ADB

Development of Solar and Wind Power

in Karnataka and Tamil Nadu

Asian Development Bank

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Preface

This publication analyzes the performance of two states in the country—Karnataka and Tamil Nadu—in their efforts towards installing solar and wind energy. It attempts to distill the reasons for their success, albeit using two very different renewable energy programs. It also covers the major initiatives taken by the country in the form of policy and regulations including the formation of a full-fledged Ministry of New and Renewable Energy, the Electricity Act, 2003, the National Electricity Policy, 2005, the National Tariff Policy, 2006, Rajiv Gandhi Grameen Vidyutikaran Yojana, 2005, and Jawaharlal Nehru National Solar Mission (JNNSM).

Karnataka is one of the leading states in the installation of solar hot water systems with an installed area of about 2.3 million square meters. On the other hand, Tamil Nadu is a leader in wind energy exploitation with a total installed capacity of 5072 MW. The report focuses on lessons learnt from these states and provides specific recommendations to create a supportive environment in other states to promote and adopt renewables-based power. Apart from the program and policy dimensions, the report deals in detail with the Indian solar industry and carries out an assessment of solar technology from the point of view of its applications in the country.

The case studies establish that while the availability of good renewable energy resources is a key determinant behind the success of the programs and other important factors include a favorable policy and regulatory environment, good grid network in the potential areas, land availability, and factors pertaining to retail technologies such as users' awareness, year-round demand, and established supply chains with reliable after-sales service. The success of wind power in Tamil Nadu underlines the crucial role played by its power utility, Tamil Nadu Electricity Board, especially in the formative years of wind power development in the state.

This study will help policy makers and academia in further strengthening knowledge solutions for renewable energy across other countries in Asia.

I would like to thank The Energy and Resources Institute (TERI), New Delhi, for undertaking the work. I would also like to thank P.W.C. Davidar, Secretary (Energy), Tamil Nadu; R. Christodas Gandhi, Principal Secretary, and Chairman and Managing Director, Tamil Nadu Energy Development Agency (TEDA); S. Ramesh, Chief Engineer, Karnataka Power Corporation Ltd (KPCL); and R. Raju, General Manager, Karnataka Renewable Energy Development Ltd (KREDL) for providing overviews of the energy and policy scenarios in their respective states as well as for sharing their experiences, perceptions, and thoughts on the subject.

I thank the wide range of stakeholders who have supported this study, especially solar system users including Bosch India Ltd, Bangalore, Hotel Sai Renaissance, Bangalore, MS Swaminathan Research Foundation, Chennai, TEDA, and KREDL; renewable energy financing organizations including Indian Renewable Energy Development Agency (IREDA) and Tamil Nadu Power Finance and Infrastructure Development Corporation (TNPFIDC), Chennai; and electricity distribution companies including Tamil Nadu Electricity Board (TNEB), Chennai and KPCL, Bangalore. Thanks are also due to Industrial and Technical Consultancy Organization of Tamil Nadu (ITCOT), BGR Energy Systems Ltd, and Indian Wind Turbine Manufacturers Association (IWTMA) in Chennai for their valuable insights on the state level policies.

Hun Kim
Country Director
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Abbreviations

ADB	Asian Development Bank
BESCOM	Bangalore Electricity Supply Company Limited
BHEL	Bharat Heavy Electrical Limited
BIPV	building integrated photovoltaic module
BOOT	build own operate transfer
BOS	balance of systems
CDM	clean development mechanism
CEL	Central Electronics Limited
CERC	Central Electricity Regulatory Commission
CERs	carbon emission reduction certificates
CLFR	compound linear fresnel reflectors
CPPs	captive power plants
CPV	concentrated solar photovoltaic
Crore	one crore is equal to ten million
CSP	concentrating solar power
CST	concentrating solar thermal
DL	distribution licensee
DNES	Department of Non-Conventional Energy Sources
DNI	Direct normal irradiance
DRDA	District Rural Development Agency
DTBUs	District-level Technical Back-up Units
EE	energy efficiency
EGT	evacuated glass solar tube
EMD	earnest money deposit
EPC	engineer-procure-construct
ESCOMs	electricity supply companies
ETC	evacuated tube collector
FPC	flat plate solar collectors
GBI	generation-based incentive
GOI	Government of India
GWh	gigawatt-hour
IDC	infrastructure development charges
IEC	International Electrotechnical Commission
IPPs	independent power producers
IREDA	Indian Renewable Energy Development Agency
IREP	Integrated Rural Energy Programme
ISCC	integrated solar combined cycle
JNNSM	Jawaharlal Nehru National Solar Mission
KERC	Karnataka Electricity Regulatory Commission
KIADB	Karnataka Industrial Area Development Board
KPCL	Karnataka Power Corporation Ltd
KPTCL	Karnataka Power Transmission Company Limited
KREDL	Karnataka Renewable Energy Development Ltd
kV	kilovolt
kW	kilowatt

kWh	kilowatt-hour
Lakh	one lakh is equal to one hundred thousand
MBPV	Moser Baer Photo Voltaic Limited
MNRE	Ministry of New and Renewable Energy
MSTPL	Maharishi Solar Technology (P) Limited
MW	megawatt
MWh	megawatt-hour
NAPCC	National Action Plan on Climate Change
NVVN	NTPC Vidyut Vyapar Nigam Limited
O&M	operations and maintenance
PPA	power purchase agreement
PPP	public–private participation
PRC	People's Republic of China
PTC	parabolic trough collectors
PV	photovoltaic
R&D	research and development
RE	renewable energy
REC	renewable energy certificate
REIL	Rajasthan Electronics & Instruments Ltd
REP	Renewable Energy Policy
ReSCOs	renewable energy service companies
RET	renewable energy technologies
RGGVY	Rajiv Gandhi GrameenVidyutikaranYojana
RIL	Reliance Industries Limited
RPO	Renewable Purchase Obligation
RVE	remote village electrification
SEGS	solar electricity generating systems
SERC	State Energy Regulatory Commissions
SES	Stirling Energy Systems
SEZ	special economic zone
SIPs	special incentive package
SLDC	State Load Despatch Center
SPG	solar power generator
TEDA	Tamil Nadu Energy Development Agency
TES	thermal energy storage
TESL	TITAN Energy Systems Ltd
TNEB	Tamil Nadu Electricity Board
TNERC	Tamil Nadu Electricity Regulatory Commission
WEG	wind energy generator

Executive Summary

For inclusive economic growth and socio-economic development commensurate growth of India's energy sector is crucial. As far as electricity supply during 2009 and 2010 is concerned, there was a deficit of around 10% (12,053 MW) and a peak deficit of 12.7% (15,157 MW). These figures do not take into account the large un-electrified parts of the country. As per the latest data available, around 14% villages remain un-electrified. The Indian government has set a goal of providing all households with electricity at an affordable price by 2012. It has been estimated that to meet the goal of full energy access, India will need to add new electricity generation capacity of at least 300 GW by 2017.

Currently most of the energy needs in the country are met through fossil fuels. However, the potential for renewable energy in India is enormous given its large landmass that receives very high solar radiation; its long coastline and high wind velocities that provide ample opportunities for both land-based and offshore wind farms; its significant annual production of biomass; and its numerous rivers and waterways that can be tapped for hydropower. Some of the major initiatives taken by the country in the forms of policy and regulations include the formation of full-fledged Ministry of New and Renewable Energy (MNRE), Electricity Act, 2003; National Electricity Policy, 2005; National Tariff Policy, 2006; Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), 2005; and Jawaharlal Nehru National Solar Mission (JNNSM). While the contribution of renewable energy is 7.7% in the overall energy mix, government is putting in a lot of efforts in increasing its share. The targets set under JNNSM of 20 GW generation by 2022 clearly shows government's commitment to achieve this target. Amongst all the renewable energy sources connected to the national grid, wind energy accounts for 70%.

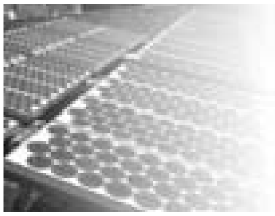
Among the states, Tamil Nadu is the leader in wind energy exploitation with a total installed capacity of 5072 MW. On the other hand Karnataka is one of the leading states in the installation of solar hot water systems with an installed area of about 2.3 million square meters. These two states are analyzed in detail to understand the reasons of their successes in two very different renewable energy programs. The particular focus has been on lessons learnt from these states, so that supportive environment can be created in other states to promote renewables-based power in other states at a faster rate. On the basis of the experiences in these states, certain broad recommendations are made in the report that may help create environment for the utilization of solar and wind power in other states as well. Apart from the program and policy dimensions, the report also deals in detail with the Indian solar industry and carries out an assessment of solar technology from the point of view of their applications in the country.

These case studies establish that while the availability of good renewable energy resources is a key determinant, the other important factors behind the success of programs include favorable policy and regulatory environment; good grid network in the potential areas; land availability; and specifically in case of retail technologies like solar water heating systems: users' awareness; year-round demand; and established supply chains with reliable after-sales service. The success of wind power in Tamil Nadu underlines the crucial role played by its power utility, Tamil Nadu Electricity Board, especially in the formative years of wind power development in the state. This was a clear departure from other states where renewable energy activities are normally looked after by the state energy development agencies.

In case of solar water heating systems, the role of mandatory regulations along with strong complete supply chain is important. Renewable purchase obligations (RPOs) may have a component on solar water heating systems as these systems act as demand side management measure. The public awareness and education being central to successful programs, it is imperative for state agencies to engage the public through sustained awareness campaigns for different user-groups; including local elected representatives. Towards this a sustained campaign may be mounted encompassing all media resources including print, radio, and television. Apart from specific recommendations, such campaigns must inform public about the places from where these devices and services can be procured. It is also important to focus on research and development to improve technology, reduce costs, and increase ease of installation and use. The other critical area pertains to training of professionals along the complete value-chain. Financial and fiscal incentives help support the growth of solar technologies. However, such incentives, especially the capital subsidy must have a sunset timeframe right from the beginning. Fiscal incentives like tax exemptions, property tax rebates, and electricity bill rebates may be more useful. The electricity distribution utilities may become vehicle to promote solar water heating systems and route the incentives such as rebate on electricity bill. This would also help in reducing the transaction costs. Renewable Energy Service Companies (ReSCOs) may also be promoted to act as a one–stop shop for solar energy-based solutions.

Solar energy should be treated as a national resource and exploitation of the same accorded priority. To bring down the cost of solar power, partial risk guarantee funds could be set up in collaboration with the multilateral development banks and through international funding for propagation of clean technologies. This would also encourage the local financiers to finance such projects. Besides, favorable policies to promote indigenous manufacturing of solar systems may help to bring down the costs. Towards this, the state may consider setting up a solar manufacturing hub for manufacturing solar systems and their components. Apart from (a) servicing the domestic markets with standard equipment and devices and (b) bringing down the costs of solar systems through economies of scale (and therefore ease of introduction of the latest technologies/processes), this hub could cater to the growing export markets as well. Another option is to set up Solar Park in the state. A Solar Park is a concentrated zone of solar development targeting 3,000 to 5,000 MW of generation capacity over time, with a solar manufacturing and technology hub and research facilities. It is believed that a solar park could facilitate reduction in the cost of solar power significantly, due to economies of scale and sharing of common transmission and infrastructure.

