Renovalia Energy, SES, Tessera, Infinia, Calico Solar, AES Solar	2.5	1,671

Source: CENER

Appendix 3. Overview of Cost Drivers in Reference Global CSP Plants

The investment cost of a CSP plant varies with the capacity of the power block, thermal storage, if any, and the size of the solar collector field, for example. In order to keep the analysis within manageable limits, it is necessary to define a reference plant for each technology.

Once a reference plant is defined, the cost of the plant and of its different subsystems and components can be assessed, as well as the performance indicators of the plant as whole and of its different subsystems and components. Based on this information and on the assessment of the operational costs of the plant, the yearly LCOE for the plant can be estimated for a given yearly electricity production. In this appendix, cost and financial inputs correspond to the state of the art CSP projects in Spain. The complete methodology of this cost analysis is described in Appendix 6.

A. Reference Plants

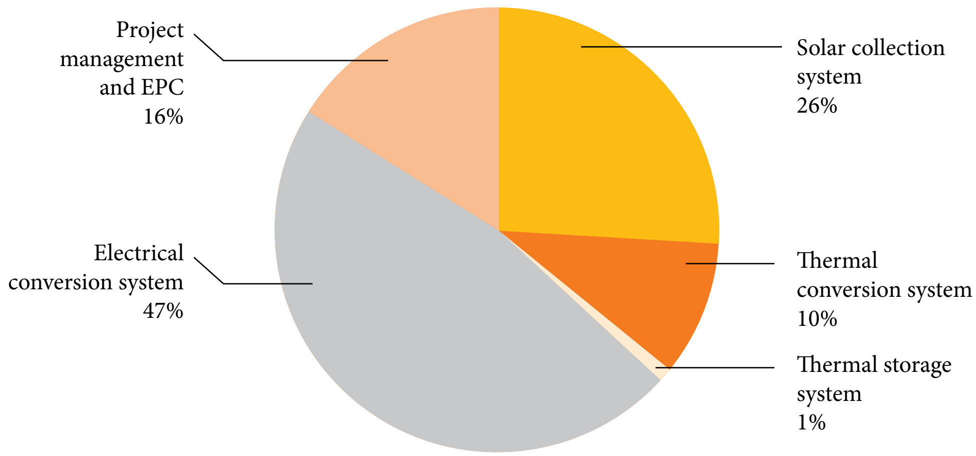
Linear Fresnel Reflector Technology

The LFR power plant chosen as a reference is a 30 MW power plant with no storage system. This Fresnel power plant has the general characteristics of the commercial Fresnel plant being built by Novatec Biosol in Puerto Errado. The collector design considered is the so-called NOVA-1, the plant having a total mirror aperture of 216,000 m^2.

The thermodynamic cycle of the electrical conversion system is a Rankine cycle of saturated steam at a working temperature of 270^{o}C and a pressure of 55 bar. The power block has a total power output of 30 MW. This power, for operational reasons, is provided by two 15 MWe turbines instead of a 30 MW turbine.

The total investment cost of the reference Fresnel power plant is US$149 million (Rs 662 crores), approximately. Figure 18 shows the cost breakdown by main functional subsystems and general cost items.

Figure 18:
Overall Investment Cost Breakdown for Linear Fresnel Reflector Reference Power Plant



Source: CENER.

As it can be observed, contrary to what is the case in other CSP technologies, in this technology the investment costs of the solar collection and thermal conversion systems are relatively small in comparison with the rest of the investment costs of the plant.

The power block investment cost is higher than it could be expected for a 30 MW power block because, as mentioned before, the plant uses two 15 MW turbines instead of a 30 MWe turbine.

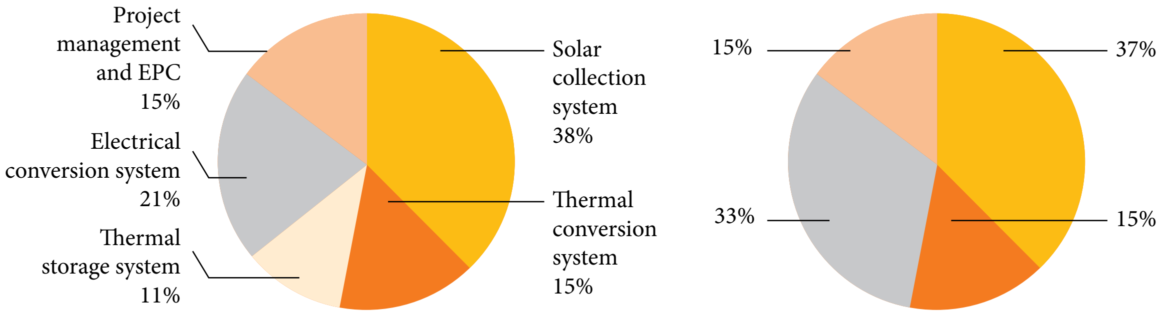
Parabolic Trough Technology

The reference plant considered for a parabolic trough installation has an installed power of 50 MWe with a Rankine thermodynamic cycle of superheated steam. The heat transfer fluid is synthetic oil, Therminol VP-1, and the power plant has a two-tank molten salt storage system with 6h capacity. The 553,920 m2 solar field is composed of Eurotrough collectors and Schott receiver tubes.

This case corresponds to typical parabolic trough designs accomplished in Spain, as it is the case of Andasol solar thermal power plants.

The total investment cost of the reference parabolic trough power plant is US$452 million (Rs 2,000 crores), approximately. Figure 19 shows the cost breakdown by main functional subsystems and general cost items.

Figure 19:
Overall Investment Cost Breakdown for Parabolic Trough Reference Power Plant, with Storage (left) and without Storage (right)



Source: CENER

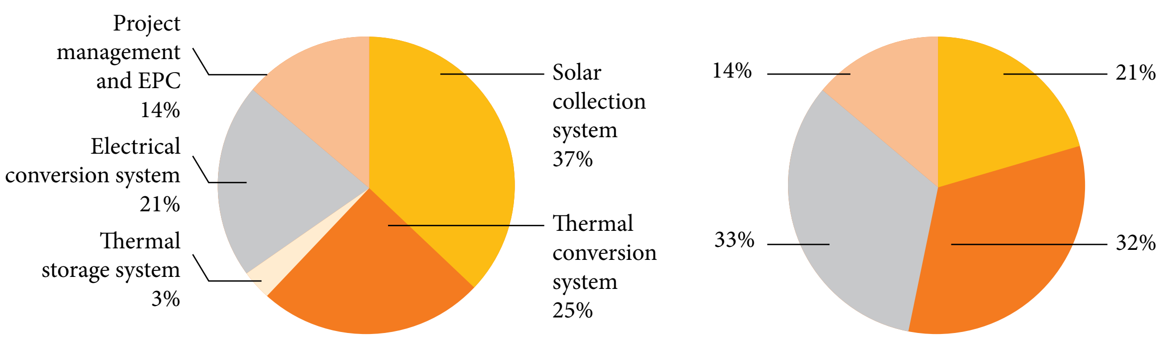
As it can be observed, subsystems directly related to specific solar components (solar collection system and thermal conversion system) represent more than the half of the total investment costs of the plant.

This cost breakdown can be compared with a parabolic trough power plant without storage of the same power capacity. The total investment cost would drop to approximately US$286 million (Rs 1,260 crores), taking into account that this reduction is not only a consequence of the exclusion of the thermal storage system but also the reduction of the solar field area.

Power Tower Technology

For the current case, a 17 MW reference power plant similar to Gemasolar with a 304,520 m2 solar field (2,648 heliostats of 115 m2) and a 15 hours thermal storage has been analyzed. The total investment cost of the reference Power Tower plant is US$237 million (Rs 1,048 crores), approximately. Figure 20shows the cost breakdown by main functional subsystems and general cost items.

Figure 20:
Overall Investment Cost Breakdown for Power Tower Reference Power Plant, with Storage (left) and without Storage (right)



Source: CENER

In this case, the solar collection system and the thermal conversion system represent more than 60 percent of the investment costs of the solar power plant.

It is also important to notice that the weight of the thermal storage system does not include the costs of the storage medium, since this has been incorporated into the thermal conversion system.

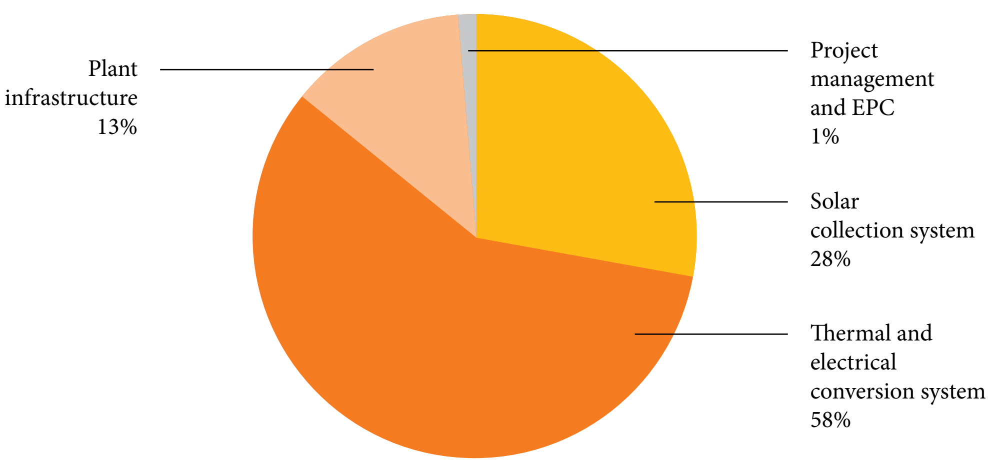
This cost breakdown can be compared with a power tower plant without storage of the same power capacity and the same configuration. The estimated total investment cost would drop to approximately US$154 million (Rs. 683 crores): this reduction is not only a consequence of the exclusion of the thermal storage system, but also the reduction of the solar field area. It is worth remarking that, for the reference power tower plant configuration, the exclusion of the storage system would probably not be profitable. Electrical production increase produced by the implementation of a 15-hour storage system makes its inclusion worthwhile.

Dish Engine Technology

For this cost analysis, we have considered a 10 MW thermal power plant consisting of 400 dish Stirling units based on the 25 kW SES design. The Stirling engine implemented is a Stirling Kockums 4-95, with hydrogen as the working fluid.

The total investment cost of the reference dish Stirling power plant is US$84 million (Rs 373 crores), approximately. Figure 21shows the cost breakdown by main functional subsystems and general cost items.

Figure 21:
Overall Investment Cost Breakdown for Dish Stirling Reference Power Plant



Source: CENER.

The lack of more specific information on the investment costs for this CSP technology has required the reorganization of the structure adopted for the cost analysis. For the current document, only two subsystems are being analyzed: the solar collection system and the combination of the thermal conversion system and the electrical conversion system.

B. Cost and Performance Evolution

The analysis of the efficiency evolution is related to the technology improvements expected in the period being considered. As it is impossible to make accurate predictions of when these efficiency improvements are going to take place, only global efficiency increases expected by 2015 and by 2020 are being considered. These efficiency improvements have been assumed to be linear through the years.

Linear Fresnel Reflector Technology

The overall investment cost of the reference plant is expected to experience a cost reduction of between 8percent and 14 percent by 2020, for factors, such as mass production in mirror assembly and support structure production and operational experience. Mirror assembly cost is mainly influenced by mass production and new reflector materials. Support structure savings comes mainly from mass production and material savings. Further reduction in this area can be achieved by standardization, which is expected to show an effect in 2015. Improvement in heat collection elements by a foreseeable technological breakthrough will further help to reduce total costs. Apart from these technical improvements, operational experience will lead to significant savings.

A global plant improvement of 3–5 percent is being expected by 2015, coming up to 13–20 percent by 2020. These figures are based on technological advances related to new designs in support structures, improvements in mirror and receiver properties, collector and receiver size increase, and slight progress in turbine efficiency.

The base case for the LCOE evolution has been calculated according to the actual investment cost detailed in the previous sections and a reference plant production of 65 GWh/year as an appropriate value for the reference plant operating in a location receiving about 2,050 kWh/m^{2}year. In this base case the LCOE obtained for 2010 is approximately US$0.19/kWh (8.3 Rs /kWh) (cost assumptions are provided in Chapter 2 in the section on Linear Fresnel Reflector Technology), and the expected reductions are between 7 percent and 13 percent by 2015 and between 15 percent and 24 percent by 2020.

Parabolic Trough Technology

The overall investment cost is expected to experience a cost reduction between 11 percent and 19 percent by 2020. These reductions are resulting from factors such as improvements in mirror assembly, support structure, thermal storage and heat collection elements, and operational experience. Mirror assembly is likely to benefit from new materials introduced for the reflecting surface. Weight reduction and standardization has a great impact on the support structure costs. A breakthrough in the thermal storage system toward a thermocline tank, which is expected in the mid to long term, has the opportunity to result in a big savings in this area. A possible increase in heat collection element size could lead to further cost reduction. Apart from these technical improvements, operational experience also has great influence on the overall investment costs.

A global plant improvement of 7–9 percent is being expected by 2015, coming up to 10–14 percent by 2020. These figures are based on technological advances related to new designs in support structures, improvements in mirror and receivers' properties, collector and receiver size increases, and slight progresses in turbine efficiency.

The base case for the LCOE evolution has been calculated according to the actual investment cost detailed in the previous sections and a production of 155 GWh/year as an appropriate value for the reference plant operating in a location receiving about 2050 kWh/m2•year. In this base case, the LCOE obtained for 2010 is approximately US$0.23/kWh (10.1 Rs /kWh) (cost assumptions and input data are provided in Chapter 2 in the section on Parabolic Trough Technology),and reductions expected are between 11 percent and 18 percent by 2015 and between 15 percent and 24 percent by 2020.

Power Tower Technology

The overall investment cost is expected to experience a cost reduction between 21 percent and 33 percent by 2020, because of cost improvements in mirror assembly, support structure, and thermal storage, as well as operational experience. Mirror assembly benefits mainly from new materials for the reflecting surface. Support structure costs are mainly influenced by weight reduction and standardization. A breakthrough in the thermal storage system toward a thermocline tank, which is expected for the mid to long term, will also lead to a significant cost reduction. Apart from these technical improvements, further savings are achieved by increasing operational experience.

Improvements of 4–6 percent and 5–8 percent are expected by 2015 and 2020, respectively. These figures are based on technological advances related to new designs in support structures, improvements in mirror and receivers' properties, and larger collector and receivers, as well as small improvements in turbine efficiency.

The base case for the LCOE evolution has been calculated according to the actual investment cost detailed in the previous sections and a production of 90 GWh/year as an appropriated value for the reference plant operating in a location receiving about 2,050 kWh/m2•year. In this base case, the LCOE obtained for 2010 is approximately US$0.21/kWh (9.5 Rs /kWh) (cost assumptions and input data are provided in Chapter 2 in the section on Power Tower Technology),and expected reductions are between 20 percent and 30 percent by 2015 and between 22 percent and 32 percent by 2020.

Dish Engine Technology

The overall investment cost is expected to experience a cost reduction between 39 percent and 53 percent by 2020. The main factors for this are mass production in mirror assembly and mass production and standardization for support structure. Apart from this, further savings are achieved by increasing operational experience.

A global plant improvement of 0.5–6 percent is being expected by 2015 and an improvement of 10–15 percent is expected by 2020. These figures are based on technological advances related to new designs in support structures, improvements in mirror and receiver properties, and collector and receiver size increase, as well as slight improvements in turbine efficiency.

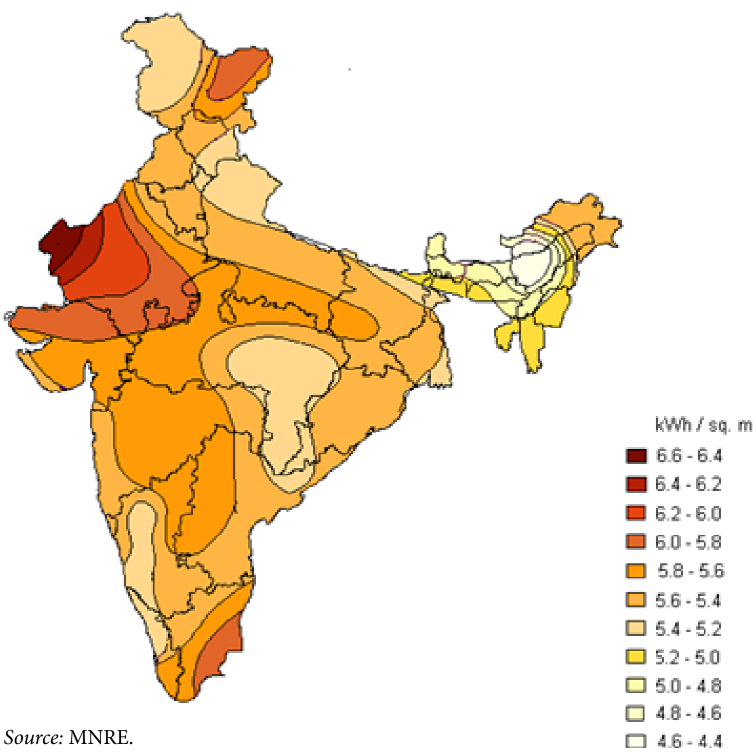
The base case for the LCOE evolution has been calculated according to the actual investment cost detailed in the previous sections and a production of 22 GWh/year as an appropriated value for the reference plant operating in a location receiving about 2050 kWh/m2•year. In this base case, the LCOE obtained for 2010 is approximately US$0.29/kWh (12.6 Rs /kWh) (cost assumptions and input data are provided in Chapter 2 in the section on Dish Engine Technology), and reductions expected are between 34 percent and 48 percent for 2015 and between 39 percent and 52 percent for 2020.