Further, it is important that the state-level policy and regulatory regime (e.g. third-party sale, tariff setting, wheeling, and banking of power) be long-term and stable. Moreover, the state needs to ensure (a) evacuation facilities at the potential sites, (b) grid access at nominal charges, if any, and (c) grid stability for reliable power off-take and better capacity utilization. The RPO must also include mechanism for timely compliance of the same. Comprehensive short-term wind energy forecasting models suitable for Indian climate and grid conditions need to be developed and deployed. Considering that a lot of wind assets in states like Tamil Nadu are old and inefficient, but are occupying the prime sites, the government should come out with a clear policy on re-powering of such sites so that the wind power generation could be increased substantially.



1

Introduction

"Power for all by 2012", was the stated goal of the Government of India (GOI) to ensure that each and every household of India irrespective of whether it was an urban or a remote rural one had access to affordable power supply by 2012. However, to this day one-third of rural households and 6% urban households are still unelectrified.[1]

Currently most of the energy needs in the country are met through fossil fuels. Coal, gas, and DSL-fired power plants account for 66% of the country's total electricity-generating capacity. The contribution of renewable energy is as low as 12% in the overall energy mix (total overall installed capacity of 201.6 GW as on 30 April 2012).[2] Across all renewable energy sources connected to the national grid, wind energy accounts for 69.5%.[3] Tamil Nadu is the leading producer of wind energy with a total installed capacity ranging from 6987.60 MW to 5072.80 MW followed by Gujarat, Maharashtra, Rajasthan and Karnataka.[4]

The government has made a serious commitment towards increasing the share of renewable energy in India's energy basket setting itself a target of 20 GW solar power generation by 2022 under the Jawaharlal Nehru National Solar Mission (JNNSM). Karnataka is also among the leading states in the installation of solar hot water systems with an installed area of about 2.3 million square meters.[5] Against this backdrop, Asian Development Bank (ADB) has entrusted Tata Energy Research Institute (TERI) with the study "Solar and Wind Power Development in Karnataka and Tamil Nadu".

1.1 Objectives of the Study

The broad objectives of the study are:

- to examine the basic features of the policy framework which has enabled and enhanced the development of solar and wind power in Karnataka and Tamil Nadu;
- to identify gaps and barriers, lessons, and takeaways from the experiences of these states to facilitate an environment in other states that is conducive to the rapid development of renewable energy;
- to introduce technology innovations through technology transfer in the field of solar energy;
- to make recommendations for the creation of an enabling environment for the utilization of solar and wind power in other states.

[1] http://online.wsj.com/article/SB10001424052970203550304577136283175793516.html
[2] http://www.cea.nic.in/reports/monthly/executive_rep/apr12/7.pdf
[3] National Renewable Energy Achievements as on 31 July 2012. http://mnre.gov.in/mission-and-vision-2/achievements/ [Accessed 24 August 2012]www.indianwindpower.com/iw_energy_economy.php
[4] Up to March 2012. http://cwet.res.in/web/html/information_yw.html, last accessed on 24 August 2012. *Renewable Watch*, Volume 1, No 1, November 2010, p. 80
[5] GKS. "Solar Water Heaters in India: Market Assessment Studies and Surveys for Different Sectors and Demand Segments." 20 January 2010. http://mnre.gov.in/pdf/greentech-SWH-MarketAssessment-report.pdf, last accessed August 2010. http://kredl.kar.nic.in/ProgressReport.htm last accessed on 12 January 2010.

1.2 Methodology

This study strikes a fine balance between analytical and theoretical research work and survey-based field research which includes interactions with various stakeholders such as developers, industry specialists, government officials, consultants and the ultimate users. Comprehensive desk research created an understanding of the institutional framework, policies, JNNSM, and global technological trends. The findings of this research provided the backdrop for examining inputs from the field which were received through interactions with agencies like Tamil Nadu Energy Development Agency (TEDA) and Karnataka Renewable Energy Development Ltd (KREDL). These nodal agencies shared views on the nuances of energy policy in India as well as the effectiveness of awareness programs in renewable energy. Tamil Nadu Electricity Board (TNEB) and Karnataka Power Corporation Ltd (KPCL) commented on the grid structures in the states. Additionally consultants active in the energy sector such as ITCOT were also approached for inputs as were the regional offices of Indian Renewable Energy Development Agency (IREDA). Field visits were made to installations, such as, (i) solar hot water systems at the Hotel Sai Renaissance in Bangalore, (ii) roof-top off-grid solar photovoltaic (PV) plant at the MS Swaminathan Institute, (iii) grid connected solar PV plant at Kolar, and (iv) institutional solar cooking by Bosch India Ltd, Bangalore. These provided perspectives of actual users of renewable energy technology.

1.3 Background

It has been estimated that to meet the stated goal of universal energy access, India will need to be able to ramp up its power production to at least 300 GW by 2017. Expansion of renewable energy resources could increase India's energy security while reducing its dependence on imported fuels. Not only are renewable energy resources generally immune to fuel price escalations, they also accrue significant environmental benefits through near zero carbon emissions. A strong case for renewable energy lies in the following factors:

- While the costs of fossil fuels are on the rise, the cost of harnessing solar and other renewable energy resources is consistently decreasing with technology advancement.
- The dependence on local (renewable) energy sources and scalability of renewable energy technologies make them well-suited to meet the power needs of remote areas that lack grid and road infrastructures.
- If India is able to fully harness its immense potential for solar and wind energy, it could emerge as a leader in the global green economy thus attracting greater investment into renewable energy.

The prospects for renewable energy in India are very attractive given the large land mass that receives among the highest solar irradiation in the world. Its long coastline and high wind velocities provide ample opportunities for both land-based and offshore wind farms. India has a significant annual production of biomass and numerous rivers and waterways that can be tapped for hydropower.

In 1992, GOI established the world's first and only ministry committed solely to the development of renewable energy resources. Earlier in 1987, IREDA was established to provide financial assistance for renewable energy and energy efficiency projects. Apart from these two major initiatives, GOI has come out with many facilitating measures to realize the enormous renewable energy potential in India:

- The Electricity Act, 2003 was a landmark legislation towards liberalizing the power market in India, encouraging competition and attracting private investment into the sector. Within the Act, the Central Electricity Regulatory Commission (CERC) is authorized to establish a preferential tariff regime for renewable energy in order to promote both generation as well as cogeneration of electricity from renewable sources. [6]
- The National Electricity Policy, 2005 stipulates the need for increasing the share of electricity from non-conventional sources and allows for the State Energy Regulatory Commissions (SERCs) to establish a preferential tariff for electricity generated from renewable sources to enable them to be cost competitive. [7]
- National Tariff Policy 2006 mandates that each SERC specify a renewable portfolio/purchase obligation (RPO) with distribution companies in a time-bound manner. These purchases are to be made through a competitive bidding process. The objective of this policy is to enable renewable energy technologies to compete with conventional sources.

[6] http://www.cea.nic.in/home_page_links/ElectricityAct2003.pdf, last accessed in October 2010
[7] Footnote 6.

- Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) 2005 aims to deliver power supply to rural households and to households below the poverty line.[8]

In India's Eleventh Five-Year Plan (2007–2012) 10% power generation capacity from renewable sources by 2012 was set as the target. Similarly, India's National Action Plan on Climate Change (NAPCC) has a goal of 15% of total grid electricity from renewable energy by 2022. In accordance with the aforementioned acts and policies, various SERCs have come out with RPOs in their respective states. A select list of such state-wise data is presented in Table 1.1.

Table 1.1 State-wise RPO as a Percentage of Total Power Consumption (Major States)

	Division	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16
Haryana	Solar	0.25	0.50	0.75	1.00	1.25	
	Total	1.50	1.50	2.00	2.00	2.50	
Uttarakhand	Solar	0.25	0.50	1.00			
	Non solar	3.75	4.50	5.00			
	Total	4.00	5.00	6.00			
Himachal Pradesh	Solar	0.00	0.10	0.10			
	Non solar	10.00	11.0	12.0			
	Total	10.00	11.10	12.10			
Uttar Pradesh	Solar	0.25	0.5	1.00			
	Non solar	3.75	4.5	5.00			
	Total	4.00	5.00	6.00			
Rajasthan	Wind	6.75	7.50				
	Biomass	1.75	2.00				
	Total	8.50	9.50				
Gujarat	Solar	0.25	0.50	1.00			
	Wind	4.50	5.5	5.50			
	Others	0.25	0.50	0.50			
	Total	5.00	6.00	7.00			
Maharashtra	Solar	0.25	0.25	0.25	0.50	0.50	0.50
	Non solar	5.75	6.75	7.75	8.50	8.50	8.50
	Total	6.00	7.00	8.00	9.00	9.00	9.00
Madhya Pradesh	Solar	--	0.40	0.60	0.80	1.00	
	Non solar	0.80	2.10	3.40	4.70	6.00	
	Total	0.80	2.50	4.00	5.50	7.00	
Chattisgarh	Solar	0.25	0.25	0.50			
	Biomass	3.75	3.75	3.75			
	Others	1.00	1.25	1.50			
	Total	5.00	5.25	5.75			
Tamil Nadu (draft)	Solar	--	0.1505	0.2505	0.25		
	Total	--	109.00	109.00	10.00		
Kerala	Solar	0.25	0.25				
	Total	3.00	3.30	3.60	3.90	4.20	4.50

[8] Rajiv Gandhi Grameen Vidyutikaran Yojana. http://rggvy.gov.in/rggvy/rggvyportal/index.html. Last accessed in August 2010.

	Division	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16
Karnataka	Solar	0.25	0.25				
	Non-solar	7-10	7-10				
	Total	7.25-10.25	7.25-10.25				
Orissa	Solar	--	0.10	0.15	0.20	0.25	0.30
	Non-solar	1.00	1.20	1.40	1.60	1.80	2.00
	Others	3.50	3.70	3.95	4.20	4.45	4.70
	Total	4.50	5.00	5.50	6.00	6.50	7.00
Bihar	Solar	0.25	0.50	0.75	1.00	1.25	
	Non-solar	1.25	2.0	3.25	3.50	3.75	
	Total	1.50	2.50	4.00	4.50	5.00	
Assam (draft)	Solar	0.05	0.10	0.15	0.20	0.25	
	Total	1.40	2.80	4.25	5.60	7.00	
Andhra Pradesh	**Total**	5.00					
West Bengal	**Total**	10.00					
Manipur	Solar	0.25	0.25	0.25			
	Non-solar	1.75	2.75	4.75			
	Others	2.00	3.00	5.00			
	Total						
Mizoram	Solar	0.25	0.25	0.25			
	Non-solar	4.75	5.75	6.75			
	Total	5.00	6.00	7.00			
Delhi	**Total**	1.00					

Note: RPOs in Karnataka vary with distribution utilities.
Source: Compiled information from renewable purchase orders of all the states.

Over the years, wind power has developed significantly in the state of Tamil Nadu. This is not only because of good wind resources in the state but also due to robust support infrastructure and a policy regime conducive to the development of non-conventional energy in the state. Growth in the installation of the solar water heaters in the state of the Karnataka can be attributed to similar factors.

1.4 About Tamil Nadu

Peak demand in the state for the year 2011-12 was 12000 MW, with per capita energy requirement of 1040 kWh per year.[9] The peak demand met for the same year was 137 kWh per year and the available energy per capita 955 kWh per year.[10] In last three years (2007–2009) the per capita energy requirement has increased by 11%.[11] Domestic sector consumed the maximum amount of power in 2009.[12]

The state has taken initiative for implementing both grid-connected and off-grid applications of the technology. Total grid interactive renewable energy deployment in the state for the year 2011-12 was 7846.07 MW (as on 31 March 2012). [13]

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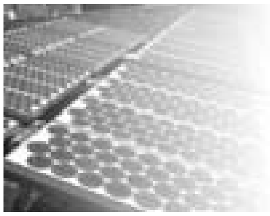
[9] As reported in Lok Sabha on 20 November 2009, www.indiastat.com, last accessed 24 November 2010. Policy Note 2012-2013, Demand No.14 by Energy Department, Government of Tamil Nadu.
Available at http://www.tn.gov.in/policynotes/pdf/energy.pdf, last accessed on 25 August 2012.
[10] As reported in Lok Sabha on 20 November 2009, www.indiastat.com, last accessed on 24 November 2010.
[11] Footnote 10.
[12] As on 11 December 2009, www.indiastat.com, last accessed on 24 November 2010.
[13] http://www.teda.in/ last accessed on 24 August 2012.

1.5 About Karnataka

Peak demand in the state for the year 2011 was 7711 MW per year with per capita energy requirement of 740 kWh per year.[14] The current installed capacity of the state is 10562.10 MW.[15] The peak demand met for the same year was 112 kWh per year and the available energy per capita 695 kWh per year.[16] For the last three years (2007–2009) the per capita energy requirement has increased by 20%. The demand–supply energy gap is found to have increased by 9% in the period 2007–2009.[17] Agricultural sector consumed the maximum amount of power in 2009.[18]

[14] Footnote 10.
[15] http://110.234.115.69/Statistics/KPTCL%20at%20a%20Glance.pdf, last accessed on 25 November 2010.
[16] Footnote 10.
[17] Footnote 10.
[18] Footnote 10.



2

Overview of Indian Solar Energy Sector

India is located on the earth's sunny belt and receives abundant energy from it. The equivalent energy potential for India is estimated at about 6,000 million GWh per year. The daily average global radiation varies from 5.0 kWh per square meter in north-eastern and hilly areas to about 7.0 kWh per square meter in western regions and the cold desert with the sunshine hours ranging between 2,300 and 3,200 per year. In most parts of India, clear sunny weather is experienced for 250 to 300 days in a year. The annual global radiation varies from 1600 to 2200 kWh per square meter.

The Thar Desert in western Rajasthan is spread over an area of 35,000 square kilometers and if properly exploited, has the potential to produce 700 to 2,100 GW of solar power. In June 2008, India released its National Action Plan for Climate Change (NAPCC). One of the missions under this plan has been christened the Jawaharlal Nehru National Solar Mission (JNNSM or NSM) with a target of producing 20,000 MW of solar power by the year 2022.

2.1 Jawaharlal Nehru National Solar Mission

Jawaharlal Nehru National Solar Mission, officially launched in November 2009 is a major initiative of GOI and the state governments to promote ecologically sustainable growth on one hand, and to cater to the energy security challenge for the country on the other. It also constitutes a major contribution by India to the global effort to meet the challenges of climate change.

The objective of the JNNSM is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. It aims to incentivize the installation of 22,000 MW of on- and off-grid solar power using both photo voltaic (PV) and concentrating solar power (CSP) technologies by 2022. It also expects to enable the adoption of a large number of other solar applications such as solar lighting, water and air heating, and water pumping.

The mission targets can be broadly summarized as:

- Creating an enabling policy framework for the deployment of 20,000 MW of solar power by 2022
- Creating favorable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership
- Moving towards grid parity by 2022 through economies of scale, technological innovation, and indigenous manufacturing to bring down the costs of solar power substantially
- Achieving 15 million square meters solar thermal collector area by 2017 and 20 million by 2022

The deployment targets across the application segments are tabulated in Table 2.1.

The mission expects to pursue its targets through more attractive feed-in tariffs, a single-window application process, and solar-specific renewable purchase obligation (RPOs) within a 3-phase approach.

Phase 1, 2010–2013: Phase 1 is focused on creating a market for solar power in India by bringing in investors, engineer-procure-construct (EPC) contractors, and equipment manufacturers. The policy framework to achieve the objectives of the National Solar Mission by 2022 is also expected to be formulated in Phase 1. Apart from this, Phase 1 acts as a platform for testing the concept of tariff discounting in renewable energy. A target of 1000 MW grid-connected solar power has been set for this phase (with solar PV and solar thermal in the ratio of 50:50).

Table 2.1 Mission Targets

Application segment	***Target for Phase 1 (2010–13)***	***Target for Phase 2 (2013–17)***	***Target for Phase 3 (2017–22)***
Solar collectors	7 million sq meters	15 million sq meters	20 million sq meters
Off-grid solar applications	200 MW	1000 MW	2000 MW
Utility grid power, including roof top	1,100 MW	4000–10,000 MW	20000 MW

Source: Jawaharlal Nehru National Solar Mission document. Available at http://india.gov.in/allimpfrms/alldocs/15657.pdf, last accessed on 24 August 2012

Phase 2, 2013–2017: During Phase 2, experience of Phase 1 will be built upon to facilitate substantial increases in capacity addition, significantly bring down cost per kWh, and achieve additional installations of 3,000 to 10,000 MW of combined PV and CSP capacity. JNNSM identifies the need for international support in the form of technology transfer and financial assistance in order to meet the higher goal. The central government will work to create a favorable environment for solar manufacturing, particularly for solar thermal technology. By 2017, 15 million square meters of solar thermal collector area is expected to be installed as also off-grid solar capacity of 1,000 MW. For Phase 2, JNNSM proposes mandatory use of indigenously produced cells and modules. The aim is to (a) create large enough domestic market and (b) create favorable conditions for the uptake of the Indian products thereby providing the impetus to local manufacturing. It is hoped that eventually the country becomes a solar hub catering to domestic as well as global demands.

Phase 3, 2017–2022: Solar power is expected to achieve grid parity by 2022 wherein off-grid solar capacity installations will reach 2,000 MW, on-grid capacity will reach 20,000 MW, 20 million square meters of solar thermal collector area will be installed, and 20 million solar lighting systems will be deployed in rural households under the third phase of JNNSM.

There will be evaluation of progress, review of capacity, and targets for subsequent phases, based on emerging cost and technology trends, both domestic and global through the 11th to the 13th Plan as also during their mid–term assessments. The aim would be to protect the government from subsidy exposure in case expected cost reduction does not materialize or is more rapid than expected.

The key features of JNNSM are listed below:

- An RPO mandated for power utilities, with a specific solar component will drive utility scale power generation in either solar PV or solar thermal. The solar purchase obligation will be gradually increased while the tariff fixed for solar power purchase will decline over time. The solar power purchase obligation for states may start at 0.25% in the Phase 1 and go up to 3% by 2022. This could be complemented with a solar specific renewable energy certificate (REC) mechanism to allow utilities and solar power generation companies to buy and sell certificates to meet their solar power purchase obligations. Recognizing that solar power is expensive, in Phase 1, a novel way of reducing financial burden on distribution utilities has been devised by way of bundling of solar power with unallocated, conventional power.
- The mission in its first two phases will promote solar heating systems, which are based on a commercially viable and proven technology. The mission is setting an ambitious target of ensuring that all applications, domestic and industrial, below 80°C are solarized.
- A key opportunity for solar power lies in decentralized and off-grid applications. In remote and far-flung areas where grid penetration is neither feasible nor cost effective, solar energy applications are cost-efficient. They ensure that people with no current access to light and power, move directly to solar, leap-frogging the fossil fuel trajectory of growth.
- Currently, market-based and even micro-credit based schemes have achieved only limited penetration in this segment. The government has promoted the use of decentralized applications through financial incentives and promotional schemes. While the 1000 MW target of the solar mission by 2017 appears small, it has the potential to transform the lives of millions of households. The strategy will be to learn from and to innovate on the existing schemes to improve effectiveness.
- The bulk of India's solar PV industry is dependent on import of critical raw materials and components including silicon wafers. Transformation of India into a solar energy hub will only be enabled if low-cost, high quality solar manufacturing is possible within the country, including balance of system components. Proactive

implementation of special incentive package (SIPs) policy, to promote PV manufacturing plants, including domestic manufacture of silicon material can facilitate this development.

- A major research and development (R&D) initiative to focus: first, on improvement of efficiencies in existing materials, devices and applications and on reducing costs of balance of systems, establishing new applications by addressing issues related to integration and optimization; second, on developing cost-effective storage technologies which would address both variability and storage constraints, and on targeting space-intensity through the use of better concentrators, application of nano-technology and use of better and improved materials. The mission will be technology neutral, allowing technological innovation and market conditions to determine technology winners.
- A Solar Research Council will be set up to oversee strategy, taking into account ongoing projects, availability of research capabilities and resources and possibilities of international collaboration.
- Pilot demonstration projects would be closely aligned with the mission's R&D priorities and designed to promote technology development and cost reduction.

The JNNSM is divided broadly in two categories, as described below.

2.1.1 Off-Grid and Decentralized, Roof-Top and other Small Solar Plants

The solar mission has set a separate target for the off-grid and decentralized roof-top and other small solar plants. These guidelines were released on 16 June 2010. In the first phase, JNNSM aims to build 200 MW of off-grid solar energy applications to meet/supplement power, heating and cooling energy requirements, and to promote 100 MW of tail-end and other small grid connected solar power plants. This will address four critical areas: access to rural households for lighting and daily power requirements; reduction in consumption of kerosene and diesel; energy demand management through solar thermal systems; and improvement of efficient transmission by feeding power at consumption points.

Off-grid and decentralized solar applications

Off-grid solar PV systems/applications up to a maximum capacity of 100 kW per site and mini grids for rural electrification up to a maximum capacity of 250 kW per site would be supported under this scheme. Soft loans for projects, including a component for working capital, will be available for technology upgradation and improvement and expansion in production facilities through refinance facility implemented through Indian Renewable Energy Development Agency (IREDA).

Multiple channel partners to upscale the program rapidly would include:

- Renewable energy service providing companies;
- Financial institutions including microfinance institutions acting as aggregators;
- Financial integrators;
- System integrators; and
- Program administrators.

Ministry of New and Renewable Energy (MNRE) would provide financial support through a combination of 30% subsidy and loans at an interest rate of 5% per annum.

List of projects selected by MNRE under this scheme is given in Appendix I.

Roof-top and other small solar power plants (below 33 kV) connected to the distribution network

In order to give a thrust to rooftop PV and other small solar power plants connected at the distribution network at voltage levels below 33 kV envisaged under Phase 1 of the JNNSM, the MNRE proposed to launch a program of generation-based incentives (GBIs). The local distribution utility in whose area the plant is located, would sign a power purchase agreement (PPA) with the project proponent at a tariff determined by the appropriate State Electricity Regulatory Commission (SERC). The GBI shall be equal to the difference between the tariff determined by the Central Electricity Regulatory Commission (CERC) and the base rate, which will be Rs 5.50 per kWh (for the financial year 2010–11), which shall be escalated by 3% every year.

Projects under this category in Phase 1 comprise:

- Projects connected to HT voltage at distribution network (i.e. below 33 kV): 90 MW aggregate capacity
- Projects connected to LT voltage i.e. 400 volts (3-phase) or 230 volts (1-phase): 10 MW aggregate capacity

The issues related to grid integration, metering, measurement and energy accounting for projects to be connected at LT level with installed capacity lower than 100 kW is complex. Detailed guidelines for such schemes will have to be issued once the clarity on such grid integration standard emerges. As a result, the present guidelines are applicable to Category 1 projects that is, with installed capacity of 100 kW and up to 2 MW having grid connectivity at HT level (below 33 kV) of the distribution network.

Under this program, IREDA would act as a program administrator and sign memorandum of understanding with concerned state distribution utilities for disbursement of GBI as per the prevailing conditions.

List of projects, selected under this scheme is given in Appendix II.