Appendix 4.
JNNSM and Regulatory Mechanism

A. Solar potential of India

Each year, the solar radiation incident on India is well over 4,500 PWh (Peta=1015). The solar irradiation map of India is shown in Figure 22.

Figure 22:
Solar Irradiation Map of India Adapted from IMD



Source: MNRE.

- Rajasthan, Gujarat, and Haryana receive the highest global solar radiation in India
- Jaisalmer, in Rajasthan, receives the maximum radiation at 6.27 kWh/m2 per day
- The average daily duration of bright sunshine in Jodhpur, Rajasthan, is 8.9 hours
- On average, the intensity of solar radiation received in India is 200 MW/km^2

B. Current Solar Landscape

Given India's potential to generate electricity through solar thermal systems, the Government of India has initiated a plan with ambitious targets to generate solar power through its Jawaharlal Nehru National Solar Mission (JNNSM). The mission envisions a capacity of 20,000 MW by the year 2022, of which 50 percent will be CSP. Phase I, up to year 2013, has a target of 1,100 MW, Phase II is from year 2013 to 2017 and Phase III is from year 2017 to 2022, with a target of 22,000 MW.

Table 50:
JNNSM Targets

APPLICATION SEGMENT	TARGET FOR PHASE I (2010–13)	CUMULATIVE TARGET FOR PHASE II (2013–17)	CUMULATIVE TARGET FOR PHASE III (2017–22)
GRID SOLAR	1,100 MW	4,000 MW	20,000 MW
OFF-GRID SOLAR	200 MW	1,000 MW	2,000 MW
SOLAR COLLECTORS	7 km^2	15 km^2	20 km^2

The JNNSM provides for NTPC's Vidyut Vyapar Nigam Ltd (NVVN) to be the designated nodal agency for procuring the solar power by entering into a Power Purchase Agreement (PPA) with solar power generation project developers who will be setting up solar projects before March 2013 that are to be connected to the grid at a voltage level of 33 kV and above.

The central government has a quota of 15 percent of the power generating capacity of NTPC (unallocated capacity) at its discretion to distribute it as it sees fit to meet the demands of various states and regions. For each MW of installed capacity of solar power, for which a PPA is signed by NVVN, the Ministry of Power (MOP) shall allocate to NVVN an equivalent amount of MW capacity from the unallocated quota of NTPC coal-based stations (which is relatively cheaper), and NVVN will supply this "bundled" power to the distribution utilities. This "bundled power" would be sold to the distribution utilities at prices determined by the Central Electricity Regulatory Commission (CERC).

The first phase of the JNNSM capacity allocation was auctioned (reverse) owing to a robust response from the industry. The auction process had seen selection of a total of seven bidders to build 479 MW power generation capacity, based on CSP in the first phase of the scheme. NVVN is the nodal agency for implementing the first phase of the program. The ceiling price was set at CERC declared tariff of 15.31 Rs /kWh. The discount offered by a potential bidder to the CERC tariff is vital for evaluation of bids for allocation of projects under JNNSM.

As an outcome, Reliance Power (RPower), Lanco, and KVK Energy will develop 100 MW capacity each while Megha Engineering, Godavari Power, and Corporate Ispat will build solar plants of 50 MW each. A 20 MW CSP plant will be developed by Arum Renewables.

Besides these seven bidders, three of the grid-connected solar power projects in India are already at an advanced stage of development (Acme Tele Power Limited, Dalmia Solar Power Limited, and Entegra Limited) and have migrated to the JNNSM under Phase I of the MNRE.

C. Regulatory Framework

In the last six years, the following significant developments have led up to the current stage of solar energy development:

- **Renewable Portfolio Obligation (RPO) of the Electricity Act-2003**

  RPO places an obligation on electricity supply companies to produce or consume a specified fraction of their electricity consumption from renewable energy sources. This mandates the SERCs to promote and support renewable energy development. CERC has tariff regulations (determination at state level) and generic RPO obligation for different states depending on RE generation capability. The RPO requirement encourages private players to focus on renewable energy in their long-term strategic plan. It is expected to attract investments in this area by mandating RPO supported by suitable policy and regulatory framework.

- **Integrated Energy Policy and Energy Security, 2005**

  From a longer-term perspective, there is a need to maximally develop domestic supply options, as well as the need to diversify energy sources, which makes renewables important to India's energy sector. Indeed, solar power could be an important player in India's attaining energy independence in the long term.

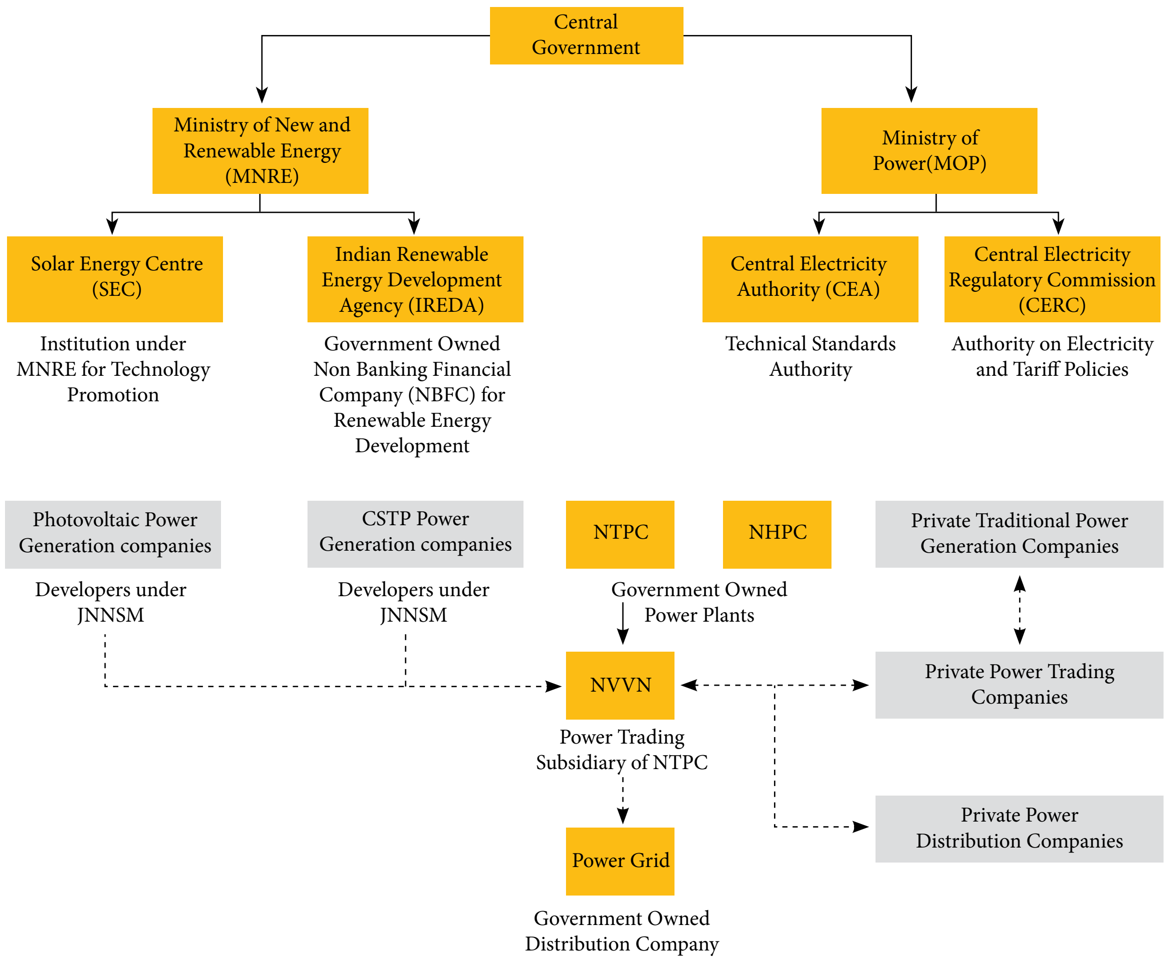
- **National Action Plan on Climate Change (NAPCC), 2008**

  With the objective to achieve a sustainable development path that advances and economic and environmental objectives, the NAPCC formulated the following eight national missions:

  – National Solar Mission (now called JNNSM)
  – National Mission for Enhanced Energy Efficiency
  – National Mission on Sustainable Habitat
  – National Water Mission
  – National Mission for Sustaining Himalayan Ecosystem
  – National Mission for a Green India
  – National Mission for Sustainable Agriculture
  – National Mission for Strategic Knowledge for Climate Change

Although efforts have been on for developing solar potential for some time, the real thrust came when the Government of India launched the Jawaharlal Nehru National Solar Mission (JNNSM) in January 2010 as one of the eight national missions under the Prime Minister's National Action Plan on Climate Change (NAPCC) in 2008.

Figure 23:
Key Government Bodies Involved in Solar and RE Development in India



Source: AQUA MCG

NAPCC has set the target of 5 percent renewable energy purchase for FY 2009–10 against the current level of around 3.5 percent. Further, NAPCC envisages that this target will increase by 1 percent for the next 10 years. This would mean NAPCC envisages renewable energy to constitute approx 15 percent of the energy mix of India. This would require a quantum jump in deployment of renewable energy across the country.

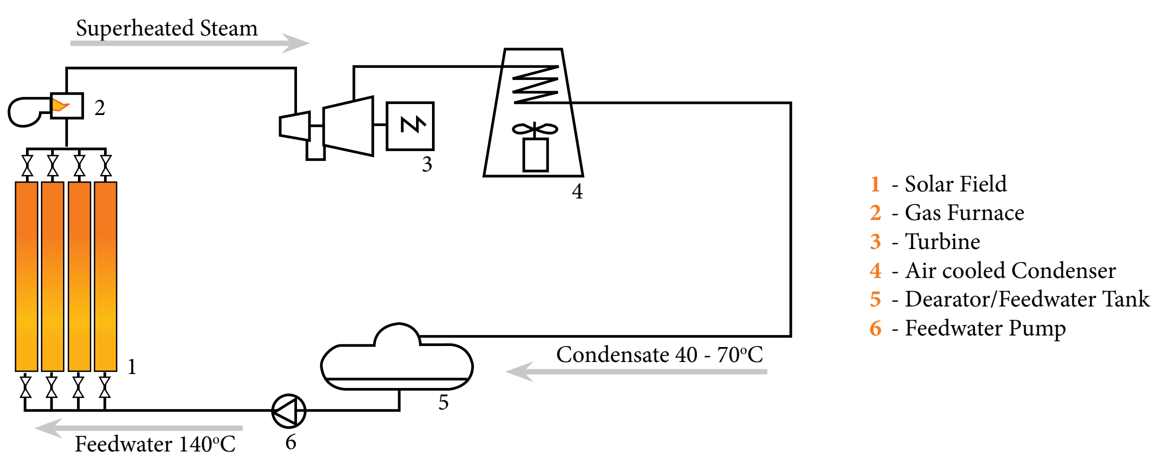
The RPO requirement stems from the need to encourage players to focus on renewable energy in their long-term strategic plan. This will ensure that over a period of time India attains energy security in a sustainable manner. It is expected to attract investments in this area by mandating RPO supported by suitable policy and regulatory framework.

Appendix 5. Solar Hybrid Systems

A. Commercially Viable Technologies

From an environmental point of view, solar-only configurations like the ones mentioned above are the best configurations, since only heat from the solar field is used to generate steam. However, since no mature TES solutions are commercially available for DSG, hybridization with a fossil fuel boiler placed in parallel to the solar field could be interesting to increase the capacity factor of the plant. In Spain the range of hybridization is limited to 12–15 percent (a fraction of the fossil fuel energy in the total thermal energy of the plant) by the legal framework, and in the United States it can reach up to 25 percent. This design allows three operation modes (solar, fossil, or hybrid) providing great levels of versatility and dispatchability.

Figure 24:
Saturated-Steam Hybrid Plant Configuration



Source: Novatec Biosol

Aside from the configuration shown in Figure 25, other hybrid design can be considered for linear Fresnel CSP plants:

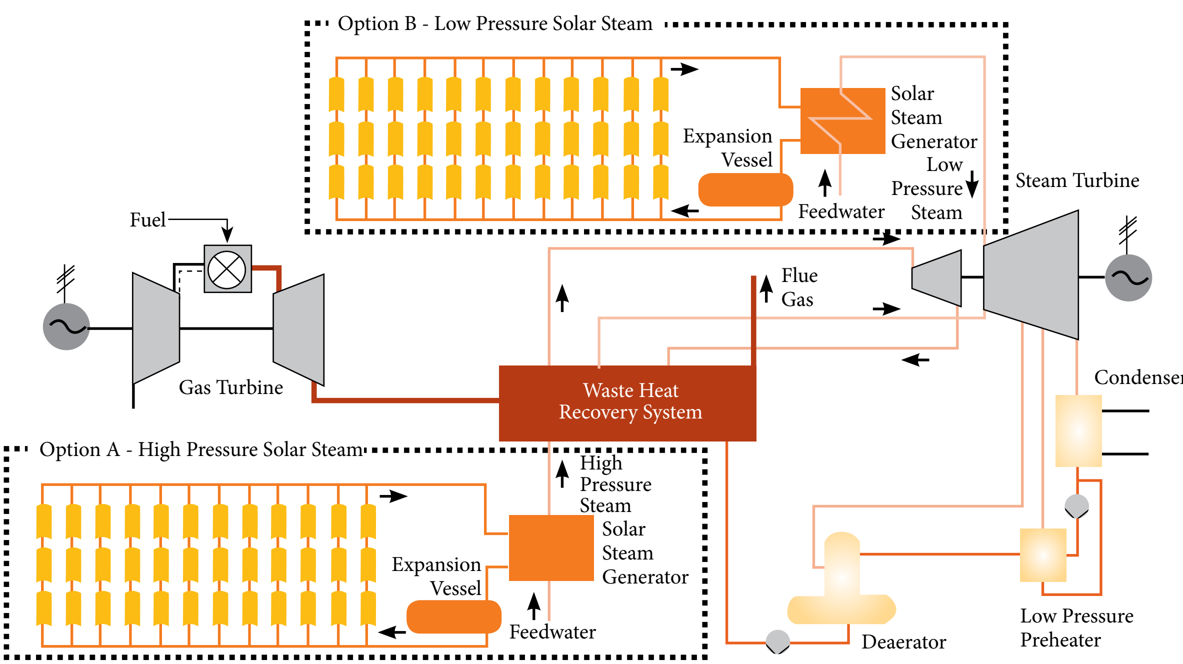
Conventional Rankine Cycle with Solar Preheating

This concept aims at adding a solar preheater to big fossil power plants in order to reduce their fuel consumption and gas emissions. 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 5 percent. However, solar energy is converted to power with high efficiencies (Morin and others 2004), and the investment cost is low, so it can be a relevant option to retrofit existing fossil fuel plants already in operation and introduce CSP 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 of integrating solar energy into a combined cycle power plant, as shown in Figure 25. They have been primarily considered for PTCs, but the characteristics of linear Fresnel collectors (low cost, low temperature, DSG) made them very relevant for ISCCs. They can be 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.

Figure 25:
Basic Scheme of an ISCCS



Source: Novatec Biosol
Note: There are two options for solar heat integration, from low pressure or high pressure solar steam

These systems benefit from the high efficiencies of combined cycles compared to Rankine cycles: some studies assess annual fuel-to-power efficiencies of about 60 percent (Dersch and others 2004; World Bank 2006; German Federal Ministry for Education, Science, Research and Technology 1996). Besides, since the investment cost for gas turbines is lower than for steam turbines, ISCCSs 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 design solar fraction is limited (lower than 15–20 percent (Dersch and others 2004)), resulting in a very low annual fraction (about 6 percent in favorable irradiation conditions; up to 12 percent a TES is included).

Although the operation of CSP plants is very similar to the operation of fossil fuel thermal plants, many options can be considered to design a parabolic trough solar plant, depending on the choice of the thermal cycle, working fluid, solar fraction determined by the hybridization (if any), and on the strategic objective of the installation. Most of them have already been described in Chapter 2 in the section on Linear Fresnel Reflector Technology.