2.1.2 Grid-connected

Guidelines for grid-connected solar power projects were released on 27 July 2010. The aggregated capacity of the grid-connected solar projects to be developed under bundling scheme in Phase 1 of JNNSM will be 1000 MW, inclusive of the capacity under migration guidelines. Projects aggregating a total capacity of 84 MW (solar thermal 30 MW and 54 MW for solar PV) have been approved for migration. The projects will be selected under this scheme in such a manner so as to provide for deployment of both solar PV technology projects and solar thermal technology projects in a ratio of 50:50, in MW terms. However, within these two broad technology groups, the selection of projects would be technology agnostic. Any demonstration projects as may be approved by MNRE from time to time shall not be considered for bundling with unallocated quota of NTPC power under this scheme. The allocation of 500 MW grid-connected PV projects was slated to be done in two batches; the first batch (150 MW) will be in the financial year 2010–11 and the second in the year 2011–12. Projects under migration guidelines, migrating from older incentive schemes to new ones, should be given priority above new projects. If applications exceed 150 MW, projects will be chosen based on the tariff discount offered by project developers on the CERC tariff. The projects for first batch of Phase 1 have been selected by NTPC Vidyut Vyapar Nigam Limited (NVVN). A total of 37 projects aggregating to a capacity of 620 MW (solar thermal 470 MW and 150 MW for solar PV) have been identified. Under the second batch, projects for remaining capacity of solar PV of 204 MW will be selected. These projects will feed into the grid at 33 kV or above. Individual projects for solar PV will have a maximum capacity of 5 MW (± 5%). Each company can apply for only one PV project and one CSP project under Phase 1.

The following conditions were laid down for the applicants under Phase 1 of JNNSM:

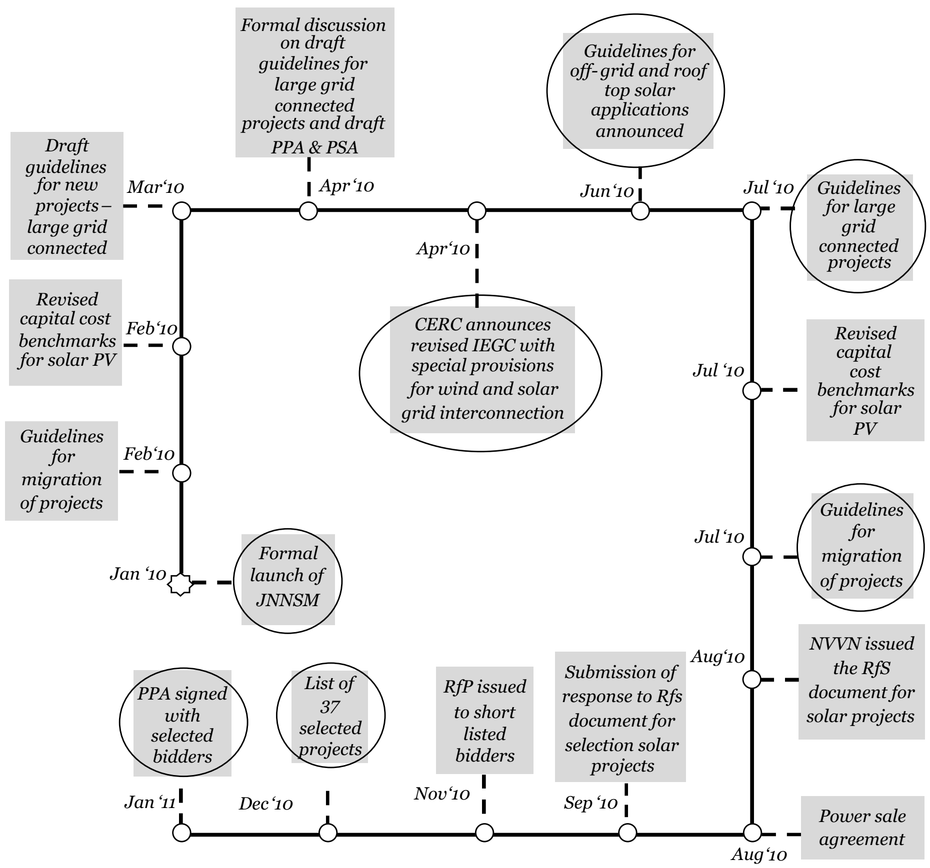
- Company should have an audited net worth of at least Rs 3 crore or equivalent US$ per MW of a project's installed capacity in at least one of the last four financial years.
- The applicant should be in a position to offer bid bond, or third-party guarantee, per MW for any discount on the offered tariff. The higher the discount, the higher the amount of the bond, ranging between Rs 10,000 and Rs 50,000 per MW on a graded scale.
- The applicant should make an earnest money deposit (EMD) in the form of a bank guarantee of Rs 20 lakh per MW along with the initial request for selection.
- A performance bank guarantee of Rs 30 lakh should be provided per MW at the time of signing the PPA.
- A project shall achieve financial closure within 180 days after signing the PPA.
- A project must be commissioned within 12 months in case of solar PV and 28 months in case of solar thermal technology after the signing of the PPA.

In case of failure to achieve this milestone, NVVN will encash the performance bank guarantee according to predefined rates. To ensure PV module quality, modules proposed for the project must qualify to the latest edition of the following International Electrotechnical Commission (IEC) PV module qualification test or equivalent from the Bureau of Indian Standards: for crystalline silicon solar cell modules–IEC 61215; for thin-film modules–IEC 61646; and for concentrator PV modules–IEC 62108. For the first batch of Phase 1, it will be mandatory for projects using crystalline silicon technology to use modules manufactured in India. Similarly, it will be mandatory for the bidders to ensure at least 30% of local content excluding land in the plants/installations of the projects.

List of projects "under migration" is attached in Appendix III and list of projects for first batch of Phase 1 (2010-11) is attached in Appendix IV. A 5 MW solar PV project from Tamil Nadu and a 10 MW solar PV project from Karnataka have made it to this list.

A comprehensive time line of development of JNNSM is shown in Figure 2.1.

Figure 2.1 A Comprehensive Timeline of Development of JNNSM



Note: IEGC Indian Electricity Grid Code; CERC Central Electricity Regulatory Commission; NVVN NTPC Vidyut Vyapar Nigam; RfP Request for proposal; RfS Request for selection; PPA Power Purchase Agreement; PPS Power Sale Agreement

Source: Jawaharlal Nehru National Solar Mission document. Available at http://india.gov.in/allimpfrms/alldocs/15657.pdf, last accessed on 24 August 2012

2.2 Indian Solar Industry

For a tropical country like India which receives ample sunshine all round the year and has an ever increasing demand for energy to fuel its industrial and socio-economic development, solar power presents immense potential to slake its energy thirst in way that is environmentally benign. The industry has witnessed rapid growth over the past few years and future prospects are bright. The country's geographical location, large population, and government support have created just the right set of circumstances for a fast emerging solar energy market attractive to both local and global investors in the industry.

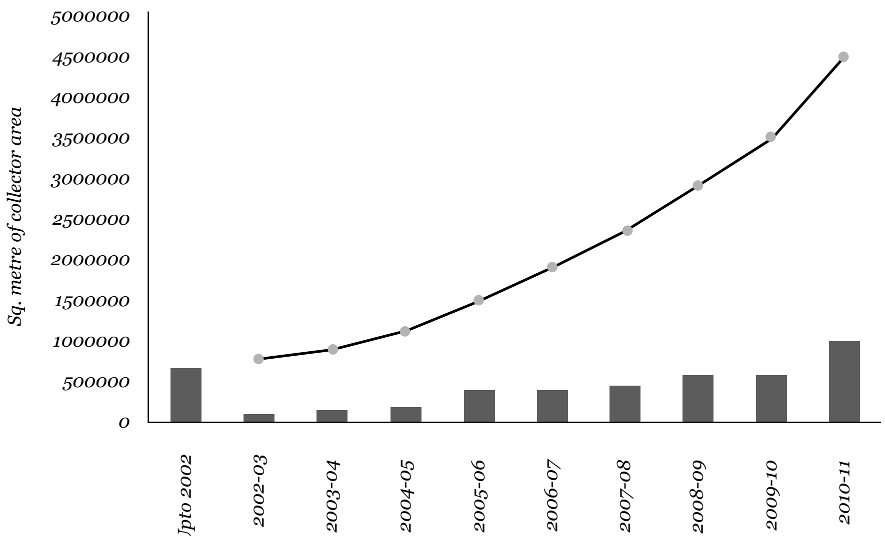
Demand for solar products has been rapidly rising for the recent years, especially in rural areas, and is expected to continue growing during the next few years. Solar street lighting systems, home lighting systems, cookers, pumps and solar water heating systems are the most popular applications in India. The solar mission with its ambitious targets has drawn the attention of local and global industrial giants to the solar power generation business.

2.2.1 Market for Solar Hot Water Systems

The global market of non-conventional energy resources has witnessed a rise in demand of solar water heaters though, compared to the People's Republic of China (PRC), the demand for solar water heaters in India is still fairly low. Nevertheless, the market in India is small but growing rapidly with both residential as well as industrial consumers showing interest in the product.

While the history of research in solar water heaters and pilot-demonstration goes back to 1960s, the first serious attempt to deploy the technology were made with the formation of Department of Non-Conventional Energy Sources (DNES) in 1982. The total installed collector area increased from 119 thousand square meters in 1989 to 525 thousand square meters in 2001, and to estimated 4.51 million square meters by end of the year 2010-11.[1] The growth in installed solar water heater area is shown in Figure 2.2.

Figure 2.2 Cumulative Installations of Solar Water Heaters in India (up to 2010)



Source: http://mnre.gov.in/file-manager/UserFiles/Year_wise_installations_swhs.pdf, last accessed on 25 August 2012

The popularity of solar water heaters increased in the country in the mid-1990s and sales showed an annual growth rate of 8% between 1995 and 2000 with over 80% of the demand arising from the industrial and commercial sectors. Between 2001 and 2004, the off-take of solar water heaters expanded at an annual rate of 20.6% which further increased to 24% in the period 2004–2008. Starting from 2001, the number of residential users of these devices increased significantly. However, the solar water heater consumption in India is disappointingly low as compared to the other countries. As per the *Renewables 2012 Global Status Report*, by the year 2010, 64.8% of the total solar water heater capacity was utilized by PRC. India's share in solar water heating capacity use was only 1.5%.[2]

As per the *Renewables 2009 Global States Report*, 80% of the total sales of solar water heaters in the year were made to the residential consumers. The hotel owners had the share of 6% in the total sales of solar water heaters. Around 6% of these devices were sold to the industrial consumers and about 3% to the hospitals.[3] This demand trend can be explained with the help of the following reasons:

- Growth in new urban housing; rising disposable income; increased propensity for consumer durables
- Arrival of the evacuated tube collector (ETC) technology and improvements in supply chain
- Energy price hike
- Policy initiatives

There are two solar water heating technologies in vogue; flat plate collector and the ETC; the latter has flourished on the strength of glass tubes imported from PRC. There are 113 approved Indian producers of solar water heaters

[1] OPET-TERI & HECOPET: Status of Solar Thermal Technologies and Markets in India and Europe. 2002; http://mnre.gov.in/file-manager/UserFiles/Year_wise_installations_swhs.pdf; last accessed on 25 August 2012

[2] Report published by the Renewable Energy Policy Network for the 21st Century, www.ren21.net.

[3] Report published by the Renewable Energy Policy Network of the 21st century, www.ren21.net

with the market share of the largest player hovering below 15%.[4] The producers do not have nation-wide brand equity and their dealer network is also limited. The manufacturing is concentrated largely in southern India with some presence in Maharashtra. Barring ETC, there has not been any major product/technology breakthrough in last two decades.