Currently there are three ISCC solar projects in advanced construction: Hassi R'Mel (Algeria), Ain Beni Mathar (Morocco), and Kuraymat (Egypt). All of them are expected to be connected on the grid within the current year. They all include a 20 MW parabolic trough solar thermal field that generates electricity combined with a natural gas boiler.

B. Case Studies of Hybrid Plants

The implementation of hybrid solar-fossil plants with PT solar fields could be interesting in the current market. In this section a techno-economic study will be presented, which estimates the LCOE of such plants for various hybridization options. All options will have a solar field equal to the one of a 50 MWe solar-only PT plant with thermal oil as HTF, located in Sevilla, and three cases are considered:

- Hybrid plant with 50 MW coal boiler and 50 MW steam turbine, corresponding to a 24 percent solar fraction in the annual power production,
- Hybrid plant with 100 MW coal boiler and 100 MW steam turbine, corresponding to a 12 percent solar fraction in the annual power production,
- Hybrid plant with 200 MW coal boiler and 200 MW steam turbine, corresponding to a 6 percent solar fraction in the annual power production,

In all cases, plants are aimed at base-load generation, with a 100 percent capacity factor. Although plant shut-downs are needed for maintenance operations, in this study the plants are assumed to operate the whole year long without stops, since the objective of this analysis is purely comparative. No hybridization with gas has been considered.

The main characteristics of the solar field used in all hybrid cases are shown in Table 51.

Table 51:
Main Characteristics for the Parabolic Trough Field Implemented in a Hybrid Plant

SOLAR FIELD AND COLLECTOR PROPERTIES	
Aperture area	249,264 m^2
Number of loops	72
Collectors per loop	4
Collector width	5.76 m
Collector length	150 m

Results obtained for the different cases purposed are shown in the following sections.

CASE 1:
Power Output 50MW with 24 percent Solar Fraction

The total investment cost of the Case 1 hybrid power plant is US$305 million (Rs 1346 crores), approximately. Table 52 shows the main characteristics considered and the main simulation results obtained.

5.4 Expected Cost Reduction

Interactions with players in the CSP field have resulted in the assessment of expected cost reductions summarized in Table 30.

Table 52:
Main Characteristics and Simulation Results for the Case 1

MAIN CHARACTERISICS			SIMULATION RESULTS		
Turbine nominal power	MW_e	50	**Annual production**	MWh_e/year	438,000
Boiler power	MW_{th}	135.5	**Cycle efficiency**	%	41
Boiler efficiency	%	90	**Total thermal energy**	MWh_{th}/year	1,068,355
Coal cost*	US$/$MWh^{th}$	10.7	**Boiler thermal energy**	MWh_{th}/year	811,000
Yearly solar fraction	%	24	**Solar Field thermal energy**	MWh_{th}/year	257,355

**Source:* EURACOAL

According to the following results obtained and the economics data, the LCOE obtained for the Case 1 hybrid power plant is US$0.092/kWh.

CASE 2:
Power Output 100 MW with 12% Solar Fraction

The total investment cost of the Case 2 hybrid power plant is US$443 M (Rs. 1959 crores), approximately. Table 53 shows the main characteristics considered and the main simulation results obtained.

Table 53:
Main Characteristics and Simulation Results for the Case 2

MAIN CHARACTERISTICS			SIMULATION RESULTS		
Turbine nominal power	MW_e	100	Annual production	MWh_e/year	876,000
Boiler power	MW_{th}	264.5	Cycle efficiency	%	42
Boiler efficiency	%	90	Total thermal energy	MWh_{th}/year	2,085,355
Coal cost*	US$/$MWh_{th}$	10.7	Boiler thermal energy	MWh_{th}/year	1,828,000
Yearly solar fraction	%	12	Solar Field thermal energy	MWh_{th}/year	257,355

**Source:* EURACOAL

According to the following results obtained and the economics data, the LCOE obtained for the Case 2 hybrid power plant is US$0.073/kWh.

CASE 3:
Power Output 200MW with 6% Solar Fraction

The total investment cost of the Case 3 hybrid power plant is US$705 million (Rs. 3,116 crores), approximately. Table 54 shows the main characteristics considered and the main simulation results obtained.

Table 54:
Main Characteristics and Simulation Results for the Case 3

MAIN CHARACTERISTICS			SIMULATION RESULTS		
Turbine nominal power	MW_e	200	Annual production	MWh_e/year	1,752,000
Boiler power	MW_{th}	516.8	Cycle efficiency	%	43
Boiler efficiency	%	90	Total thermal energy	MWh_{th}/year	4,074,355
Coal cost*	US$/$MWh_{th}$	10.7	Boiler thermal energy	MWh_{th}/year	3,817,000
Yearly solar fraction	%	6	Solar Field thermal energy	MWh_{th}/year	257,355

**Source:* EURACOAL

According to the following results obtained and the economics data, the LCOE obtained for the Case 3 hybrid power plant is US$0.061/kWh.

C. Tariff Calculations for a Solar Thermal—Biomass Hybrid Plant

Considering the project of Rs. 14 crores/MW (Rs. 12 crores/MW for solar block + Rs. 1.5 crores/MW for the biomass boiler and fuel handling and ash handling systems+ Rs. 0.5 cr/MW for misc) for a solar thermal biomass hybrid plant, the tariff from such a plant works out to be Rs 6.68/KWh based on a plant CUF of 80 percent with solar contribution at 23 percent (as per CERC norms). The assumptions are tabulated in Table 55.

Table 55:
Financial Calculations for a CSP-Biomass Hybrid Plant

S. NO.	ASSUMPTION HEAD	SUBHEAD	SUBHEAD (2)	UNIT	PARAMETER VALUES
1	Power generation	Capacity	Installed power generation capacity	MW	1
			Capacity utilization factor	%	80%
2	Project cost	Capital cost/ MW	Normative capital cost	Rs lakhs/MW	1,400.00
			Capital cost	Rs lakhs	1,400.00
			Capital subsidy	Rs lakhs	-
			Net capital cost	Rs lakhs	1,400.00
3	Financial assumptions	Debt:equity	Tariff period	Years	25
			Debt	%	70%
			Equity	%	30%
			Total debt amount	Rs lakhs	980.00
			Total equity amount	Rs Lac lakhs	420.00
		Debt component	Loan amount	Rs lakhs	980.00
			Moratorium period	Years	1.5
			Repayment period (including moratorium)	Years	11.5
			Interest rate	%	13.39%
		Equity Component	Equity amount	Rs lakhs	420.00
			Return on equity for first 10 years	% pa	19.00%
			Return on equity 11th year onwards	% pa	24%
			Discount rate	%	22.00%
		Depreciation	Depreciation rate for first 10 years	%	7%
			Depreciation rate 11th year onwards	%	1.33%
		Incentives	Generation based incentives	Rs lakhs pa	0
			Period for GBI	Years	NA

Cont...

S. NO.	ASSUMPTION HEAD	SUBHEAD	SUBHEAD (2)	UNIT	PARAMETER VALUES
4	O&M	Normative O&M expense		Rs lakhs/MW	13.74
		O&M expense per annum		Rs lakhs	13.74
		Escalation factor for O&M expense		%	5.72%
		Biomass expense (variable cost of biomass @ Rs 3/KWh)			150
5	Working capital	O&M expense	(of O&M)	Months	1
		Maintenance spares		%	15%
		Receivables		Months	2
		Interest on working capital		% pa	12.89%
6	Starting and stopping power	Power for starting & stopping of plant	(of gross generation)	%	0.00%
		Power cost from grid		Rs /kWh	0
		WACC	15.97%		

Appendix 6. Cost Analysis Approach

This appendix includes the full methodology of the cost analysis approach carried out in the present report.

A. Outline

The investment cost of a CSP plant varies with the power of the conventional power block (for example, steam turbine or Stirling motor), the capacity of the thermal storage, if any, and the size of the solar collector field. In order to keep the analysis within manageable limits, it is necessary to define a reference plant for each technology.

Once a reference plant is defined, the cost of the plant and its different subsystems and components can be assessed, as well as the performance indicators of the plant as whole and its different subsystems and components. Based on this information, and on the assessment of the operational costs of the plant, the yearly LCOE for the plant can be estimated for a given yearly electricity production.

What is left is to determine, year by year from the starting to the final year of the cost analysis period, the reductions in cost that the different components and subsystems of the plant will experience, as well as the improvements in the performance indicators that could be expected. This information can then be used to determine, for each one of the four CSP technologies, the expected evolution of the LCOE as a function of time for the period analyzed within the study: 2010–20.

With the outlined scheme, the price paid to be able to provide a quantitative analysis of the expected LCOE evolution of the different CSP technologies is particularized. The evolution of the LCOE for each commercially available CSP technology is quantified just for a specific reference plant, whose configuration is fixed over the period of analysis, and just for a specific location, which is indirectly specified by assessing the amount of electricity the reference plant will produce.

In the next sections, the details of the approach just outlined are further explained, and the results obtained are presented for each one of the four CSP technologies considered.

B. Limitations and Boundary Conditions

Excluded Costs

Because of their strong dependency on the location of the power plant, their relatively CSP technology independence, and the difficulty to make sensible generalizations about them, the following costs are not included in the cost analysis:

- Costs associated with the connection to the electricity grid.
- Costs associated to the purchasing or renting of the land where the CSP plant will be built
- Costs of water.

The first cost is strongly dependent on the specificities of the electricity grid in the area in which the CSP plant is located, and on the particular electricity regulations and policies of the country or region, while the second varies widely from country to country, and within a country from place to place.

Quality and Availability of Cost Data

As stated in the introduction, the commercial deployment of CSP technologies is at a very early stage and is not taking place at the same pace for all technologies. The only two technologies that are clearly past the demonstration stage are parabolic trough and tower. This has a substantial impact in the quantity and quality of the costs data available for each technology.

Table 56 presents a gross and overall estimate of the uncertainty that can be associated to the cost data available for each technology. As shown in the table, the uncertainties of the cost data for all technologies are rather large. This is only because of the small number of commercial CSP plants in operation, but also because of difficulties in obtaining the data from industry, and by the large statistical dispersion of that data.

Table 56:
Overall Estimate of the Uncertainty Associated to the Costs Data by Technology

TECHNOLOGY	LF	PT	CR	PD
COSTS DATA UNCERTAINTY	>30%	15%	20%	>30%

Source: CENER.

The large uncertainty associated with the cost data of the different CSP technologies is further complicated by the fact that for some technologies, such as towers and dishes, the current status of the technologies may not be representative of their mid-term evolution.

C. Investment Cost Evolution

The two drivers considered in the cost evolution model are as follows:

- Experience.
- Technology breakthroughs.

Experience is modeled by experience curves. These curves express how costs are expected to decrease as a function of the experience the industry gains in the use of the technology over the years. The parameter used to quantify experience is the cumulative installed power capacity of CSP plants of a given technology. The mathematical expression of an experience curve is the following:

$$\frac{C_2}{C_1} = R \cdot^{\log_2 \frac{P_2}{P_1}}$$

Where

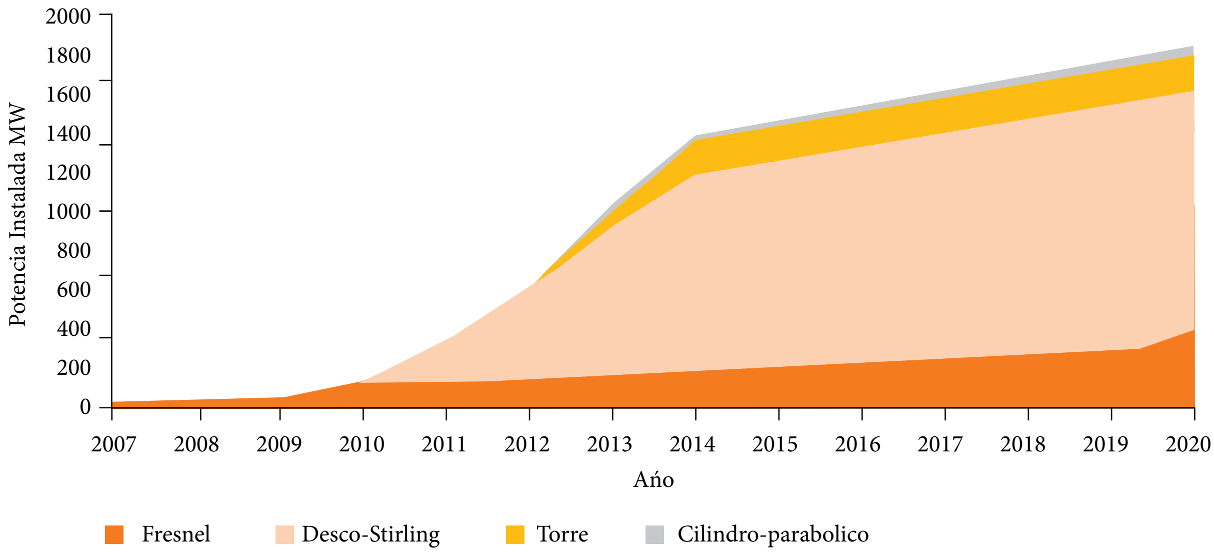
- C_1 is the cost of the product at the reference time,
- C_2 is the cost of the product at the future instant for which it has to be assessed,
- P_1 is the accumulated experience until the reference time,
- P_2 is the accumulated experience until the future instant for which the cost has to be assessed,
- PR is the progress ratio, which is the cost reduction that is expected each time that the amount of the product is duplicated.

The indicator chosen to account for the experience is the installed capacity for each technology. It has to be noted that the experience has to be estimated on a worldwide basis. The expected evolution of the installed capacity worldwide for the four main CSP technologies is shown in Figure 26. The progress ratio is chosen specifically for each subsystem (solar collection, thermal conversion, electrical conversion, and thermal storage) of each reference plant.

For each CSP technology, breakthroughs are expected to be achieved at some points in the future for key technology components. They are assumed to significantly lower the cost of their corresponding component, or to improve the component's efficiency, or both. These breakthroughs are expected to be obtained from R&D activities carried out at present. The date estimated of this evolution is in accordance to the results currently obtained and reported. To simplify the model, these breakthroughs are divided into two groups: the ones that will occur between 2011 and 2015, and the ones that will occur between 2015 and 2020. In some cases, a certain cost reduction is expected as a consequence of a specific behavior of the market. In these cases, the expected cost reduction substitutes the experience curve, since it is expected to have a larger impact on the final cost reduction.

Figure 26:

Expected Evolution of Installed Capacity Worldwide for Four CSP Technologies, 2010–20



D. Cost Evolution Scenarios

The way of representing the cost evolution related to each component has been carried out by ranges of percentage showing a sector of cost reduction probability going from a conservative estimation, which excludes some optimistic breakthroughs, to the most optimistic scenario, including every breakthrough foreseen, as well as the highest reduction percentages estimated. Indeed, two scenarios have been considered for the cost evolution:

- In the conservative scenario, for each reference plant, the LCOE is calculated using the minimum value within the variation range of the estimated yield, and the maximum value within the variation range of the estimated costs. Besides, only the most probable breakthroughs are included and conservative values of the progress ratio are considered to determine the experience curves.
- In the optimistic scenario, for each reference plant, the LCOE is calculated using the maximum value within the variation range of the estimated yield, and the minimum value within the variation range of the estimated costs. Besides, most of the possible breakthroughs are included and optimistic values of the progress ratio are considered to determine the experience curves.

E. Financial Analysis

The LCOE is calculated for the four reference plants. This economic indicator can be defined as the value, in current currency, that would have to be assigned to each unit of energy produced by power plant during a given period to equal the total costs incurred during this period, also expressed in current currency. The economic model developed for the calculation of the LCOE is as follows.

If Q_n is the amount of energy produced by the plant during year n, d is the discount rate, C_n is the total of incurred costs in the plant during year n, the LCOE can be determined thanks to the following expression.

$$\mathrm{LCOE} = \frac{\sum_{n=1}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}}$$

N is the number of years covered by the analysis, typically equivalent to the project or investment life. C_n includes the investment costs during the initial years of construction and commissioning of the plant, O&M costs, land costs, and financial costs, including amortization and interest payment. The discount rate indicates the present value of future cash flows and depends, among other parameters, on the interest rates, inflation rates, and expected profitability of the investment.

Since a discount rate is chosen for the discount rate is the weighted average cost of capital (WACC) needed to finance the construction of the plant. Such a cost is calculated as the weighted average of the cost of the debt and of the equity's expected profitability.

The annual costs of the plant include initial investment and all operating costs that have to be incurred to ensure the correct operation of the installation, such as O&M costs and financial costs. The amount of these total annual costs, since the relative weight of the specific costs that compose it varies over the course of the years. Investment costs, O&M costs, and annual production are different for each reference plant. However, to get comparable results, the financial parameters used to calculate the LCOE are the same for all technologies. They correspond to typical parameters used to finance CSP plants in Spain.

Appendix 7. Cost Evolution for various CSP Technologies

A. Linear Fresnel Reflector Technology

Table 57:
Investment Costs for the 30 MW LF Plant without Thermal Storage

CONCEPT	COST (US$ million)	COST (Rs crores)
Solar collection system	39.2	173.2
Mirrors	3.7	16.3
Support structures	19.4	85.8
Drive mechanisms	2.3	10.1
Land leveling	3.9	17.2
Foundations	2.2	9.5
Assembly	6.2	27.2
Assembly facility	1.5	6.8
Thermal conversion system	16.0	70.8
Receiver tubes (considered 4m unit)	11.8	52.1
Piping, valves and spare parts	2.4	10.6
Natural Gas Boilers	1.8	8.0

Cont...

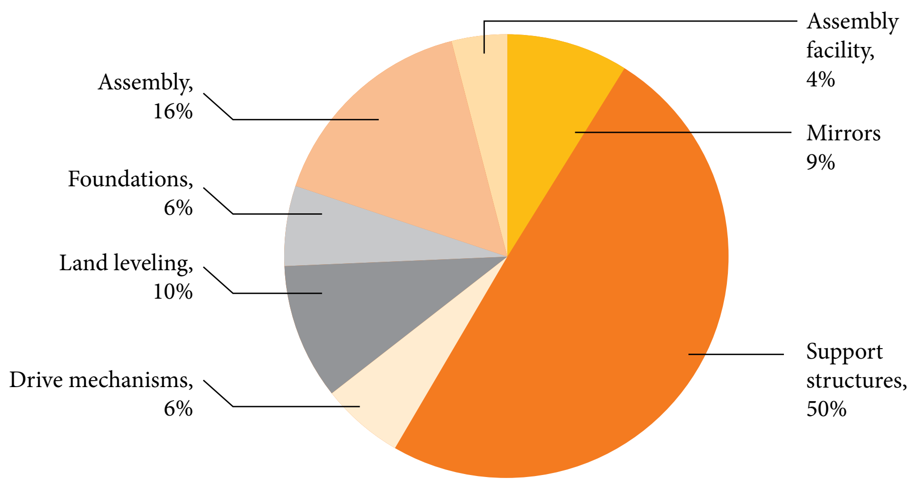
CONCEPT	COST (US$ million)	COST (Rs crores)
Thermal storage system	0.9	3.8
Thermal storage medium (water). N/A	0.0	0.0
Tank 162m3 (civil work included)	0.9	3.8
Heat exchangers. N/A	0.0	0.0
Pumps. N/A: Included in the power block	0.0	0.0
Electrical conversion system	72.1	318.5
Oil/steam heat exchanger. N/A	0.0	0.0
Power block	37.1	164.0
Balance of plant (BOP)	24.2	107.1
Civil work	10.7	47.4
Project management and EPC	21.7	95.8
Project management	2.1	9.5
EPC (17%)	19.5	86.4
TOTAL	**149.8**	**662.1**

Source: CENER, 2011.

Cost Breakdown by Subsystem

- **Solar collection**
  The investment cost of the solar collection system includes construction-related costs, such as land leveling, foundations, assembly, and assembly facilities. It also includes the cost of the key technological components presented in the Activity 1.1. Figure 27shows the subsystem investment cost breakdown by key components and cost items.

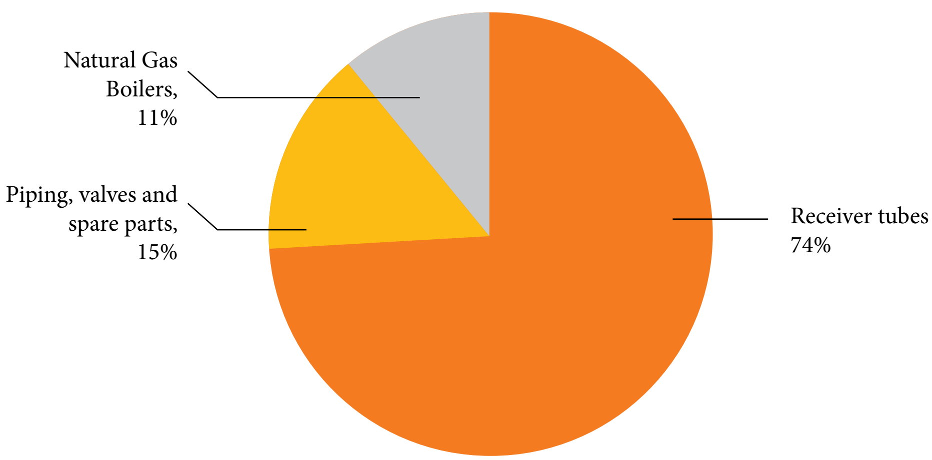
Figure 27:
Cost Breakdown Diagram for Solar Collection System of LF Power Plant



As it is shown in the figure, the current weight of the support structures in comparison to the rest of the solar collection system cost items is high.

- **Thermal conversion**
  The thermal conversion system is less complex than in other technologies, because it directly generates the steam that goes to the turbine, avoiding secondary fluids and the heat exchanger, for example. Costs involving receiver tubes have been estimated in accordance with available prices for parabolic trough technology, for the commercialized receiver tube with a quasi-standard dimension of 4 m. Costs of the thermal conversion system have been studied according to three main components or group of elements, as Figure 28 shows.

Figure 28:
Cost Breakdown Diagram for Thermal Conversion System of LF Reflector Power Plant



- **Thermal storage**
  Storage system has not been included in the reference plant for this technology. However, there is a consideration to be made. The configuration of this plant makes it necessary to have a steam separator that keeps controlled the properties of the steam produced along the collectors. This steam separator consists of either a single or several steam drum/ tank that store saturated steam, acting as a buffer. The system is not specifically designed with storage purposes, but it gives the power plant some reaction time, which would help in short transient conditions. This is the reason this installation can be considered in this subsystem. For the current case, two tanks of 160 m3 capacity each have been considered in the installation.

- **Electrical conversion**
  As mentioned already, the power block has a total power output of 30 MW, with two turbines of 15 MW. The cost breakdown of the system is shown in Figure 29.

Overall Investment Cost Evolution

The overall investment cost of the reference plant is expected to experience a cost reduction between 8 percent and 14 percent by 2020, as shown in Figure 30.

Figure 29:
Cost Breakdown Diagram for Electrical Conversion System of LF Reflector Power Plant

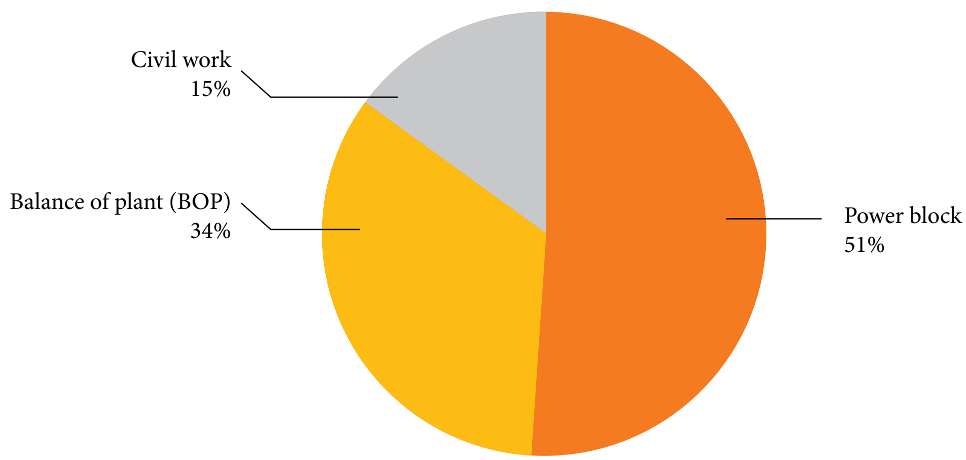
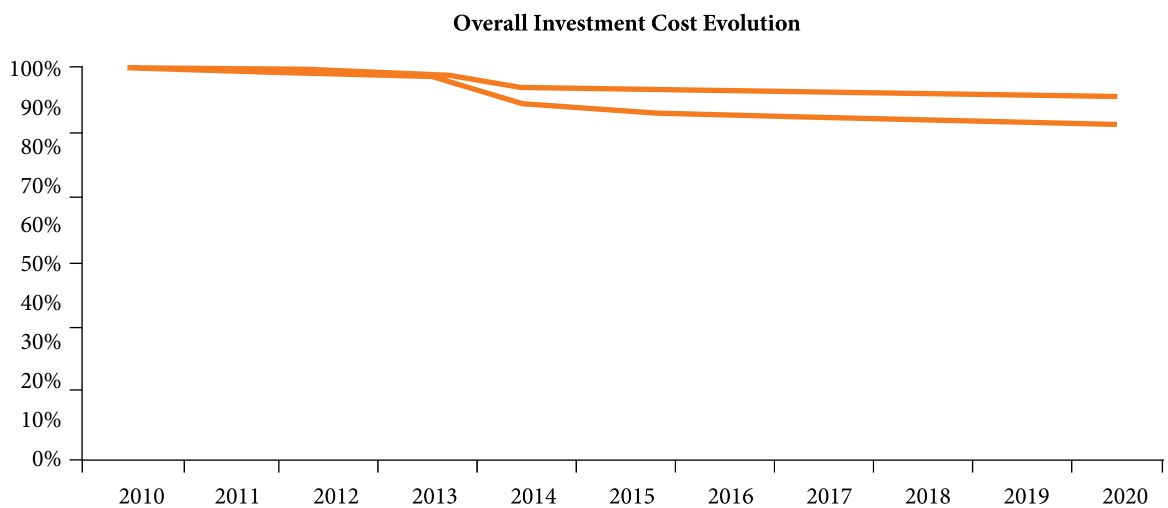


Figure 30:
Overall Investment Cost Evolution of the LF Reflector Power Plant



Main factors considered for the estimation of the cost evolution for linear Fresnel reflector technology are summarized in Table 58.

Cost Evolution Detailed by Subsystem

- **Mirror assemblies**
  Cost reductions related to mirror assemblies are mainly a consequence of the implementation of the mass production, as well as the possible introduction of new reflector materials. Current mirror technology adapted to linear Fresnel reflector is well known, and no special breakthroughs are foreseen. The cost decrease related to the

Table 58:
Summary Table of the Main Factors Considered for the Estimation of the Cost Evolution for Linear Fresnel Reflector Technology

Subsystem	Component	Decrease factor	Midterm cost decrease potential	Long-term cost decrease potential
Solar collection	Mirror assemblies	Mass production	4–5%	6–8%
		Mass production and material savings	20–25%	25–35%
	Support structures	Standardization (breakthrough)	6–12%	—
	Drive mechanism	Experience curve	P.R. = 85–87%	
Thermal conversion	Heat collection elements	Wide operational improvement	15–20%	
		Size increase (breakthrough)	10%	—
Electrical conversion	Power block	Experience curve	P.R. = 99–100%	
	BOP	Experience curve	P.R. = 90–95%	

Source: CENER, 2011

mass production is estimated to be around 4–5 percent at a midterm (2015), reaching a decrease up to 6–8 percent in the long term.

- **Support structure**
  Current support structure designed for linear Fresnel reflector collectors has still a margin to be optimized. Only a couple of specific Fresnel collectors have been implemented in existing power plants, so the cost reduction expected for this component is expected to be oriented in this direction. Changes related to the implementation of the mass production and the material savings can have an important impact of 20–25 percent in the midterm (2015) and of 25–35 percent in the long term (2020).

  An important factor to take into account is standardization. Nowadays a regulation of the CSP technology is being carried out and it is expected to play an important role in every CSP technology. This is explained more widely in the respective parabolic trough section, since this is the technology used as a starting point with the regulation process. Since parabolic trough technology is expected to have an impact in 2014, it is estimated that, for the rest of the CSP technologies, this breakthrough will occur at least one year later. The standardization is estimated to entail an additional cost reduction between 6 percent and 12 percent in the structure cost reduction in 2015.

- **Others components of the solar collection subsystem**
  The rest of the elements included in the solar collector system are not expected to achieve remarkable cost reductions. For the reflector drive mechanism, only a cost reduction related to the experience curve is being considered, taking a progress ratio of 85–87 percent. Neither will the rest of the components and labor work contemplated experience a noteworthy cost decrease.

- **Heat collection elements**
  A wide cost reduction of this element has been estimated, related mainly to the short operational experience of this technology. By 2020, a continuous cost reduction up to

15–20 percent will be estimated. Besides, a possible breakthrough has been regarded, in accordance with the parabolic trough technology prediction. It has been identified in the parabolic trough technology the option of increasing the size of the receiver tubes, thus reducing the manufacture investment costs. This change would also be related with vacuum tubes in linear Fresnel technology, which have a similar configuration. This optimistic foreseen will have an impact of approximately 10 percent in the cost reduction, by 2016.

- **Thermal storage**
  No special comments can be made to the cost reduction associated to the current system, since it is being understood in this section. The cost of the buffer system is a stable cost and it is not expected to experience a considerable decrease.

- **Electrical conversion**
  Elements associated to conventional installations have already experienced a big impact on their cost reduction in the latest years. That is the reason why, in general, for the plant configuration here considered a reference for implementing a saturated steam Rankine cycle, no additional improvements are estimated that can cause a further cost reduction than the expected experience curve. For this analysis, a progress ratio of 99–100 percent has been chosen for the power block, since the cost evolution of this system is limited by the hard operational conditions of the power plant, and a ratio of 90–95 percent has been taken for the BOP.

B. Parabolic trough technology

Table 59:
Investment Costs for the 50 MW PT Plant with 6 Hours Thermal Storage

CONCEPT	COST (US$ million)	COST (Rs crores)
Solar collection system	170.7	754.6
Mirrors	27.7	122.5
Support structures	55.4	245.0
Drive mechanisms	6.0	26.7
Land leveling	16.6	73.5
Foundations	27.7	122.5
Assembly and assembly facility	37.3	164.5
Thermal conversion system	66.6	294.5
Thermal oil	5.1	22.4
Receiver tubes	29.4	129.9
Ball joints	1.0	4.2
Piping, valves and spare parts	3.1	13.5
Oil forwarding skid (filters, piping, pumps, tanks, assembly)	19.9	88.0
Oil purification system	0.5	2.4
Fire protection system, inertization system	3.9	17.5
Natural gas boilers	3.8	16.7

Cont...

CONCEPT	COST (US$ million)	COST (Rs crores)
Thermal storage system	52.3	231.3
Storage medium (molten salts)	21.0	93.0
Molten salts forwarding skid (tanks, pumps, piping)	18.0	79.6
Heat exchangers	7.3	32.2
Initial filling system	1.7	7.6
Civil work	4.3	19.0
Electrical conversion system	94.4	417.1
Oil/steam heat exchanger	17.2	75.8
Power block	37.2	164.3
Balance of plant (BOP)	25.7	113.8
Civil work	14.3	63.2
Project management and EPC	67.8	299.5
Project management	2.1	9.5
EPC (17%)	65.7	290.3
TOTAL	**452.0**	**1997.6**

Source: CENER, 2011.

Table 60:
Investment Costs for the 50 MW PT Plant without Thermal Storage

CONCEPT	COST (US$ million)	COST (Rs crores)
Solar collection system	106.7	471.4
Mirrors	17.3	76.6
Support structures	34.7	153.1
Drive mechanisms	3.8	16.7
Land leveling	10.4	45.9
Foundations	17.3	76.6
Assembly	20.8	91.9
Assembly nave	2.5	10.9
Thermal conversion system	43.3	191.5
Thermal oil	3.2	14.0
Receiver tubes	18.4	81.2
Ball joints	0.6	2.6
Piping, valves and spare parts	1.9	8.5
Oil forwarding skid (filters, piping, pumps, tanks, assembly)	12.4	55.0
Oil purification system	0.5	2.4
Fire protection system	1.6	7.2
Inertization system	0.8	3.7
Natural Gas Boilers	3.8	16.7

Cont...