In the residential sector, there are 0.7 million solar water heater user households, 65% of which are concentrated in Karnataka and Maharashtra. The system cost for a household varies from Rs 20,000 to Rs 60,000, depending on the size and standard. It is positioned as an electricity-saving consumer durable. ESCO[5] or pay-per-use models have not been attempted in any significant way. There is overall satisfaction with the product experience though some concerns are being voiced over the after-sales support. The residential heaters are mainly used to heat bath water. The average size of the domestic installations that were surveyed is around 150 liters per day.

In the hotel sector, experience across regions and hotel/guest-house standards suggests that areas that demand hot water for more than 9 months in a year may be considered high demand areas while at the lower end are those that do so around 4 months a year. The hotel industry must generally provide for year-round demand for hot water and the rising cost of conventional power supports the case in favor of solar power heaters. Roof availability is not a significant barrier for hotels that have a capacity of more than 15 rooms but capital cost is and can be a prohibitive factor.

Compared to hotels, awareness/exposure levels are low amongst hospitals and hostels. Supply hour management/regulation is a key advantage for both these sectors, and roof availability is not a noticeable constraint.

The experience in industries is limited and scattered. Solar heaters may be used for heating boiler feed water in rice-mills, pulp and paper, tea-gardens, leather, and textile processing. Industries such as dairy, fertilizer, some sub-sets of textiles, as also industrial canteens which use oil-fired boilers are also prime candidates for solar heaters. In rural areas, households, dhabas, primary health-centers, hostels and village-industries (silk-reeling, textile-dyeing, puffed rice-making) are important markets for solar heaters. Major roadblocks to the popularization of solar heaters in rural areas lies in the high capital cost, common recourse to biomass, absence of piped water supply systems, roof design/strength and a non-existent supply chain.

The latest available figures on sectoral breakup of functional solar water heaters penetration are for the year 2009 from the MNRE report on solar water heaters in India-2010, which assumes the 85% of total solar water heaters installed as functional (Table 2.2).[6]

Table 2.2 Estimated Break-up—Functional SWH Installations till 2009

Sector	***million sq m***
Residential (80%)	2.108
Hotels (6%)	0.158
Hospitals (3%)	0.079
Industry (6%)	0.158
Other (Railway + Defense + Hostel + Religious places, other) (5%)	0.132
Total	**2.635**

Source: *Report on Solar Water Heaters in India: Market assessments studies and surveys for different sectors and demand segments*, prepared by Greentech Knowledge Solutions (P) Ltd, New Delhi, submitted to Project Management Unit, Global Solar Water Heating Project, Ministry of New and Renewable Energy, January 2010

The report also gives some projections for potential of solar water heaters in India based on the historical trend, consideration of utilization of solar water heaters in new buildings and some supportive policies. This projection is given in Table2.3.

[4] *Report on Solar water heaters in India: Market assessments studies and surveys for different sectors and demand segments,* prepared by Greentech Knowledge Solutions (P) Ltd, New Delhi , submitted to Project Management Unit, Global Solar Water Heating Project, Ministry of New and Renewable Energy**,** January 2010

[5] An energy service company (acronym: ESCO or ESCo) is a commercial business providing a broad range of comprehensive energy solutions as also innovative financing solutions for the implementation of energy savings projects, energy conservation, energy infrastructure outsourcing, power generation and energy supply, and risk management.

[6] Footnote 4

Table 2.3 SWH Potential under Realistic Scenario (cumulative million sq m)

	2010	2013	2017	2022
Residential	2.58	4.25	7.68	15.74
Commercial/institutional				
Hotels	0.19	0.35	0.61	0.97
Hospital	0.10	0.17	0.27	0.43
Others	0.18	0.27	0.39	0.52
Industry	0.19	0.33	0.57	1.05
Total	**3.24**	**5.37**	**9.52**	**18.70**

Source: *Report on Solar Water Heaters in India: Market assessments studies and surveys for different sectors and demand segments*, prepared by Greentech Knowledge Solutions (P) Ltd, New Delhi, submitted to Project Management Unit, Global Solar Water Heating Project, Ministry of New and Renewable Energy, January 2010

Many states are promoting solar based applications in a big way through incentives as well as regulatory measures. As shown in Table 2.4, both, Tamil Nadu and Karnataka are among the top five states with excellent potential for the application of solar water heating systems.

Table 2.4 Top Five States in India

State	Residential (million sq m)	Commercial / institutional (million sq m)	Total (excluding industrial) (million sq m)
Karnataka	3.72	0.16	3.88
Maharashtra	3.50	0.31	3.80
Tamil Nadu	1.53	0.14	1.67
Andhra Pradesh	1.08	0.09	1.17
Gujarat	0.90	0.06	0.96

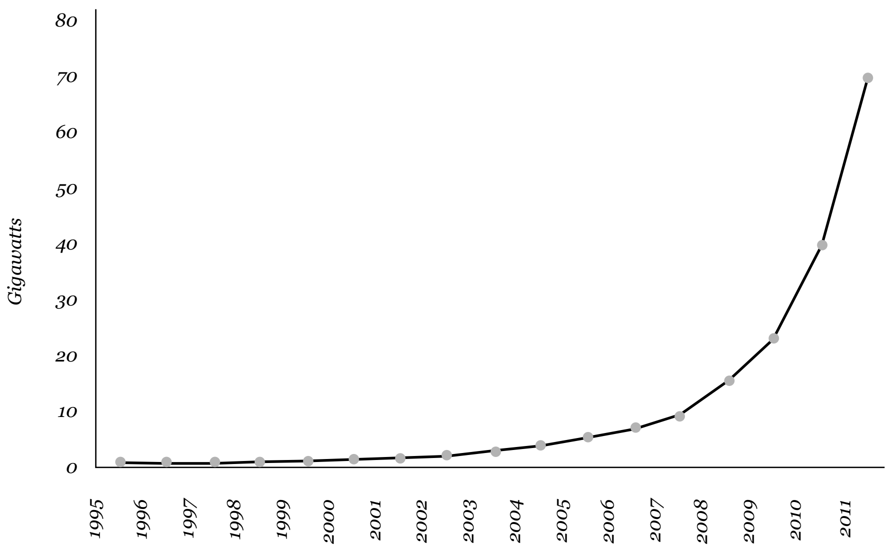
Note: Data pertains to cumulative SWH potential in million sq m. for 2022 under the realistic scenario
Source: *Report on Solar Water Heaters in India: Market assessments studies and surveys for different sectors and demand segments*, prepared by Greentech Knowledge Solutions (P) Ltd, New Delhi, submitted to Project Management Unit, Global Solar Water Heating Project, Ministry of New and Renewable Energy, January 2010

2.2.2 Solar PV Market

India ranked seventh worldwide in solar PV cell production and ninth in solar thermal power (non-electric) generation in 2009-10.[7] The global PV market has experienced vibrant growth for more than a decade with an average annual growth rate of 40%. Almost 30 GW of new solar PV capacity came into operation worldwide in 2011, increasing the global total by 74% to almost 70 GW.[8] Figure 2.3 shows the global total installed capacity of PV for the past two decades.

In India too, rapid growth in being witnessed with the emergence of many private manufacturers of solar energy equipment.

Figure 2.3 Solar PV Total Global Capacity, 1995-2011



Source: *Renewables 2012, Global Status Report*, published by REN21, www.ren21.net

India is a new entrant in the market which is still pacing up fast. However, as on date the Indian solar PV manufacturing sector is much bigger than the country's total installed capacity. The installed capacity of solar power in India was estimated between 481.48 MW grid-connected and 81.01MW by end of 2012, whereas, the overall manufacturing capacity of solar PV modules is about 1250 MW, about twice the cumulative installed capacity.[9] While a few participants such as Bharat Heavy Electricals Ltd and Bharat Electronics Ltd cater to the demand from government projects like remote electrification and so on, many other companies such as XL Telecom and Solar Semiconductor sell a major share of their products to export markets. Indian manufacturers have been exporting 70% of their cell capacity and 80% of their module production capacity.[10] In the absence of clear policy to make the domestic market for solar PVs attractive, private companies have historically been more inclined to explore export opportunities rather than catering to domestic needs in order to leverage the lucrative profits that large export orders bring in.

A value chain of Indian companies involved in the PV market is shown in the Figure 2.4. One of the mission objectives for India is to take a global leadership role in solar manufacturing (across the value chain) of leading edge solar technologies, and to target dedicated manufacturing capacities for poly silicon material of about 2 GW per annum capacity. The Ministry of New and Renewable Energy (MNRE) and Ministry of Industry are working together to chalk out a plan of action for the same.

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[7] MISSION 120 MW. Websol Energy Systems Limited Annual Report, 2009-10. Available at http://www.webelsolar.com/investors_relation/investors/annual_report_2009-10.pdf, last accessed on 25 August 2012

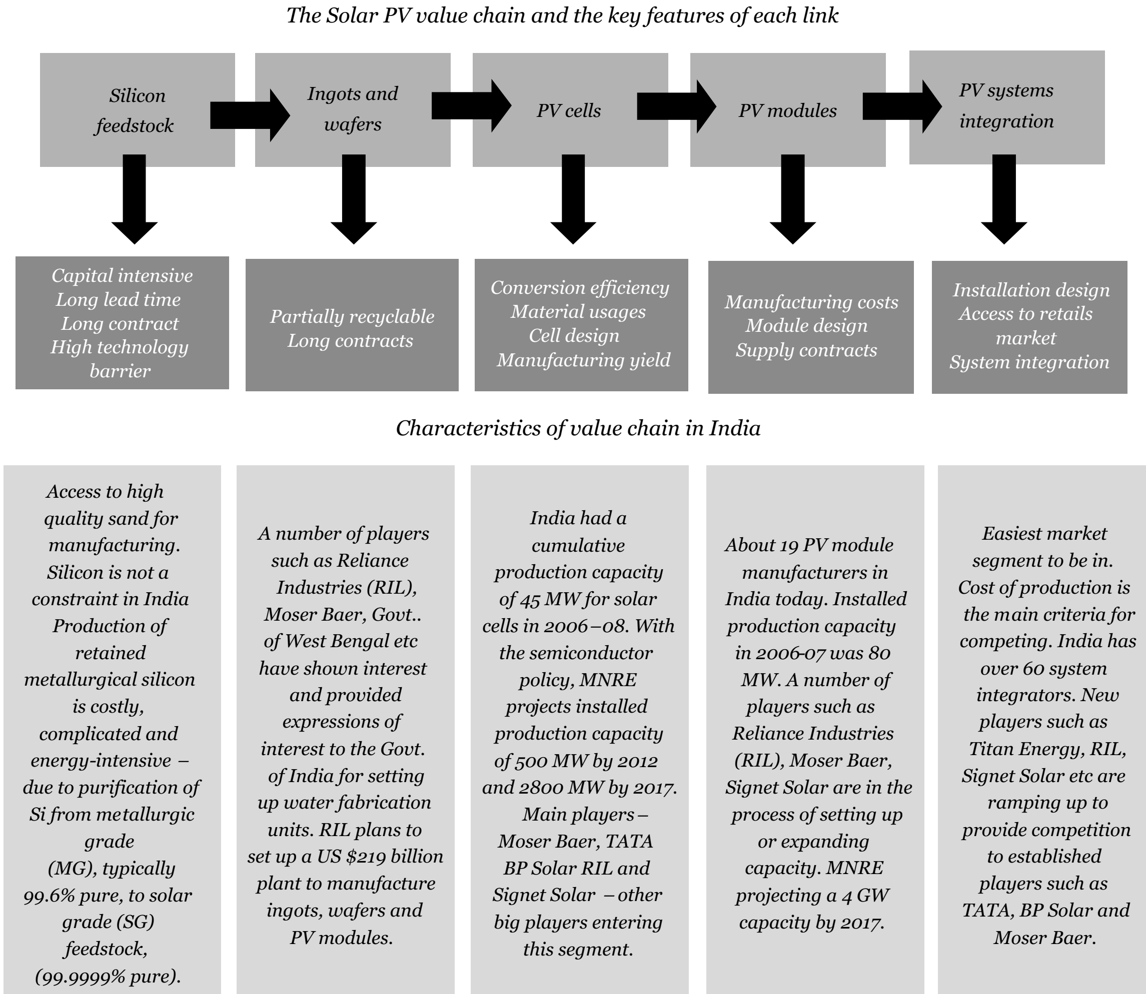
[8] *Renewables 2012, Global Status Report*, published by REN21, www.ren21.net

[9] For an estimation of the capacity of solar power in India please see, Government of India. 2012. *Annual Report 2011-12*. New Delhi: Ministry of New and Renewable Energy. For overall manufacturing capacity of solar PV modules please refer to *The India Solar Handbook*, June 2012 edition by Bridge to India, bridgetoindia.com.