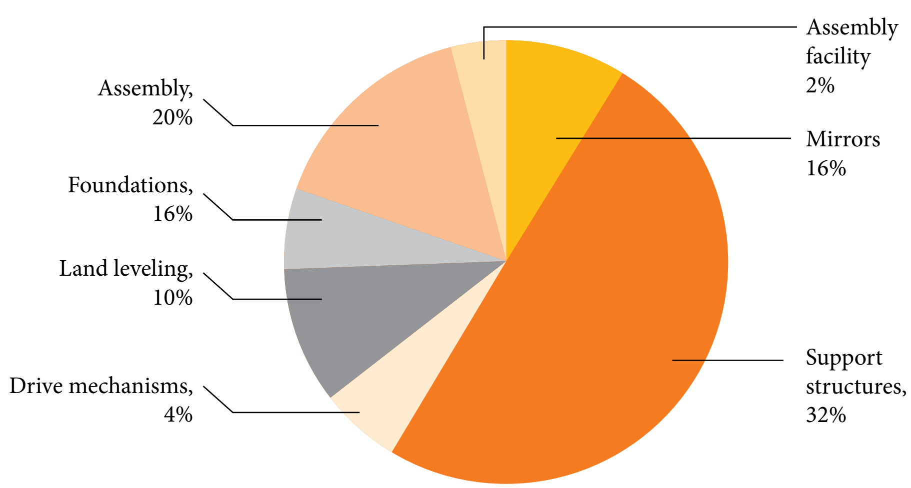
CONCEPT	COST (US$ million)	COST (Rs crores)
Electrical conversion system	94.4	417.1
Oil/steam heat exchanger	17.2	75.8
Power block	37.2	164.3
Balance of plant (BOP)	25.7	113.8
Civil work	14.3	63.2
Project management and EPC	44.0	194.6
Project management	2.1	9.5
EPC (17%)	41.9	185.2
TOTAL	**288.4**	**1274.6**

Source: CENER, 2011.

Cost Breakdown by Subsystem

- **Solar collection**
  The solar collection system includes not only main components already explained, but also work costs related to this system. The associated cost breakdown can be seen in Figure 31.

Figure 31:
Cost Breakdown for the Solar Collection System of the Reference PT Power Plant



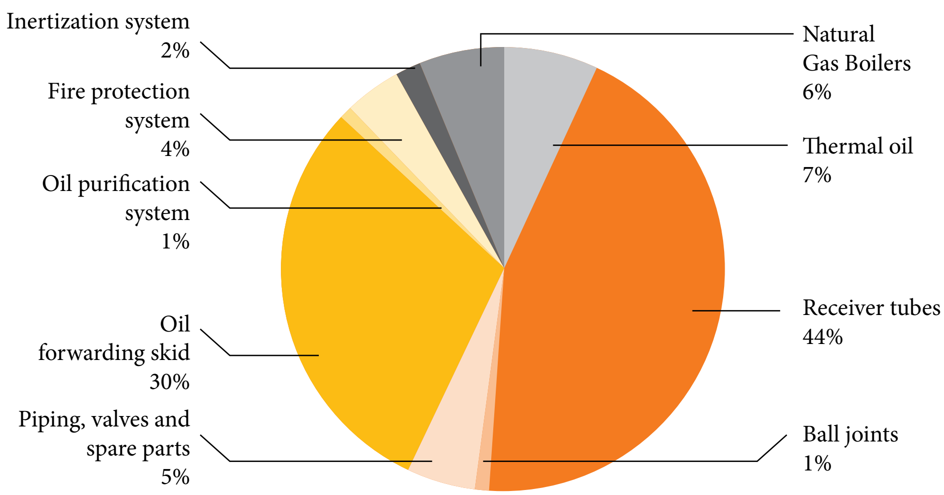
As it can be observed, the support structure is the element with the most important weight (32 percent) in the solar collection system, followed by mirror assemblies (16 percent).

- **Thermal conversion**
  The thermal conversion system takes into account not only receiver tubes and thermal oil, but also the whole infrastructure associated with the use of the thermal oil. That means oil-forwarding skid, oil purification system, inertization system, and fire

protection system. This last component has been included in this system because of its strong relation with the synthetic oil, even if it can also be considered as a part of the balance of plant (BOP) integrated in the electrical conversion system.

Another component included here is the natural gas boiler. This decision has been made because of the function of the boiler, which is heating the synthetic oil when needed. That leads to a direct relation with the thermal conversion system. The cost breakdown estimated for the thermal conversion system is shown in Figure 32.

Figure 32:
Cost Breakdown for the Thermal Conversion System of the Reference Power Plant



It can be observed that a high percentage of the investment cost related to the thermal generation system involves the receiver tubes (44 percent).

- **Thermal storage**
The thermal storage system considered consists of two tank molten salts thermal storage, which can supply a total thermal power of 300.000 MWh. The cost breakdown related to each component or activity corresponding to the current system can be observed in Figure 33.

Figure 33 shows that a high fraction of the investment costs, 40 percent, is related to the storage medium. However, all the equipment needed specifically for forwarding this storage medium also means a high fraction (35 percent) of the overall system costs.

- **Electrical conversion**
Investment costs related to the electrical conversion system have been mainly divided in three different sections: the power block, the BOP, and the heat exchanger. In general, the heat exchanger can be considered a part of the power block, since it operates at the same operating conditions as the rest of the components also here included. However, in the current cost analysis, it has been chosen to analyze it separately. The cost breakdown estimated for this system can be observed in Figure 34.

Figure 33:
Cost Breakdown for the Thermal Storage System for the Reference Power Plant

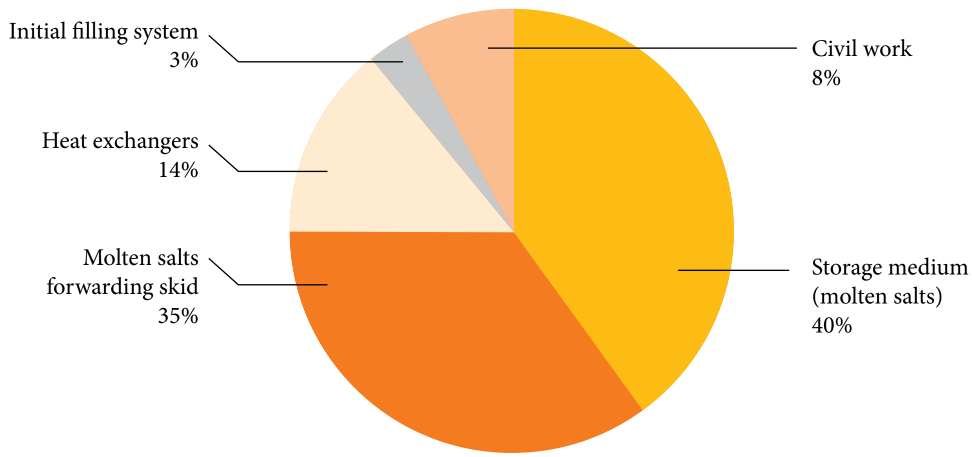
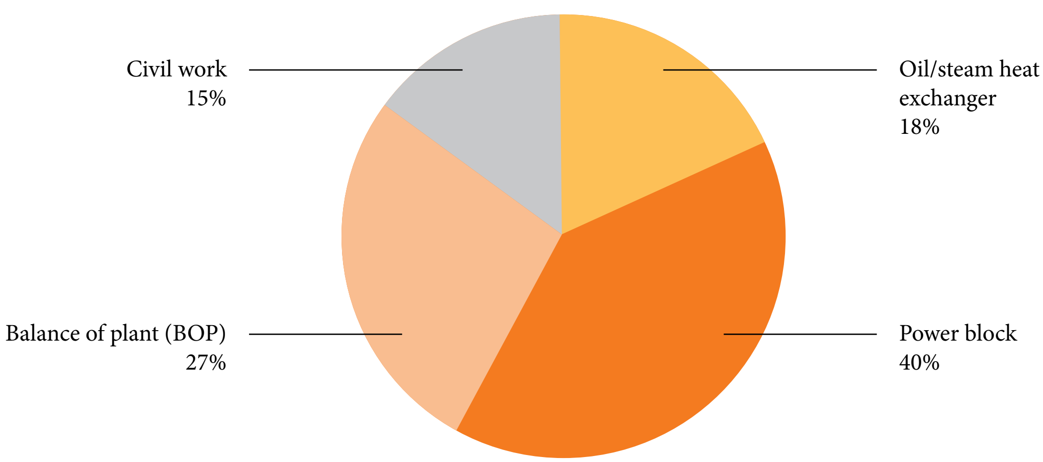


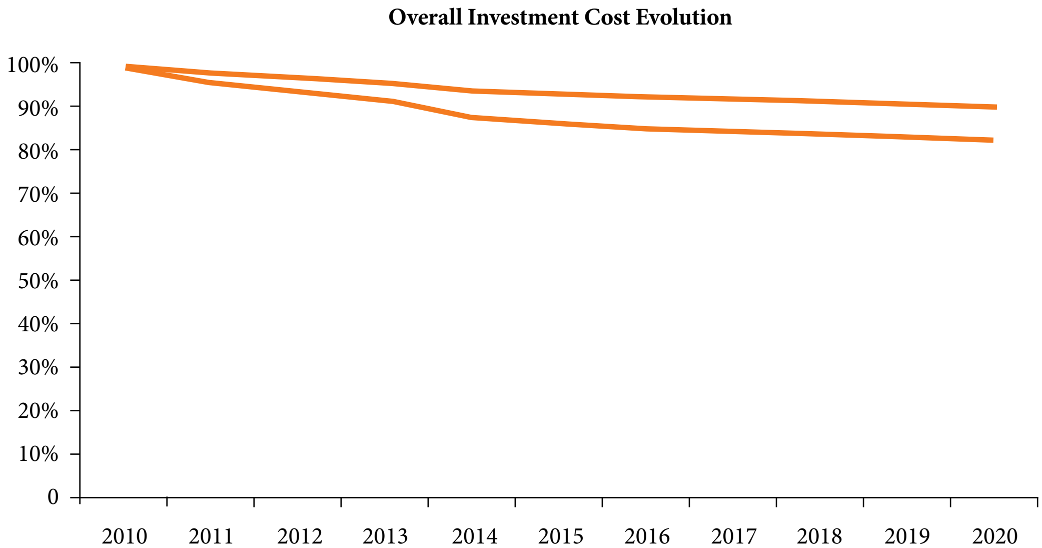
Figure 34:
Cost Breakdown for the Electrical Conversion System for the Reference Power Plant



Overall Investment Cost Evolution

The overall investment cost is expected to experience a cost reduction between 11 percent and 19 percent by 2020, as can be seen in Figure 35.

Figure 35:
Overall Investment Cost Evolution for the Power Tower Technology



Main factors considered for the estimation of the cost evolution are summarized in Table 61 below.

Table 61:
Summary Table of the Main Factors Considered for the Estimation of the Cost Evolution for CR Technology

Subsystem	Component	Decrease factor	Mid term cost decrease potential	Long-term cost decrease potential
Solar collection	Mirror assemblies	New mirror concept	8–10%	18–22%
	Support structures	Mass production and material savings	12–20%	25–30%
		Standardization (breakthrough)	6–12%	—
	Drive mechanism	Experience curve	P.R. = 85–87%	
Thermal conversion	Heat collection elements	Operational improvements: glass to metal seal.	15–20%	
		Size increase (breakthrough)	15%	—
	Oil/water heat exchangers	Experience curve	P.R. = 75–85%	
Thermal storage	Molten salts	Thermocline concept	20%	—
	Fluid handling system	Thermocline concept	10%	—
Electrical conversion	Power block	Experience curve	P.R. = 99–100%	
	BOP	Experience curve	P.R. = 90–95%	

Source: CENER, 2011

Cost Evolution Detailed by Subsystem

- **Mirror assemblies**
  Glass-silver mirror technology has been used for a long time. This means that the important cost reduction related to this technology is negligible. Only cost reductions related to a new mirror expertise could be considered. This means the introduction of new materials (aluminum, polymeric) in the market, some of which are already under development and testing. Main barriers experienced by these new designs are related to the degradation of the materials, but it is expected that, in the period analyzed, these problems will be mostly solved. The cost reduction related to a new mirror concept is estimated around 8–10 percent for a midterm and around 18–22 percent for a long term, taking into account both the material cost and savings related to the manufacture processes.

- **Support structure**
  Cost reduction associated to trough support structure is expected to be related mainly to two factors: On the one hand, structures are expected to experience a weight reduction that would lead to material savings of between 5 and 10 percent of the current weight. This advance is expected to have a great impact in manufacture costs, and the impact can be estimated in reference to the lessons learned from the automobile sector. This way, cost reductions have been estimated to experience an effect in short/midterm (2015) of 12–20 percent of the current support structure cost reaching up to 25–30 percent by 2020. On the other hand, the standardization will play an important role in this technology. Up to now, there is a lack of regulation and law according to standardization of this technology. With the appearance of a CSP regulation, which establishes the design criteria of structure designing, conservative stands in component design can be avoided. This also happened with other renewable energies. It is interesting to remark that two current collector designs show a difference close to 15 percent in the wind loads assumed for the structure design. This standardization is estimated to entail an additional cost reduction near to 6–12 percent in the structure cost reduction for a midterm.

- **Other components of the solar collection subsystem**
  The rest of the elements included in the solar collector system are not expected to have remarkable cost reductions. The trough drive mechanism is expecting a cost reduction as a consequence, mainly, of the experience curve. For this component, a progress ratio of 85–87 percent can be expected. Neither will the rest of the components and labor work contemplated experience a noteworthy cost decrease.

- **Heat collection elements**
  The most significant awaited cost reduction of the heat collection element is related to the increase in their length. However, up to now, receiver tubes have a dimension that could be defined as "standardized," since every commercial collector design has been intended in relation to these HCE dimensions. That is why, for short- or midterm estimation, this possibility is not being considered. Furthermore, an increase in the diameter will imply a proportional increase of the mirror aperture, as well as its length, so this cost reduction cannot be applied only to receiver tubes, since it also leads to a redesign of the whole solar collector assembly. This possible action line is expected to have an impact

of 15 percent of the heat collection element's current investment costs. However, it has to be remarked that this change would affect not only the heat collection element, but also the design of the whole solar collector. For a global estimation, this measure could imply up to 7 percent decrease of the whole plant investment costs. Other factors to be considered are mainly related to specific improvements, like the glass to metal seal. Nowadays the technology used for this seal is complicated and thus expensive. This cost reduction is estimated as a consequence of advances in this manufacture technology. It is also possible to have a cost reduction derived from the use of heat collection elements of different characteristics in some field areas working at a lower temperature. Less sophisticated receiver tubes can be implemented in certain places of the solar field getting an associated cost reduction.

- **Other components of the thermal conversion subsystem**
  Other elements included in this system, mainly related to the heat transfer fluid and its handling system, will not experience remarkable cost reductions. Synthetic thermal oil has been used for a long time, so a remarkable cost reduction is not being expected. A change in the working fluid would be the only breakthrough to be expected. However, this change would mean a complete cost analysis different from the current reference situation, as a new plant configuration will be needed having a great impact in investment costs. However, considering the plant as a whole, a replacement of the current working fluid into molten salts could decrease the total plant cost around 20 percent in a midterm, increasing the efficiency up to 6 percent. In the case of implementing direct steam generation technology, this change would lead to a cost reduction of around 4 percent, reaching an efficiency total increase of the plant around 7 percent. Otherwise, evolution of heat exchangers has been considered an experience curve with a progress ratio of 75–85 percent.

- **Thermal storage**
  In a mid- to long term (2015), it is expected that the current storage system configuration of two tanks of molten salts will evolve to only one thermocline storage tank, a concept currently being developed. Even if this change would mean a change in the technology of the current reference power plant, it has been handled as a breakthrough. The thermocline tank concept will cause a reduction in the amount of molten salts needed, with an expected impact in cost reduction around 20 percent. The molten salts forwarding skid, including pumps, piping, tanks, and other elements needed in the system, will also have an impact associated to the reduction of the molten salts quantity. Some elements will experience a cost reduction proportional to the storage medium, like storage reservoirs, but other elements are not directly related. It has been estimated an impact of 10 percent for the fluid handling system.

- **Electrical conversion**
  Electric conversion system is mainly composed of conventional components with a large experience, so the primary reduction costs considered are mainly related to the experience curve related to power block and balance of plant. The progress ratio considered is the same as the case of the linear Fresnel reflector technology, so the same considerations can be applied.