[10] *The India Solar Handbook*, June 2012 edition by Bridge to India, bridgetoindia.com.

India houses a sizeable industrial base which comprises nine manufacturers of solar cells and 19 manufacturers of PV modules. Additionally, 60 companies are engaged in the assembly and supply of solar PV systems. List of major players in solar PV industry in India is presented in Table 2.5.

Figure 2.4 Solar PV Value Chain in India



Source: Compiled by authors

Table 2.5 Indian Solar PV Manufacturing Companies

S. No.	Name of company	Focus area in solar PV	Brief profile (manufacturing)
1	Reliance Industries Limited (RIL)	Manufacturing and development of SPV based power plants	The Reliance Group is India's largest private sector enterprise, with businesses in the energy and materials value chain. The entire group's annual revenues are in excess of US$ 27 billion.
2	Moser Baer Photo Voltaic Limited (MBPV)	Present across the entire value chain and investments in multiple PV technologies	Moser Baer India Ltd. is India's largest and the world's third largest manufacturer of removable optical storage devices. Area of Investment in Solar PV Moser Baer has set up a subsidiary called MBPV for its foray into SPV. **Manufacturing:** MBPV has invested US$ 58 million (Rs 260 crore) in an SPV cell and module manufacturing plant in India with a capacity of 80 MW. The current production capacity of 90 MW crystalline cells, 100 MW crystalline modules, and 50 MW thin films with expansion plans in place
3	TATA BP Solar	Manufacturing and consultancy services	TATA BP Solar is a joint venture between TATA Power Company and BP Solar. TATA BP Solar has a fully integrated solar manufacturing plant, including cell manufacture, module assembly and Balance of Systems (BOS), all at one site. TATA BP Solar provides customized solar solutions for lighting, water pumping, water heating and backup power. TATA BP Solar has also designed specialized applications for railway signaling systems and offshore platforms. **Manufacturing:** State-of-the-art 125 MW module manufacturing facility, one of the largest in Asia and capable of manufacturing modules from 0.3Wp to 280Wp and beyond, four manufacturing units.
5	Indo Solar	Manufacturer of multi-crystalline PV cell	Currently 160 MWp capacity, to be expanded to 260 MWp by end of 2011 fiscal year. Line C will have the capability to produce both multi and mono crystalline cells.
6	Maharishi Solar Technology (P) Limited (MSTPL)	Manufacturing	MSTPL, an ISO 9001:2000 certified company, was established in1999 to harness solar energy for application in residential, commercial, industrial and agricultural areas. **Manufacturing:** The company has set up a vertically integrated manufacturing facility to produce multi-crystalline silicon ingots, wafers, cells, modules and systems. The plant capacity is 2.5 MW per annum and is being expanded to 15 MW per annum by 2010. The company is also foraying into polysilicon. It has set up a 100 ton R&D project, which the company plans to scale up to 3,000 tons at a later stage.
7	Websol Energy Systems Ltd. (formerly Webel SL Energy Systems Ltd.)	Manufacturer of photovoltaic monocrystalline solar cells and modules	Present capacity of the company is 42 MW and this will ramp up to 60 MW by May 2011 and to 120 MW by 2012.
8	Photon Energy Systems Limited	Manufacturer of mono/multi crystalline PV Modules	Established in 1995, annual capacity of 30 MW
9	Bharat Heavy Electrical Limited (BHEL)	Manufacturing, concept-to-commissioning services	BHEL is the largest engineering and manufacturing enterprise in India in the energy-related/infrastructure sector today. BHEL manufactures over 180 products under 30 major product groups and caters to core sectors of the Indian economy, viz., power generation and transmission, industry, transportation, telecommunication, renewable energy, etc. **Manufacturing:** BHEL has made substantial investments in the renewable energy space, especially in solar technologies. It supplies both SPV and solar thermal products. BHEL manufactures high efficiency mono-crystalline

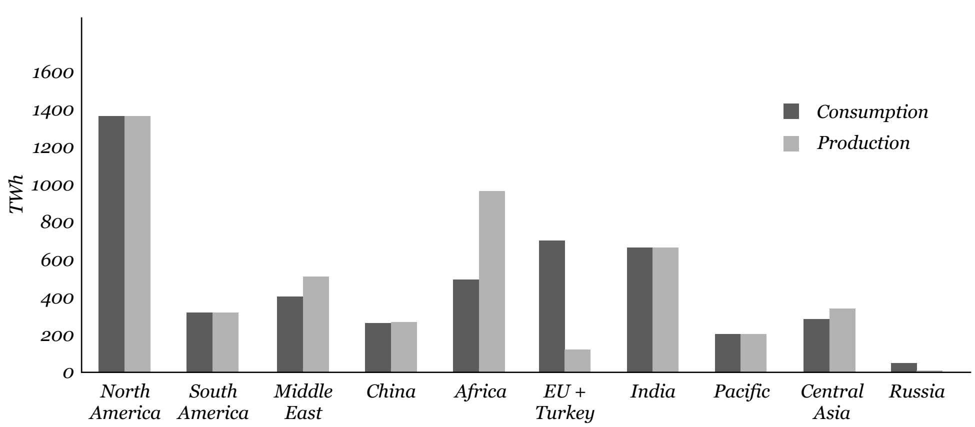
S. No.	Name of company	Focus area in solar PV	Brief profile (manufacturing)
			solar cells using highly efficient CZ single crystalline technology. BHEL also manufactures a wide range of SPV module suitable for a variety of applications. BHEL has also undertaken the development of SPV based power plants on a turnkey basis across India, which include stand alone and grid connected plants as well as hybrid systems.
10	Central Electronics Limited (CEL)	Manufacturing and consultancy services	CEL is one of the largest manufacturers of SPV cells, modules, and systems in India. CEL has undertaken in-house development and R&D to convert a laboratory concept into an industrial technology for SPV manufacturing. **Manufacturing:** CEL has an integrated production facility to manufacture mono-crystalline silicon solar cells and modules with the state-of-the-art screen-printing technology. The company has supplied over 0.15 million SPV systems in India and abroad, covering both rural and industrial applications. CEL's SPV modules are the only ones from India certified both for design and quality by the European Commission–Joint Research Centre at Ispra, Italy. CEL has now got plans to scale up its production facilities of SPV cells and modules from 2 MWp per annum through better production management.
11	TITAN Energy Systems Ltd (TESL)	Module Manufacturing and Turnkey Solar Power Plant EPC company	TESL having the manufacturing capacity of 3 MWp in 1999, expanded to 15 MWp in 1999, currently operates a manufacturing capacity of 100 MW and is expanding significantly its module production to achieve manufacturing capacity of 500 MW
12	Rajasthan Electronics & Instruments Ltd (REIL)	Manufacturing and consultancy services	REIL is a joint venture between the Government of India and the Government of Rajasthan and has been conferred the status of a 'Mini Ratna'. REIL started operations in the SPV sector in 1985 through the development of an SPV module manufacturing facility that has now expanded to cover balance of systems for a large number of applications. The company develops products through in-house R&D and has a capacity of 2 MW per year on single shift basis.

Note: Wp Wattspeak; SPV Solar photovoltaic; MWp Megawatts peak
Source: Compiled by authors

2.2.3 Concentrated Solar Thermal Power Market

In the medium term, India is expected to be one of the world's major CSP players, following USA and North Africa, as shown in Figure 2.5.

Figure 2.5 Production and Consumption of CSP Electricity by 2050



Source: International Energy Agency. 2010. *Technology Road Map – Concentrated Solar Power*. France: OECD/IEG

Several private sector players have expressed interest in the solar thermal space in India. These include India-based firms, international organizations, and joint-venture partnerships between Indian firms and global players.

In March 2009, India-based ACME Group signed a 1 GW licensing agreement with e-Solar for US$30 million to develop projects in India and thus received an equity stake in the US company. Then ACME signed a 50 MW PPA with BSES Delhi in January 2010, with commissioning planned for 2011. Other technology promoters, including Power Cube Pvt. Ltd. and Electrothermal India Ltd., are seeking CSP solutions that circumvent grid instability, primarily for industrial supply. The Italian consortium Solare XXI has announced a technology supply agreement with Entegra Ltd. of India for a 10 MW commercial plant in Rajasthan [Emerging Energy], and another 10 MW CSP power plant, also in Rajasthan. Suryachakra MSM Solar India Pvt Ltd is a joint venture company formed between Suryachakra Power and MAN Solar Millennium for transfer of CSP Technology to project developers in India. This joint venture aims to indigenize technology components and minimize import of critical components to achieve cost reductions. Given India's solar power potential of 5,000 trillion KWh per year, a favorable regulatory atmosphere, and the supply–demand gap, it is only natural that solar power will be one of the thrust areas of future Indian governments.

Indian and international players engaged in diversifying into solar power plant business are looking at business avenues as project promoters, equipment manufacturers and / or EPC contractors. A comprehensive list of stakeholders across the value chain has been provided in Figures 2.6 and 2.7.

International

Figure 2.6 Global Value Chain of Players in Concentrated Solar Power

International

R&D	*Manufacturers*	*Project developers*	*Investors/ creditors*	*Regulators*	*EPC*	*Operators/ IPP*	*Utilities*
CIEMAT/PSA	***~ 3M***	***Abengoa***	***ADB***		***Abener***	***Abengoa***	
CNRS	***• Alstom***	***Acciona***	*Banc sa badell*		***Acciona***	***Acciona***	
CERTH	*~ Balcke-Durr*	*ACS*	*Banesto*		*Aries*	*ACS*	
DLR	*~ Defi Systemes*	*Albiasa Solar*	*Caja Madrid*		*« Astrom*	*Aries*	
DOE	** Flabeg*	*Aries*	*Calyon*		*± Babcock*	*Enerstar*	
Fraunhofer ISE	***• GE***	*Ausra*	*CAM*		*Montajes*	*FPL Energy*	
IDEA	*¤ GEA Iberica*	*Brightsources*	*Cofides*		*Cobra*	*Iberdrola*	
IEA Solar Paces	**** Guardian***	*Enerstar*	*Commerzbank*		*± Duro*	*Ibereolica Solar*	
INETI	*# Kraftenlagen*	***esolar***	*EIB*		*Felguera*	*Masdar*	
NREL	*Munchen*	*Iberdrola*	*Fidelity*		*Elecnor*	*Solar Millennium*	
PSI	*• MAN Turbo*	*Ibereolica*	***ING***		***+ Fichtner***	*Valoriza*	
SANDIA	*• Novatec Biosol*	*Solar*	***JBIC***		*+ Flagsol*	*Sener*	
Weizmann	** Rioglass*	*Novatec*	*KfW IPEX*		*FPL Energy*		
Institute	** Saint-Gobain*	*Biosol*	*Lupus Alpha*		*Iberese*		
	# Schott Solar	*SES*	*Masdar*		*Isolux*		
	• Siemens	*Skyfuel*	*Natixis*		*Kraftanlagen*		
	# Solel	***Solar***	*Piraeus Bank*		*Munchen*		
	¤ SPX Cooling	***Millennium***	*Santader*		***Man Solar***		
	~ Thermodyn	*SolarReserve*	*Sl Capital*		***Millenium***		
	Valoriza	*Torresol*	*Societe Generale*		*M+W Zander*		
		Swisscanto			*Sener*		

Note: * Glass/Mirrors, # Receivers, Collectors, Turbines, € Cooling equip., ~ Others, + Engineering/ consulting, Just engineering, Just construction Companies highlighted in bold have already established business in India.