C. Power tower technology

Table 62:
Investment Costs for the 17 MW CR Plant with 15 Hours Thermal Storage

CONCEPT	COST (US$ million)	COST (Rs crores)
Solar collection system	86.8	383.7
Mirrors	5.2	23.1
Support structures	36.6	161.7
Drive mechanisms	26.5	117.1
Land leveling	4.6	20.2
Foundations	3.0	13.5
Assembly	8.7	38.5
Assembly facility	2.2	9.6
Thermal conversion system	58.3	257.8
Heat exchange fluid (molten salts)	8.8	38.7
Solar receiver	36.0	159.3
Mechanical system (piping, salts pumps)	5.0	22.1
Fire protection system	0.8	3.4
Inertization system	0.4	1.9
Natural gas boilers	1.5	6.8
Civil work: receiver tower	5.8	25.6
Thermal storage system	71.5	316.0
Storage medium (molten salts); N/A: Included in receiver	0.0	0.0
Molten salts forwarding skid (tanks, pumps, piping)	5.4	23.8
Heat exchangers. N/A	0.0	0.0
Initial filling system	0.5	2.3
Civil work	1.3	5.7
Electrical conversion system	50.9	225.0
Heat exchangers salts/steam	7.0	30.9
Power block	20.3	89.9
Balance of plant (BOP)	15.7	69.2
Civil work	7.9	34.7
Project management and EPC	34.0	150.4
Project management	3.0	13.5
EPC (15%)	30.9	136.7
TOTAL	237.2	1048.4

Source: CENER, 2011

Table 63:
Investment Costs for the 17 MW CR Plant without Thermal Storage

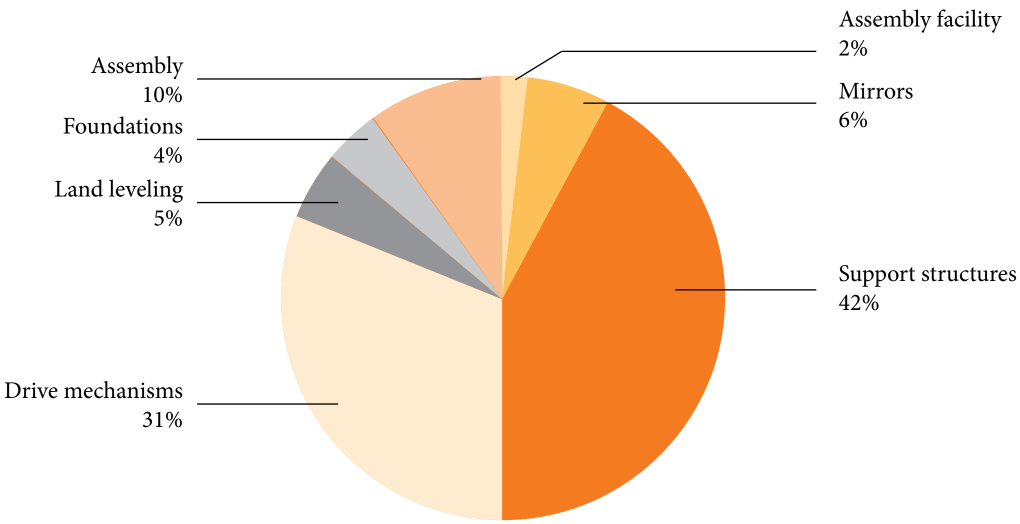
CONCEPT	COST (US$ million)	COST (Rs crores)
Solar collection system	32.3	142.8
Mirrors	1.9	8.6
Support structures	13.6	60.3
Drive mechanisms	9.9	43.7
Land leveling	1.7	7.5
Foundations	1.1	5.0
Assembly	3.2	14.3
Assembly facility	0.8	3.6
Thermal conversion system	49.9	220.6
Heat exchange fluid (molten salts)	0.3	1.2
Solar receiver	36.0	159.3
Mechanical system (piping, salts pumps)	5.0	22.1
Fire protection system	0.8	3.4
Inertization system	0.4	1.9
Natural gas boilers	1.5	6.8
Civil work: receiver tower	5.8	25.6
Thermal storage system	0.1	0.6
Storage medium (molten salts). N/A: included in receiver	0.0	0.0
Molten salts forwarding skid (tanks, pumps, piping)	0.2	0.8
Electrical conversion system	50.9	225.0
Heat exchangers salts/steam	7.0	30.9
Power block	20.3	89.9
Balance of plant (BOP)	15.7	69.2
Civil work	7.9	34.7
Project management and EPC	22.3	98.6
Project management	2.0	8.8
EPC (15%)	20.3	89.7
TOTAL	155.6	687.6

Source: CENER, 2011

Cost Breakdown by Subsystem

- **Solar collection**
  A solar collection system can be very different from a specific power tower plant to another. The current case has fixed a specific solar field according to the Gemasolar power plant, which considers a circular plant layout with heliostats of the Senertrough design. With these characteristics, the breakdown of to the solar collection system is shown in Figure 36.

Figure 36:
Cost Breakdown for the Solar Collection System of the Reference Power Tower Plant



As it can be observed, the major fraction from the costs of the solar collection system is associated with the support structure of the solar collector assembly, corresponding to a percentage of 42 percent. In the second place, drive mechanisms represent 31 percent of the system. It is interesting to observe that mirrors only represent a 6 percent of the whole system, almost a third of the fraction that this component represented in parabolic trough (16 percent). This is a consequence of the curvature process carried out in the parabolic trough technology that adds an additional cost as a consequence of the bending process.

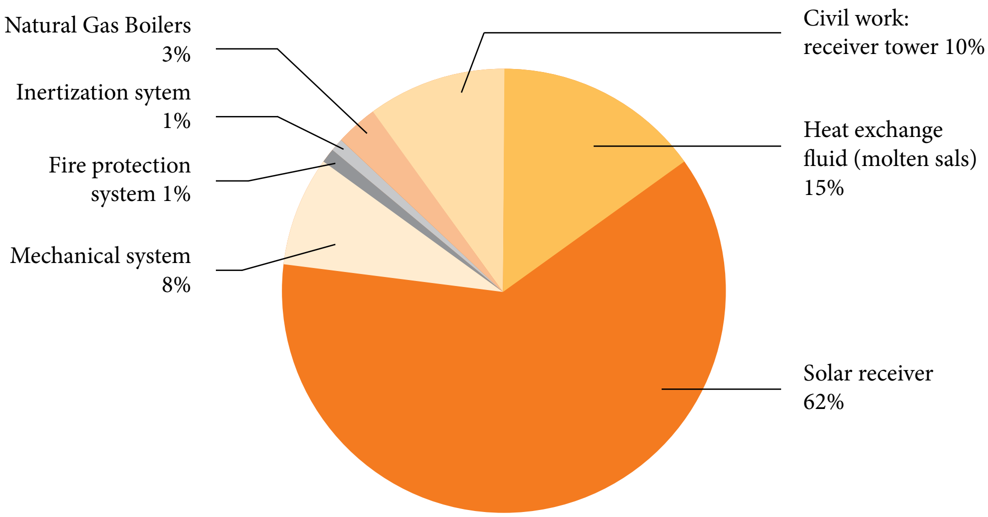
- **Thermal conversion**
  Thermal conversion of a power tower plant has not many things in common with the already analyzed linear Fresnel reflector technology and parabolic trough technology. The solar receiver is a unique element for the whole solar collection system which is located atop a tower. This implies some new considerations:

  – There is a new element included in this system, derived from the need to have the receiver at a high distance from the ground: the receiver tower. This adds new investment costs related not only to new material, but also to building work.
  – Heat exchange fluid has been replaced by salts, with a lower cost than synthetic oil.
  – The need to pump the new thermal fluid to the receiver, located in the top of the tower, implies new and more powerful equipment (pumps as well as piping, valves, for example). However, auxiliary equipment is not implemented in the solar field because the working fluid does not flow across, as happened in the parabolic trough.

The breakdown related to the thermal conversion system is shown in Figure 37.

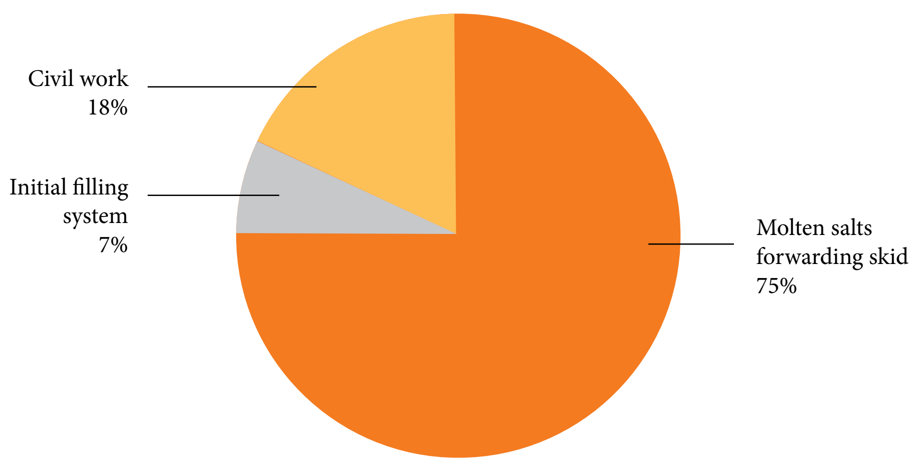
As it can be observed, the solar receiver has an important weight of the thermal conversion system (62 percent).

Figure 37:
Cost Breakdown for the Thermal Conversion System of the Reference Power Tower Plant



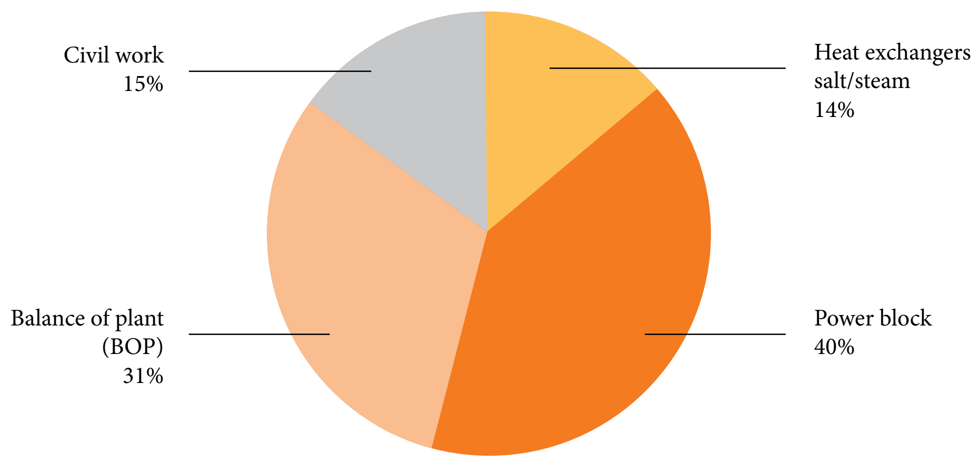
- **Thermal storage**
  The thermal storage system considered in the current case is also a two-tank molten salts storage system. The main difference to be noted in this case in comparison to the previous cases is that no heat exchanger is needed. In this case, the storage medium (molten salts) has not been included in the thermal storage system, since it is the same as the heat transfer fluid considered in the solar collection system.

Figure 38:
Cost Breakdown for the Thermal Storage System of the Reference Power Tower Plant



- **Electrical conversion**
  Electrical conversion system has no special remarks to point out. The main difference of this case in comparison to both cases already analyzed is the heat exchanger. Linear Fresnel reflector technology has no need for a heat exchanger, since it operates with direct steam generation, and parabolic trough has implemented an oil/steam heat exchanger. The current case also needs a heat exchanger, but in this case, the technology used is a salts/steam heat exchanger.

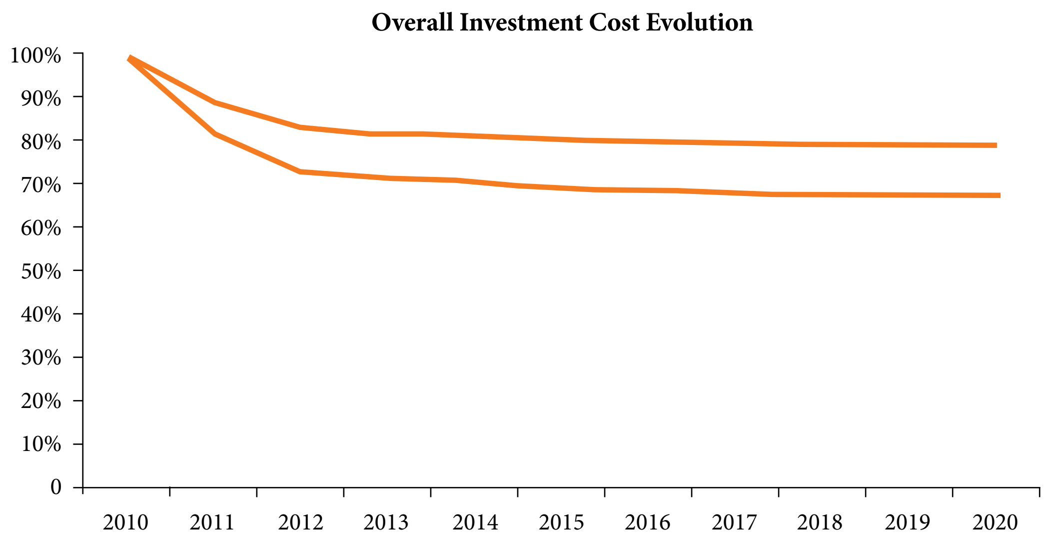
Figure 39:
Cost Breakdown for the Electrical Conversion System of the Reference Power Tower Plant



Overall Investment Cost Evolution

The overall investment cost is expected to experience a cost reduction between 21 percent and 33 percent by 2020, as can be seen in Figure 40.

Figure 40:
Overall Investment Cost Evolution for the Power Tower Technology



Main factors considered for the estimation of the cost evolution for Power Tower technology are summarized in Table 64.

Table 64:
Summary Table of the Main Factors Considered for the Estimation of the Cost Evolution for CR Technology

Subsystem	Component	Decrease factor	Midterm cost decrease potential	Long-term cost decrease potential
Solar collection	Mirror assemblies	New mirror concept	4–5%	6–8%
	Support structures	Mass production and material savings	15–18%	17–20%
		Standardization (breakthrough)	6–12%	—
	Drive mechanism	Experience curve	P.R. = 85–87%	
Thermal conversion	Solar receiver	Experience curve	P.R. = 90–95%	
		Molten salts/water heat exchanger	Experience curve	P.R. = 75–85%
	Oil/water heat exchangers	Experience curve	P.R. = 75–85%	
Thermal storage	Molten salts	Thermocline concept	20%	—
	Fluid handling system	Thermocline concept	10%	—
Electrical conversion	Power block	Experience curve	P.R. = 99–100%	
	BOP	Experience curve	P.R. = 90–95%	

Source: CENER, 2011

Cost Evolution Detailed by Subsystem

- **Mirror assemblies**
  Similar considerations can be made to this component in comparison to the other technologies. Only cost reductions related to new mirror knowledge could be taken into account. The cost reduction related to a new mirror concept is estimated around 4–5 percent for the midterm and around 6–8 percent for the long term, similar to the linear Fresnel reflector technology.

- **Support structure**
  Cost reduction associated to support structure is expected to be associated to the same factors as already explained in the parabolic trough technology. Even if the impact related to the standardization is considered the same as in linear Fresnel reflector technology, cost reduction related to weight reduction and mass production is expected to have an effect of around 15–18 percent by 2015 and 17–20 percent by 2025. The breakthrough caused by standardization has also been considered in the range of 6–12 percent.

- **Other component of the solar collection subsystem**
  The rest of the elements included in the solar collection system are not expected to have remarkable cost reductions. The trough drive mechanism is expecting a cost reduction as a consequence, mainly, of the experience curve. For this component, a progress ratio

of 85–87 percent can be expected. Neither will the rest of the components and labor work contemplated experience a noteworthy cost decrease.

- **Heat collection elements**
  The solar receiver implemented in the current case consists mainly of stainless steel tubes, where molten salts flow through and absorb the radiation of the solar field. Hence, no special cost reductions are expected, so an experience curve of 90–95 percent has been considered.

- **Other components of the thermal conversion subsystem**
  The rest of the elements are not expected to experience big changes. Heat exchanger has been considered with a similar evolution to the respective case in parabolic trough technology. An experience curve of 75–85 percent progress ratio has been adjusted. For the rest of the equipment, typical progress ratios are given, too, for their respective experience curves. The most different element included in this system in comparison with the other technologies studied is the receiver tower. However, this element is a typical construction with extensive experience in sectors related to big infrastructures. Therefore, its expected cost evolution can be considered negligible.

- **Thermal storage**
  Similar considerations can be made for this system to those already mentioned in the parabolic trough section. The thermocline tank concept, in case it will be implemented, will cause a reduction in the amount of molten salts needed, and will cause an expected impact in cost reduction around 20 percent. The rest of the equipment will experience a cost reduction of 10 percent.

D. Parabolic Dish Technology

Table 65:
Investment Costs for the 10 MW PD Plant without Thermal Storage

CONCEPT	COST (US$ million)	COST (Rs crores)
Solar collection system	20.9	92.3
Mirrors	2.3	10.1
Support structures	8.1	36.0
Drive mechanisms	5.1	22.8
Mechanic assembly	2.6	11.4
Land leveling	0.5	2.4
Foundations	0.4	1.6
Assembly	1.5	6.7
Assembly facility	0.3	1.1
Plant infrastructure	9.2	40.4
Electrical equipment assembly	3.0	13.3
Electric infrastructure	4.9	21.5
Lighting, safety and lightning conductor	0.5	2.2
Transformer station civil works	0.8	3.3

Cont...