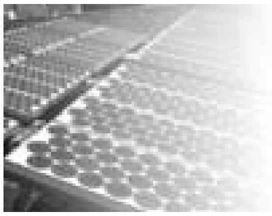
Indian Organizations

Figure 2.7 Indian Value Chain of Players in Concentrated Solar Power

Indian organizations

R&D	Manufacturers	Project developers	Investors/ creditors	Regulators	EPC	Operators/ IPP	Utilities
SEC TERI IIT Mumbai IIT Chennai NAL Gandhia Solar Clique Solar CGRI		About 30Nos Abengoa Astonfield ACME Solar JSW Energy Dalmia Infinia	IREDA PFC REC IL&FS SBI ADB World Bank Deutche Bank Standard Chartered Kotak Mahindra	CERC SERCs	BHEL L&T Essar ABENCS NTPC	New Promoters	State utilities Private utilities Tata Power Jodhpur Vidyut Vitaran Nigam Ltd. Rajasthan Rajya Vidyut Prasaran Nigam Ltd. GPCL GETCO

Note: The Indian players except R & D institutes are the ones who have shown interest in developing CSP portfolio. Some of them are actively considering project development, setting up manufacturing facilities etc

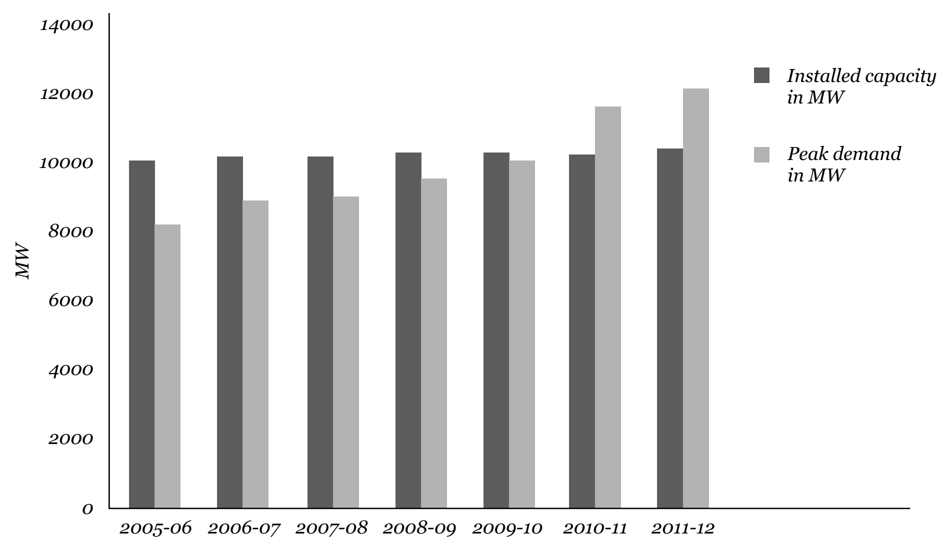


3

Power Scenario in Tamil Nadu

Tamil Nadu has power generation capacity across hydro, thermal, gas and wind through a mix of state-owned, central, and privately operated power plants where the contribution of the state-owned wind power plants is only 0.2% of the total.[1]Tamil Nadu accounts for 32% of India's total consumption of non-conventional energy (grid connected) and about 42% of the state's energy that comes from renewable resources (as on 29 August 2012).[2] Almost all of these efforts are privately driven and funded. Besides good renewable energy resources in the state, one of the reasons for promotion of renewable energy power in Tamil Nadu pertains to the fact that it does not have any coal resources.

Figure 3.1 Trend of Installed Capacity and Per Capita Consumption in Tamil Nadu



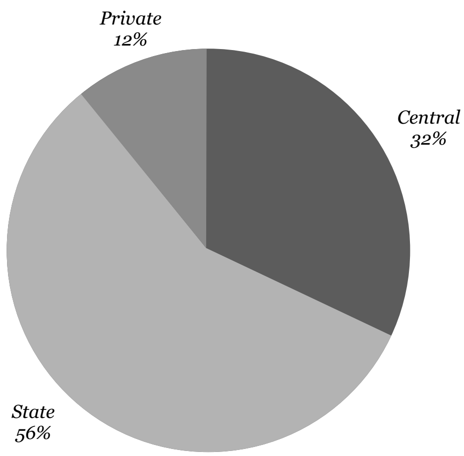
Source: Policy Note, 2012-2013 by Energy Department, Demand No. 14, Government of India, Tamil Nadu. Available at: http://www.tn.gov.in/policynotes/pdf/energy.pdf. Last accessed on 20 November 2012

Peak demand in the state for the year 2011–12 was 12000 MW with per capita energy consumption of 1040 units (2010-11 figures).[3] Industrial sector consumed the maximum amount of power in 2009-10.[4]

[1] By October 2011 http://www.teda.in/index.php?r=site/index&id=4K4O7q4M8A [accessed on 26 August 2012]
[2] http://www.indiastat.com; last accessed on 26 August 2012]; http://www.tangedco.gov.in/template1.php?tempno=&cid=0&subcid=184; last accessed on 26 August 2012
[3] Policy Note, 2012-13,Energy Department, Government of Tamil Nadu
[4] As on 11 December 2009, www.indiastat.com [accessed 26 August 2012]

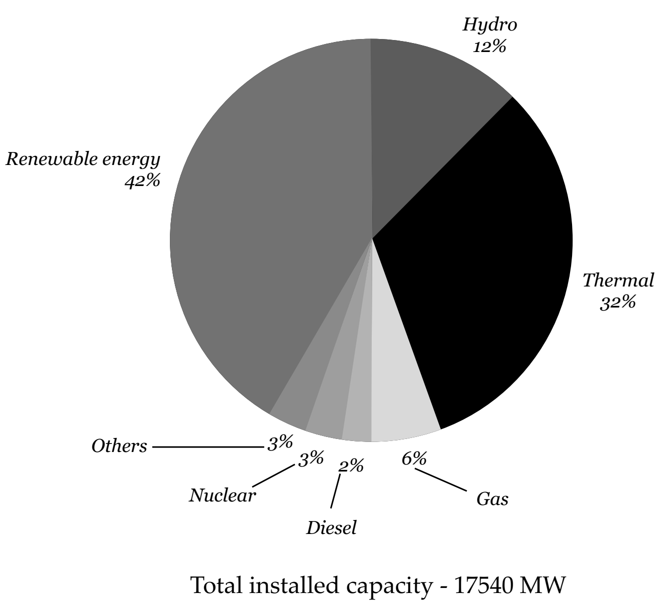
Currently Tamil Nadu Electricity Board (TNEB) has a total installed capacity of 10,237 MW which includes all central, state as well as independent power producers (IPPs). Besides these, the state also has installations in resources like windmills, biomass and cogeneration up to 7303 MW. As of now, the total installed renewable energy installed capacity in Tamil Nadu is 7846.07 MW.[5] Figures 3.3 and 3.4 highlight the current power share status in the state.

Figure 3.2 Installed Capacity by Ownership



Source: As on 19 March 2012. www.indiastat.com, last accessed on 26 August 2012

Figure 3.3 Installed Capacity by Resource



Source: As on 19 March 2012. www.indiastat.com, last accessed on 26 August 2012

Tamil Nadu Energy Development Agency (TEDA), a state government entity established in 1985, deals with renewable energy related projects. The renewable energy potential of the state has been presented in Table 3.1. It can be seen that wind energy has the maximum potential in the state, followed by solar energy.

The state has taken initiatives for implementing both grid-connected and off-grid applications of the technology, as explained in detail in the next section. Total grid interactive renewable energy deployment in the state for the

[5] www.teda.in, last accessed on 26 August 2012

year 2009 was 5089 MW (as on 30 June 2009). Tables 3.2 and 3.3 summarize the various renewable energy resources deployed in grid-interactive power generation and off-grid purposes, respectively.

Table 3.1 Renewable Energy Potential of Tamil Nadu

Renewable energy	Potential (MW)
Wind energy	5374/14497
Solar energy	4.5 – 6 kWh/m^2/day
Small hydro	660
Co-generation	450
Biomass	1070

Notes: Wind energy 5374 MW at 50m height and 14497 MW at 80m height.
Sources:
1. Wind energy, http://www.cwet.tn.nic.in/html/departments_ewpp.html, last accessed on 25 August 2012;
2. Solar energy, http://www.nrel.gov/international/images/dni_annual.jpg, last accessed 24 August 2012; and
3. Biomass Energy Statistics 2012. Available at http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2012_28mar.pdf, last accessed on 25 August 2012.

Table 3.2 Grid Interactive Renewable Energy Deployment (as on 31 March 2012)

Small hydro power	Wind power	Bio-power (Biomass)	Bio-power (waste to energy)	Cogeneration of power	Solar power	Total capacity
90.05	6970.62	161.15	4.25	610.10	10	7846.07

Source: www.teda.in, last accessed on 26 August 2012

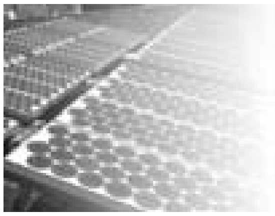
Tamil Nadu is the leading state in wind energy with 6971 MW capacity installed (as on 31 March 2012).[6] The state also generates the third largest amount of biomass energy with around 340 MW capacity installed.[7]

6 http://www.inwea.org/aboutwindenergy.htm, last accessed on 2 December 2010.
7 http://greenworldinvestor.com/2010/09/27/green-invsting-in-india-how-tamil-nadu-became-the-biggest-alternative-energy-state/ last accessed on 7 December 2010.

Table 3.3 Off-grid Renewable Energy Deployment

States/ UTs	No. of biogas plants	No. of water pum-ping wind mills	No. of SPV Pumps	Solar photovoltaic				Solar water heater systems	Aerogen hybrid system (KW)	Solar cooker (Nos.)	Biomass gasifiers (MW)	Waste to energy		Remote Village Electri-fication Villages/
				SLS (Nos.)	HLS (Nos.)	SL (Nos.)	PP (Nos.)					Industrial (MW)	Biogas (Mwe)	Hamlets
Tamil Nadu	218,009	60	829	6350	600000	3213	739	4206	25	1536	10327	6.14	-	101

Notes: SLS: Street lighting system; HLS: Home lighting system; SL: Solar lantern; PP: Power plants; SPV: Solar photo voltaic. Data related to HLS, SL, and PP is dated March 2012. Data on solar water heater systems is dated November 2011.
Source: www.indiastat.com, last accessed on 26 August 2012; data for solar water heater systems is sourced from http://www.teda.in/site/index/id/9K5k8a9k4m, last accessed on 26 August 2012.