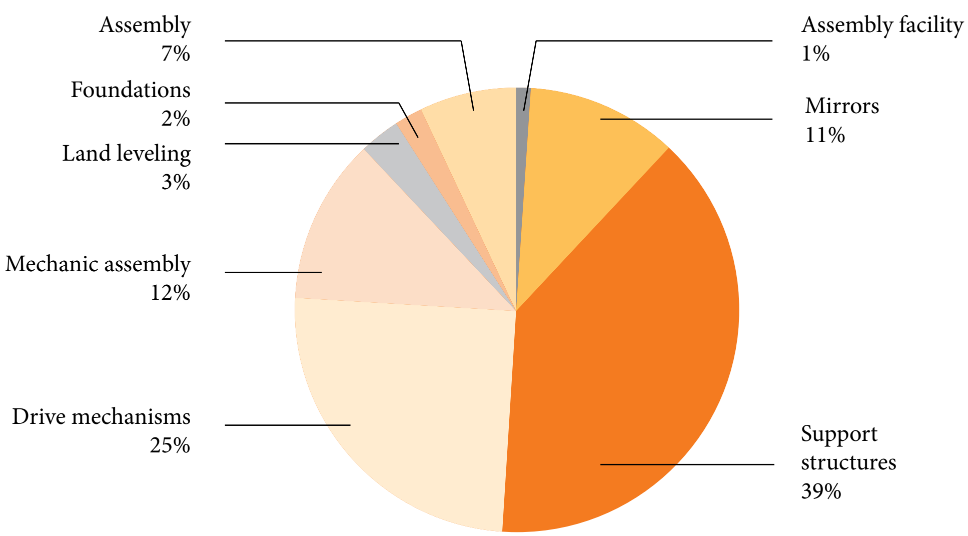
CONCEPT	COST (US$ million)	COST (Rs crores)
Thermal and electrical conversion system	42.6	188.3
Receiver-electric motor	34.3	151.7
BOP	8.3	36.6
Project management and EPC	11.7	51.8
Project management	0.7	3.2
EPC (15%)	11.0	48.6
TOTAL	84.2	372.2

Source: CENER, 2011

Cost Breakdown by Subsystem

- **Solar collection**
  For this subsystem, the cost analysis carried out can be observed in Figure 41.

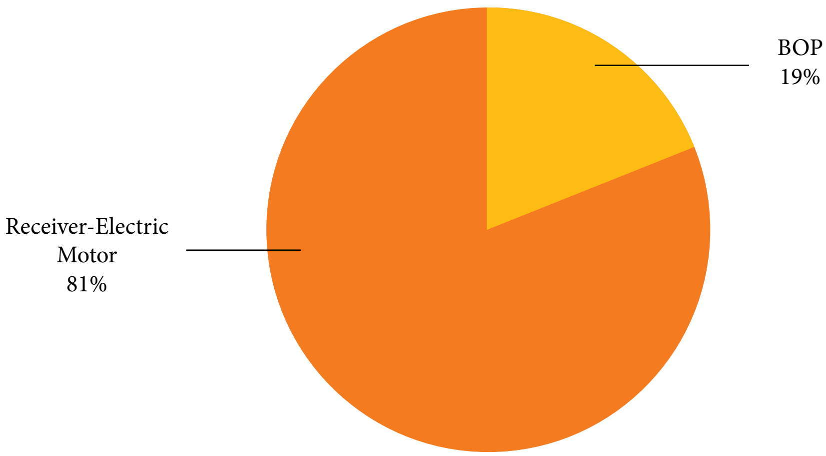
Figure 41:
Cost Breakdown for the Solar Collection System of the Dish Stirling Reference Power Plant



As it can be observed, the component that means the major percentage of the solar collection system is the support structure (39 percent).

- **Thermal and electrical conversion**
  This system has been divided into only two groups of components. In the first one, the joint of the thermal receiver and the Stirling motor have been gathered. In the second group, the auxiliary elements that are needed (such as a cooling system) have been included. The cost breakdown is shown in Figure 42.

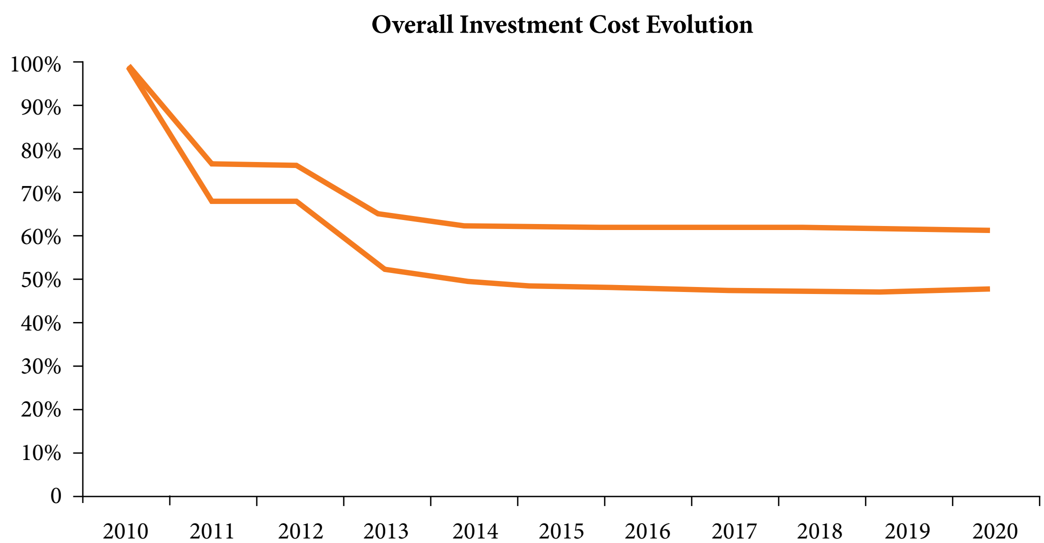
Figure 42:
Cost Breakdown for the Thermal and Electrical Conversion Systems of the Dish Stirling Reference Power Plant



Overall Investment Cost Evolution

The overall investment cost is expected to experience a cost reduction between 39 percent and 53 percent by 2020, as it can be seen in Figure 43.

Figure 43:
Overall Investment Cost Evolution of the Dish Stirling Technology



Main factors considered for the estimation of the cost evolution for dish Stirling technology are summarized in Table 66.

Table 66:
Summary Table of the Main Factors Considered for the Estimation of the Cost Evolution for PD Technology

Subsystem	Component	Decrease factor	Midterm cost decrease potential	Long-term cost decrease potential
Solar collection	Mirror assemblies	Process' automation and mass production	20–25%	35–40%
	Support structures	Mass production and material savings	17–20%	25–28%
		Standardization (breakthrough)	6–12%	—
Solar to electrical energy conversion	Receiver-electric motor and BOP	Experience curve	P.R.=90–95%%	

Source: CENER, 2011.

Cost Evolution Detailed by Subsystem

- **Mirror assemblies**
  Investment costs related to mirror assemblies are expected to experience a considerable decrease. Up to now, this technology has been scarcely developed and a wide margin in improvement of this component can be foreseen. It has been estimated that process automation and mass production will be able to get a decrease of around 20–25 percent in a midterm, and around 35 percent and 40 percent in a long term.

- **Support structure**
  The support structure will follow the same trend as the rest of the technologies. That means that a breakthrough caused by the standardization will reduce the costs in 2015 around 6–12 percent, and an additional cost reduction related to material savings and other factors is estimated around 17–20 percent in the midterm, and 25–28 percent in the long term.

- **Solar to electrical energy conversion**
  Because of the lack of information, it is not easy to make an estimation of the economical evolution of this system. However, the power block, consisting mainly in the Stirling engine, is a technology known for decades, and it is considered as a mature system. For the current systems, the cost evolution will be considered an experience curve of 90–95 percent progress ratio.

Appendix 8. Approach to Data Research and Modeling

A. Primary Research

Methodology

A significant portion of the study was devoted, through primary research, to understanding the capability and maturity of the different value chain players, as well as the market dynamics that are expected to emerge over the three phases of JNNSM. Detailed questionnaires to capture important market and organization specific parameters were developed and administered with the target companies. The primary research aimed to gather as much information as possible through face-to-face interactions with the senior management of the target organizations. Most of the questions were intentionally kept qualitative and open ended to encourage detailed discussion on the subject. The responses were tabulated and converted into quantitative values wherever possible, and further analyses were performed on those quantitative values to arrive at various indicative numbers that are presented throughout the report.

The questionnaire contained questions related to both internal and external factors, which are supposed to play a major role in the overall success of JNNSM, of the target organization (Table 67):

Table 67:
External and Internal Factors Considered at the Questionnaire

Internal factors	External factors
1. Client Information	1. Social and Political Factors
2. Organization	2. Economic Factors
3. Supply Chain	3. Technology Factors
4. Cost	4. Legal and Environmental
5. Competency	5. Factors

For complete details of the questionnaire that was administered, refer to Appendix 1.

Table 68 gives a summary of the number of value chain players who had participated in the primary research. For a complete list of companies in each value chain segment, refer to sections below.

Table 68:
Number of Value Chain Players Involved in the Primary Research

Value Chain Player	No of organizations
Developers	5
EPC players	2
Technology providers	3
Component manufacturers—heat exchangers	1
Component manufacturers—turbines	2
Component manufacturers—mirrors/receiver tubes	5
Component manufacturers—tracking & drive mechanism	2
Component manufacturers—HTF	2
Component manufacturers—HTF pumps	2
Component manufacturers—support structures	1
Component manufacturers—glass bending equipment	1
Government body	1
Academic/research institution	3

In general, inputs from them were immensely beneficial in understanding the minimum market potential, cost numbers for setting up CSP plants in India, potential for cost reduction through localization of production, and supplier ecosystem development, as well as the impact on the Indian economy. It also helped in understanding the current capability of individual players in CSP value chain, the target cost numbers for Indian developers, both at an overall and at a component level, the levers for cost reduction in India for CSP manufacturing, and the expectation of the value chain players from the government in developing the overall market.

All the calculations arrived at using the responses from the primary survey are for installed capacity per MW. No calculations have been made on electrical production.

It is important to keep in mind that, when talking about costs per MW, we also have to consider the characteristics of the plant analyzed, concerning not only the type of technology implemented, but also the hours of storage, for example. The final cost per MW, as well as the final production per year, may differ depending on the final plant configuration and technology used.

The Indian scenario and the development in Phase I of JNNSM consider CSP power plants without thermal storage in order to calculate the investment numbers per MW, market size, and economic and labor impact.

Primary Survey Questionnaire

Cost Factors:

Capital investment	What is minimum capacity required for a new plant? What is the capital investment needed?
Cost breakup	What is the approximate cost breakup for the component? What are the main direct and indirect costs? Is the process labor intensive?
	Raw materials form what percentage of the sales value? Where are these sourced from?
	Conversion costs form what percentage of the sales value?
Cost per unit	What is the approximate cost per unit of the CSP component made by you?
	What is the extent of cost reduction per unit that can be expected with mass manufacturing in future years for the CSP components?
Modification cost	Do you have additional line capacities? Can you modify them to manufacture CSP components? What are the costs involved in this modification?
Issues and challenges	What are the main cost drivers? What are the challenges in keeping the main cost drivers down?

Competency Factors:

Core competency	What is your main competency? What are the characteristics of your competency? Is it based on flexibility, speed, precision, and reliability?
Substitutes	Do you have competitors who share similar competencies? How do you distinguish yourself from them?
Adaptability for CSP	How easily can you tap into your core competency for CSP component manufacturing? Do you expect any synergies between the new setup and products you manufacture?
International collaboration	Do you have collaboration with international players for R&D and technology transfer activities? If yes, can you name a few?
Manpower skills	What kind of skills do you need to develop within your employees to manufacture CSP components?
Equipment upgrades	Do you need significant equipment upgrades in your current setup to manufacture CSP components? If yes, what kind of upgrades are required?

Risk Factors:

Business risk	What risks are involved in CSP component manufacturing? (Inadequate demand, demand variability, changing technology, competition from foreign players, lack of standardization, for example.)
Demand projections	Do you have any demand projections for the CSP components? Does this also include export potential? What is the minimum market demand that you are targeting to invest in the CSP component manufacturing?
Incentives	What are the various incentives for CSP component suppliers? Do they get any carbon credits?
Financing the projects	What are various sources of attractive financing for CSP component manufacturing for developing their potential?
Project feasibility	What is your expected rate of return on this project? What is your time horizon?
Equipment upgrades	Do you need significant equipment upgrades in your current setup to manufacture CSP components? If yes, what kind of upgrades are required?

Political and Social Factors:

Political	
Procedural issues	What are the hurdles commonly faced while bidding for the project and implementing it?
Regulation and deregulation trends	Has government changed its stance on regulations in the nonconventional energy domain in the past? What were the reasons for the change? What has been its impact?
Social and employment legislation	Is there any legislation specified for solar project component manufacturers?
Tax policy, and trade and tariff controls	What kind of provisions has been made available by the government to increase the attractiveness for investment in solar power? (For example, feed-in tariffs, discount in tariffs, income tax rebate, accelerated depreciation, and import duties.)
Environmental and consumer protection legislation	Please state if any.
Likely changes in the political environment	State whether you perceive any change in the business environment in case of a change in political environment.
Social	
Education and occupations	Likely job creation by investment per MW? Education and awareness benefits?
Media views and publicity	Benefits from CSR activities? Media's role to popularize solar power?

Technology Factors:

Key technology	What are the key technologies that you would need to make the CSP component manufacturing viable in India? Can this technology be used for large-scale production? Do you know the industries that will be helpful in developing the technology further?
Support	Do you have any support from the government or other Indian or international players to develop CSP manufacturing potential within India?
Access	Do you have the access to relevant technology, patents, licenses, IPRs , and manufacturing techniques needed for manufacturing of CSP components?
Equipment upgrades	Do you need significant equipment upgrades in your current setup to manufacture CSP components? If yes, what kind of upgrades are required?

Supply Chain Factors:

Manufacturing environment	Products are in which of the following manufacturing environments? For example, made to stock, assembled to order, made to order, engineer to order? Please elaborate. Please give percentage revenue contribution from each manufacturing environment related to CSP components.
Complete supply chain for CSP component	Can you describe the supply chain for a CSP component category?
	Where are the factories located for manufacture?
	Where are the key raw materials sourced from—locally and abroad?
Issues and challenges	What are the key supply chain issues and challenges faced for CSP components? Please elaborate.

Table 69:
List of Companies Interviewed

WHO IN THE INDUSTRY	Company Name	Base Location
Developer	Acme Tele Power limited	Gurgaon
Developer	Entegra Limited	Mumbai
Developer	Lanco Infratech Limited	New Delhi
Developer	Aurum Renewable Energy Pvt Ltd	Mumbai
Developer	Godavari Power	Raipur
EPC Player	L&T	Mumbai
EPC Player	BHEL	Delhi
Technology provider	Abengoa Solar	Mumbai
Technology provider	Areva Solar	Delhi
Technology provider	Clique Developments Pvt. Limited	Mumbai
Heat exchangers	Thermax	Pune
Turbines	BHEL	Delhi
Turbines	Maxwatt	Delhi
Mirrors	Saint Gobain	Chennai
Mirrors	Gujarat Guardian India Ltd	Ankleshwar
Mirrors	AIS Glass (Potential)	Mumbai
Government body	MNRE	New Delhi
Academic institution	IIT Bombay	Mumbai
Industry association	FAST	
Research institution	NAL	Bangalore
Receiver tubes	Schott	
Mirrors or receiver tubes	Borosil(potential)	Mumbai
Tracking and drive mechanism	Boschrexroth	Mumbai
Tracking and drive mechanism	Parker Hanifinn	Mumbai
HTF	Dow Chemicals	Mumbai
HTF	Solutia Chemicals	Mumbai
HTF pumps	KSB India	Pune
HTF pumps	ITT India	Mumbai
Support structures	Kalpataru Power Transmissions Limited (potential)	
Glass bending equipment	Glasstech	

B. Scenario Modeling for CSP in India

Economic benefit of JNNSM was modeled using three scenarios that can emerge over the lifespan of the mission. In the case of complete target achievement per mission, the phase-wise capacity additions will happen, as shown in Table 70.

Table 70:
Phase-Wise Capacity Additions for CSP Technologies in India, Optimistic Scenario

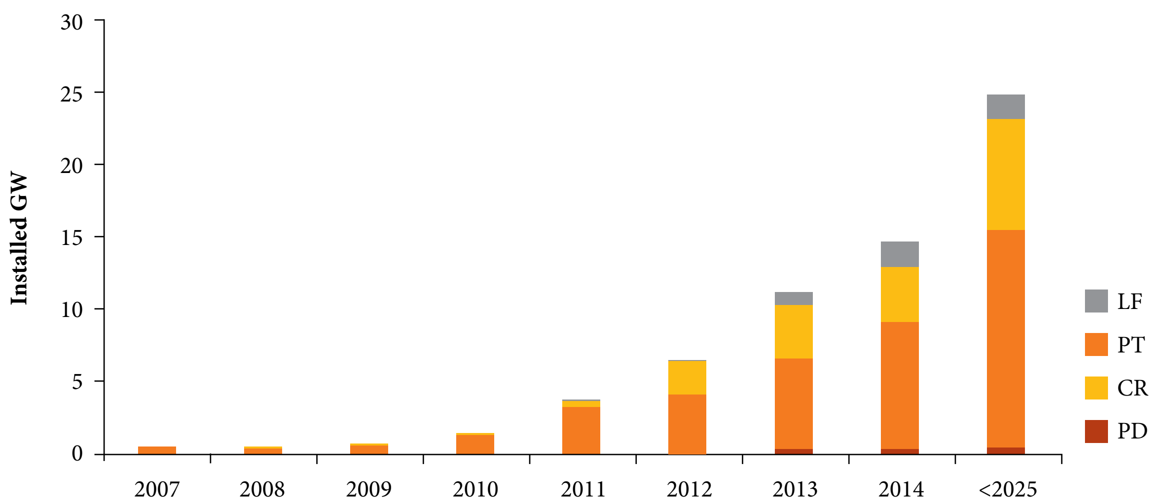
DESCRIPTION	PHASE I (2010–13)	PHASE II (2013–17)	PHASE III (2017–22)
Cumulative JNNSM targets for CSP (MW)	500	2,000	10,000
Capacity additions (MW)	500	1,500	8,000
CR market size(MW)	10	495	2,800
PT market size(MW)	490	1,005	5,200

Source: CENER; AQUA MCG, 2011.

Capacity addition for each phase was calculated using the additional capacity commissioned in that phase over and above the installed capacity from the previous phase. Considering the global trends, Table 74 also considers CR a commercially successful technology for CSP in the future.

The ratio of PT to CR in the overall capacity addition in Table 71 was derived from the assumptions of CENER and Emerging Energy Research. Figure 44 gives a breakup of the different technologies in CSP installed GW until 2025.

Figure 44:
Pipeline of the Different Technologies until 2025



Source: CENER; Emerging Energy Research 2010.

Annual capacity additions in MW per year were calculated using a straight line method, assuming that JNNSM was implemented successfully. Table 71 describes capacity addition per year over the three phases of JNNSM. Table 71 also assumes that 2,000 MW of capacity will be built for export in Phase III.

Table 71:
Capacity Addition per Year over the Three Phases of JNNSM

DESCRIPTION	PHASE I (2010–13)	PHASE II (2013–17)	PHASE III (2017–22)
Total capacity additions (MW)	167	375	1,600
CR market size(MW)	3	124	560
PT market size(MW)	163	251	1,440
PT market size(MW)	490	1,005	5,200

Source: CENER; AQUA MCG, 2011.

Considering the above factors, the three scenarios in Table 72 have been considered for analysis.

Table 72:
Scenarios Considered for the Analysis

DESCRIPTION	INSTALLED CAPACITY IN 2022 (MW)	EXPORT MARKET DEMAND IN 2022 (MW)
Scenario A (Pessimistic)	2,000	0
Scenario B (Moderate)	6,000	0
Scenario C (as per JNNSM, Optimistic)	10,000	2,000

Source: CENER; AQUA MCG, 2011.

Optimistic Scenario C:
JNNSM is achieved as intended and a total of 10 GW of CSP is installed by the year 2022.

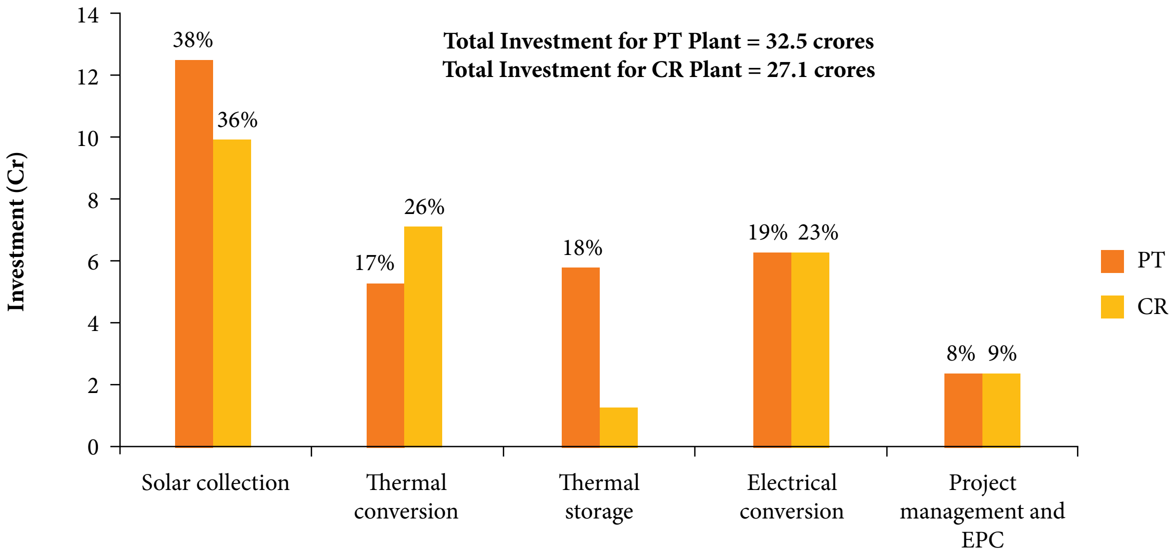
Moderate Scenario B:
60% of JNNSM targets are achieved by the year 2022.

Pessimistic Scenario A:
20% of JNNSM targets are achieved by the year 2022.

In order to calculate the economic impact, investment costs have been estimated for a reference plant of 100 MW capacity and 8 hours of thermal storage as follows (investment costs are given in crores/MW).

It should be kept in mind that CR technology has been incorporated, since it is globally considered a more advanced and promising technology. However, since there is only one CR plant being setup in India, which is of a very small size (10 MW), the cost estimates given are very approximate and are based on similar plants in other parts of the world.

Figure 45:
Investment Costs Breakdown by Subsystem for PT and CR Power Plants in Terms of Percentage



Source: CENER; AQUA MCG, 2011.

C. Estimation of Minimum Demand Requirement

While JNNSM outlines the planned capacity addition over the three phases, that itself is not a sufficient condition for indigenization of certain technologies and local manufacturing of components. Subsequently, at what point global manufacturers and suppliers will invest in a local manufacturing facility (minimum demand expectation, Figure 5) was estimated from the primary research, as outlined in Section 1 of this appendix.

Following questions were asked to the component manufacturers to understand their expectation for local manufacturing setup (under "Economic Factors" in the questionnaire):

Risk Factors:

Business risk	What risks are involved in CSP component manufacturing? (For example, inadequate demand, demand variability, changing technology, competition from foreign players, and lack of standardization.)
Demand projections	Do you have any demand projections for the CSP components? Does this also include export potential? What is minimum market demand that you are targeting to invest in the CSP component manufacturing?
Incentives	What are the various incentives for CSP component suppliers? Do they get any carbon credits?
Financing the projects	What are various sources of attractive financing for CSP component manufacturing for developing their potential?
Project feasibility	What is your expected rate of return on this project? What is your time horizon?

Averages of the above minimum demand numbers were taken and plotted against technology complexity to show the minimum demand requirements for localization of component production in Figure 5.

Table 73:
Tabulated Results of the Questions Asked to Component Manufacturers

Component or Material	Local Manufacturing Capability	Min requirement	Cumulative Target for Phase III (2017–22)
Turbines	3	100–110	5
Structures-CR	4	50	3
Structures-PTC	4	50	4
Solar steam generators	4	50	2.5
Molten salts	2	25	1.5
Receiver tube-LF	3	100	4
Mirrors PTC- partial manf.	4	140–160	2.5
Receiver tube-PTC	1	200–220	5
Mirrors flat-CR	3	200–225	2
Mirrors PTC-complete manf.	2	300–350	4
Tracking devices PTC	2	450–500	4
Tracking devices CR	1	500–600	3.2
HTF	2	500	3.5

D. Estimation of Market Size and Cost Reduction Potential

Market size for CSP components were estimated using the planned capacity additions over the three phases on a yearly basis, and the estimated cost of components per MW—derived based on inputs from manufacturers, component suppliers, and developers, as gathered from the primary research detailed above. Estimated cost of components per MW was taken as the average value of all the cost numbers for the upcoming plants in JNNSM Phase I.

Table 74 summarizes the cost reduction potential over the years as expected by different values chain players in the market and per megawatt cost for Indian plants over the three phases of the JNNSM.

Table 74:
Expected Percent Cost Reduction in Phase II and Phase III

COMPONENT	PHASE I (2010–13)	PHASE II (2013–17)	PHASE III (2017–22)
Structures—PTC		20	40
Structures—CR		10	10
Solar steam generators		27	27
Mirrors—parabolic		27	27
Mirrors—flat		0	11
Tracking devices—CR		0	30
Tracking devices—PTC		0	38
HTF		0	0
Receiver tube		0	32
Turbines		27	27

This cost reduction is due to Local Manufacturing, Logistics Savings, Customs Duty Savings and IP. They value depict the average value of responses in primary survey.

Accordingly, component-wise cost per MW for Phase II and Phase III of the JNNSM was projected using the following expression:

Component cost per MW in Phase 2

= *(Component cost per MW in Phase 1)*
× *(Expected percentage cost reduction)*

The output table for the above expression is given in Table 75, with details of average cost numbers per MW in Phase II and Phase III of JNNSM.

Table 75:
Cost in Rs Crores per MW in Each Phase of JNNSM

COMPONENT	PHASE I (2010–13)	PHASE II (2013–17)	PHASE III (2017–22)
Structures—PTC	2.00	1.60	1.20
Structures—CR	2.00	1.80	1.80
Solar Steam Generators	0.80	0.58	0.58
Mirrors-Parabolic	1.08	0.79	0.79
Mirrors-Flat	0.45	0.45	0.40
Tracking Devices—CR	2.65	2.65	1.86
Tracking Devices—PTC	0.40	0.40	0.25
HTF	0.75	0.75	0.75
Receiver Tube	1.31	1.31	0.89
Turbines	1.64	1.19	1.19

Subsequently, total market size of the above components (Table 76) is calculated using the following expression:

Total market size for each component in eachphase of JNNSM

= *(Costper MW for each component in each phase of JNNSM)*
× *(Planned capacity addition in MW per year in JNNSM)*

Table 76:
Market Size in Rs Crores per Year in Each Phase of JNNSM

COMPONENT	PHASE I (2010–13)	PHASE II (2013–17)	PHASE III (2017–22)
Structures—PTC	293	360	1056
Structures—CR	7	223	1008
Solar steam generators	133	219	934
Mirrors—parabolic	158	177	694
Mirrors—flat	2	56	224
Tracking devices—CR	9	328	1039
Tracking devices—PTC	59	90	218
HTF	110	169	660
Receiver tube	192	295	785
Turbines	273	448	1911

E. Estimation of Direct and Indirect Economic Impact

Direct and indirect economic impact was calculated for all the three possible outcome scenarios in JNNSM. Direct economic impact was defined as the total investment each year in CSP plants under the three different scenarios separately.

Indirect economic impact was calculated using expected localization of different component manufacturing in all the three phases and their expected value addition to the economy as a whole. For calculation of indirect economic impact, it was assumed that 65 percent of the imported cost of components constitutes the total value of material and services that will in turn be the amount of local economic activity, if produced indigenously.

Expected localization of different components for the three different phases under scenario A, B, and C are given in Table 77.

Table 77:
Expected Indigenization of Components (Percentage) for Different Scenarios

CSP components	Scenario C			Scenario B			Scenario A		
	PH. I	PH. II	PH. III	PH. I	PH. II	Ph. III	Ph. I	Ph. II	Ph. III
Solar collection									
Mirrors	0	50	100	0	0	50	0	0	40
Support structures	100	100	100	100	100	100	100	100	100
Drive mechanisms	0	0	100	0	0	80	0	0	0
Foundations	100	100	100	100	100	100	100	100	100
Assembly	100	100	100	100	100	100	100	100	100
Assembly facility	100	100	100	100	100	100	100	100	100
Thermal conversion									
Thermal oil									
Receiver tubes	100	100	100			80			
Ball joints	100	100	100	100	100	100	100	100	100
Piping, valves and accessories	100	100	100	100	100	100	100	100	100
Oil forwarding skid (filters, piping, pumps, tanks, assembly)	100	100	100	100	100	100	100	100	100
Oil purification system	100	100	100	100	100	100	100	100	100
Fire protection system	100	100	100	100	100	100	100	100	100
Inertization system	100	100	100	100	100	100	100	100	100
Natural Gas Boilers	100	100	100	100	100	100	100	100	100
Thermal storage									
Storage medium (molten salts)									
Molten salts forwarding skid (tanks, pumps, piping)	100	100	100	100	100	100	100	100	100
Heat exchangers	100	100	100	100	100	100	100	100	100
Initial filling system	100	100	100	100	100	100	100	100	100
Civil work	100	100	100	100	100	100	100	100	100

Cont...

CSP components	Scenario C			Scenario B			Scenario A		
	PH. I	PH. II	PH. III	PH. I	PH. II	Ph. III	Ph. I	Ph. II	Ph. III
Electrical conversion									
Power block		100	100		100	100		100	100
Balance of plant (BOP)	100	100	100	100	100	100	100	100	100
	100	100	100	100	100	100	100	100	100
Electrical system	100	100	100	100	100	100	100	100	100
	100	100	100	100	100	100	100	100	100
Civil work	100	100	100	100	100	100	100	100	100
Project management and EPC									
Project management	100	100	100	100	100	100	100	100	100
EPC	100	100	100	100	100	100	100	100	100

Based on above localization projection for components, direct and indirect economic impact was worked out and presented in the Table 78:

Table 78:

Direct and Indirect Economic Impact

SCENARIO	ECONOMIC IMPACT	PHASE I	RIOGLASS SOLAR INC	SCHOTT	TOTAL (LOCAL IP)	SCHOTT
A	Direct	1,097	2,084	8,400	76	13
	Indirect	437	1,020	4,168		
B	Direct	3,233	6,114	24,132	83	16
	Indirect	1,288	2,983	12,961		
C	Direct	5,369	10,027	49,170	90	20
	Indirect	2,370	5,434	28,725		

Local share in 2022 was calculated as a ratio of total value of local component supply to CSP plants and total investment in CSP plants in 2022.

Overall cost reduction by 2022 was derived from the primary survey mentioned in section 1.

F. Estimation of Job Creation: Labor Impact

Estimates for jobs both during construction and during ongoing O&Mfor the reference plant of 100 MW and 8 hours thermal storage are as follows, based on interactions with developers on the skills, resources, and manpower required (from the primary research detailed in section1).

Jobs during construction:

- 100 managerial staff
- 250 directly employed skilled staff
- 2000 indirectly employed unskilled contractlabor

Jobs produced by ongoing O&M:

- 50 managerial staff
- 100 directly employed skilled staff
- 200 indirectly employed unskilled contract labor

Based on the above numbers, job creation per year for construction, O&Mand local manufacturing were calculated considering all the three possible outcome scenarios (A, B and C), as shown in the Table 79:

Table 79:
Job Creation per Year for Construction, O&M, and Local Manufacturing for the Three Possible Scenarios

Scenario	Type of Job	Construction			Local Manufacturing			Operation		
		PH. I	PH. II	PH. III	PH. I	PH. II	Ph. III	Ph. I	Ph. II	Ph. III
A	Managerial staff	33	75	400	30	67	360	17	37	200
	Skilled labor	83	187	1,000	75	169	900	33	75	400
	Unskilled labor	665	1,500	8,000	600	1,350	7,200	67	150	800
B	Managerial staff	**100**	**225**	**1,200**	**90**	**200**	**1,080**	**50**	**110**	**600**
	Skilled labor	250	562	3,000	225	505	2,700	100	225	1,200
	Unskilled labor	2,000	4,497	24,000	1,800	4,050	21,600	200	450	2,400
C	Managerial staff	**167**	**375**	**2,000**	**150**	**338**	**1,800**	**83**	**190**	**1,000**
	Skilled labor	417	938	5,000	375	845	4,500	165	375	2,000
	Unskilled labor	3,333	7,500	40,000	3,000	6,750	36,000	333	750	4,000

Where,

Total manpower required in each phase of JNNSM (skill-wise)

= (Total manpower required for a 100MW plant)
× (Expected capacity addition in each phase of JNNSM (all three possible outcome scenarios))

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'Development of Local Supply Chain: The Missing Link for Concentrated Solar Power Projects in India' study is a diagnostic of the manufacturing potential of India's local industries supply components and related engineering and operation and maintenance services for Concentrated Solar Thermal Power (CSP) projects. The study looks at the domestic manufacturing capability for CSP projects to support solar power development in India and realized the resulting economic benefits. It also shows developing indigenous value chains could lower the overall project costs and spur industrial growth & R&D capacity in the long run.

This study is part of a series of publications on the topic. The earlier publication was focused on the Middle East and North Africa (MENA) region. These studies are published to communicate the World Bank's views on pressing issues and stimulate policy & public discussions.

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