4

Institutional Framework and Policies on Renewable Energy in Tamil Nadu

4.1 Tamil Nadu Energy Development Agency Institutional Framework

The government of Tamil Nadu recognized the significance of renewable energy resources and set up a separate agency as a registered society, called the Tamil Nadu Energy Development Agency (TEDA) in 1985. It is the nodal agency for the promotion of renewable energy and energy conservation in the state, under the overall administrative control of the Energy Department. The objective behind the establishment of TEDA was as follows:

- To promote the use of new and renewable sources of energy and to implement projects there of
- To promote energy conservation activities
- To encourage research and development on renewable sources of energy

The TEDA is actively engaged in:

- Identification and potential estimation of renewable energy in the state
- Creating awareness on the potential and prospects for use of renewable energy
- Enhancing contribution of renewable energy in the overall energy mix in the state grid

Tamil Nadu Energy Development Agency has played very active role in promoting renewable energy in the state.

1. It facilitates wind power development by undertaking wind resource assessment, setting up demonstration wind farms, offering financial incentives, etc. Indeed, the initial wind power demonstration projects were instrumental in facilitating private sector investments in wind in the country by establishing techno-economical feasibility of wind energy. The costs and quantum of wind power generation observed helped in framing out first guidelines for the preferential tariff.
2. It encourages investment through attractive power purchase policies such as wheeling and banking facilities at concessional rates for captive use, reasonable tariff for power sold to Tamil Nadu Electricity Board (TNEB).
3. It has carried out taluk/district level biomass assessment studies and encouraged private investment in biomass power projects.
4. It has taken up implementation of electrification of un-electrified habitations using solar lighting and other renewable energy sources.
5. It facilitates setting-up of grid interactive solar power plants.
6. It has developed a Renewable Energy Policy (REP) for the state.

4.2 Policies and Programs

Policies encourage/mandate that utilities buy renewable energy based power, promote companies that are interested in setting up renewable energy projects, support equipment companies that manufacture renewable energy equipment, and incentivize private and government entities to undertake R&D related to renewable energy through largely financial, fiscal incentives or special directives in India. Policy initiatives encourage domestic private as well as foreign direct investments with a provision of fiscal and financial incentives such as tax holidays, accelerated depreciation, and duty rebates. While policy measures at the center are administered through the

Ministry of New and Renewable Energy (MNRE), state governments make available infrastructural facilities for wheeling of power and buying power from renewable units. Some of the fiscal incentives provided by the central government for solar and wind power is listed in Table 4.1.

Table 4.1 Policy Framework and Key Incentives for Renewable Energy Technologies

Technology	***Policy framework***	***Key incentives***
Wind power	• Fiscal and financial incentives • Wheeling, banking, third party sale, buy-back facility by states • Capital subsidies and sales tax incentives in certain states	• Concessional import duty on specified wind turbine parts • 80% accelerated depreciation • Customs and excise duty relief • Loans through Indian Renewable Energy Development Agency (IREDA) • Tax holiday for power generation project
Solar photo voltaics	• No specific conditions for JV formation 100% EOU to set up a manufacturing plant • Technology transfer for manufacture of silicon solar cells and PV systems	• Ministry of New and Renewable Energy (MNRE) financial incentives for solar PV grid connected power projects • IREDA financial package for solar photovoltaic (power generation systems) • MNRE financial incentives for solar photo voltaic systems

Source: Ministry of New and Renewable Energy, Government of India, New Delhi

4.2.1 Grid Interactive Power Generation

The installed generating capacity had grown manifold from 156 MW in 1950–1951 at the beginning of the First Plan to 7924 MW in 2002–2003 at the beginning of Tenth Plan with a compound annual growth rate of 8% and it has reached 10237 MW by the year 2010–11.[1] Tamil Nadu is the leading Indian state in grid-connected renewable energy based power, especially wind energy. During the Ninth Five Year Plan (1997–2002), wind capacity in the state increased from 728 MW to 6971 MW, which is 27% of the TNEB's grid capacity, much higher than the target of 10% set by government to be achieved by 2012.[2] The total installed capacity of wind energy in the state was 6970.62 MW as on 31 March 2012. In recognition of Tamil Nadu's commendable achievement in wind power generation, the state was awarded the first prize for its wind power program (2002–2007). A package of incentives which include fiscal concessions, custom duty, excise duty exemption and 10-year tax holiday are available for wind power projects from the government. Intra-state open access regulations have been notified and preferential tariff orders are in place for wind power projects, as determined by Tamil Nadu Electricity Regulatory Commission (TNERC). A tariff of Rs 3.51 per kWh has been fixed for the period of 1 August 2012 to 31 July 2014. The wind mills commissioned prior to this order date till September 2008 are eligible for a tariff of Rs 3.39 per kWh.[3]

Tamil Nadu Electricity Board has introduced the concept of banking in 1986 to encourage generation of wind energy. The banking of wind power can be done for up to one year, commencing from 1st April and ending on 31st March of the following year, and the banking charge is 5%. Similarly, wheeling and transmission charges including line losses at stand 5% for both captive use and third party sale of wind energy in the case of high tension and extra high tension consumption; for low tension services, the charges stand at 7.5%.

A package of incentives which includes fiscal concessions such as accelerated depreciation, concessional customs duty, excise duty exemption, income tax exemption on projects for 10 years, etc. are available from Government of India for biomass-based power projects. Since December 2006, capital subsidy in lieu of interest subsidy is being provided by MNRE for grid interactive renewable energy projects (except wind in private sector) through concerned financial institutions, after the project has been successfully commissioned. In the case of

[1] *Policy note 2012-13*, Energy Department, Government of Tamil Nadu
[2] Comprehensive Tariff Order on Wind Energy, Order 6 of 2012, 31 July 2012 by TNERC. Available at http://tnerc.tn.nic.in/ last accessed on 27 August 2012
[3] Comprehensive Tariff Order on Wind Energy, Order 6 of 2012, 31 July 2012 by TNERC. Available at http://tnerc.tn.nic.in/ last accessed on 27 August 2012.

bagasse co-generation, projects in cooperative/public/joint sector sugar mills, 50% of the subsidy amount is released to the financial institutions after sanction of loan and the balance after successful commissioning. In 2009, Commission adopted "Cost Plus Two Part Tariff" wherein two part tariff is adopted when the fuel cost is considered a pass through and varies from time to time. The variable component of tariff takes care of such price escalation. In the recently released tariff orders by TNERC, effective from 1 August 2012, the rate for purchase of power by TNEB is Rs 3.06 per unit and Rs 3.188 per unit for the year 2013–14. Ministry of New and Renewable Energy subsidy is available for all projects generating power from urban and industrial wastes. In case of solar power, the state is working as per Jawaharlal Nehru National Solar Mission (JNNSM) guidelines, the details of which have been discussed in the specific section on JNNSM.

4.2.2 Stand-alone RE System

In view of its inherent advantages, the state government had made the use of solar water heating systems mandatory in certain types of new buildings in the state in the year 2002, by amending the building by laws. The Ministry of the New and Renewable Energy is providing capital subsidy per unit collector area at the rate of 30% of the benchmark cost. Besides capital subsidy, soft loans at 5% interest are available for balance cost.

The state government had earlier provided subsidy to domestic and institutional users for installing solar water heating systems. But now, it has been restricted to 100% cost for installation in government institutions. Every year, a few government hostels/hospitals have been provided with these systems. As in November 2011, a total of 25657.96 square meter collector area has been covered in domestic, government, and private institutions through installation of 4206 in-system installations.[4]

Around 750 SPV home lighting systems and 6000 SPV street lighting systems were installed in Tamil Nadu in 2012, which in turn have been allotted to various districts through district collectors for implementation under the subsidy scheme.. Under Part-II scheme for 2007–2008, the state government sanctioned Rs 10.00 lakh for providing 5 solar vaccine refrigerators to primary health centers in remote areas to provide the essential vaccines and life-saving medicines to the needy.

Tamil Nadu achieved 100% rural electrification a long time ago. But there are still a few remote habitations in forest areas which could not be electrified due to problems of long distance and forest clearance etc. Based on the list of habitations furnished by TNEB, which might not be electrified through grid, MNRE sanctioned the Remote Village Electrification (RVE) Phase-I program for electrification of 150 remote habitations using solar lighting systems. The cost, including 5 years maintenance, is to be shared by the central and state governments. The work was completed in March 2007 by providing 5190 SPV home lighting and 283 SPV street lighting systems in 128 habitations in 12 districts at a total cost of Rs 8.25 crore. Some of the other habitations were subsequently electrified by TNEB.

Further under Phase-II, it is proposed to take up electrification of 74 additional habitations in 6 districts. When this scheme is implemented, Tamil Nadu will achieve the distinction of completing electrification of all un-electrified remote habitations as identified by TNEB.

The Ministry of New and Renewable Energy introduced Village Energy Security Program with the objective of meeting the total energy needs of unelectrified and remote hamlets using locally available renewable energy sources. In Tamil Nadu, 4 hamlets in Krishnagiri, Dharmapuri, and Dindigul districts have been selected for implementation as test projects, through the District Forest Officers, for which 90% cost (Rs 49.54 lakh) is provided by MNRE and the balance by the state government. The work in Periakallupalli and Jodugarai in Krishnagiri district, Karapadi in Dharmapuri district have been completed whereas the work in Thenmalai in Dindigul district is nearing completion.

The state government also provided subsidy at 30% of cost for installation of toilet-linked biogas plants in institutions and women sanitary complexes in Panchayats.

4.2.3 Other Schemes

The Integrated Rural Energy Programme (IREP) which was earlier implemented in 21 blocks only was revamped by MNRE and extended to all the rural districts in the state. The scheme involves preparation of detailed energy plans in three selected village clusters in each district by the District IREP Cell in the District Rural Development Agency (DRDA) Office with the assistance of local technical institutions as District-level Technical Back-up Units (DTBUs) under the guidance of the state IREP Cell (in TEDA Office) and the state-level TBU.

[4] http://www.teda.in/site/index/id/9K5k8a9k4m last accessed on 27 August 2012.

Renewable Energy Parks are being set up in various institutions to create awareness among the public on the uses of renewable energy devices. Government of India (MNRE) subsidizes 75% of the cost of equipment for the first district level park and 50% for the second park in the same district. So far, 19 energy parks are functioning in 18 districts of Tamil Nadu. Further a State Energy Park is being set up at Tamil Nadu Science and Technology Centre, Kotturpuram in Chennai.

The state government has sanctioned funds for carrying out a study and collect data on private wind mills installed in the state and their performance during 2007–2008.

A special economic zone (SEZ) is being set up in Tamil Nadu with support from TEDA for manufacturing government approved RE devices. On 14 July 2007, the Government of Tamil Nadu signed an MoU with private promoters for the first SEZ of this kind in the world, exclusively for renewable energy projects in Chengleput taluk and Kancheepuram district.

4.3 Awareness and Promotion

From time to time TEDA takes up a number of activities not only for the promotion of renewable energy but for energy efficiency in the state, which is also a part of its mandate. Its activities related to promotion and advocacy include:

- Promotion of cogeneration in sugar mills for the first time in India in 1992 through pilot projects in cooperative sugar mills, which later attracted huge investments from the private sector.
- Encouragement to decentralized power generation for rural applications through solar lighting, solar water/air heating, solar/wind mill, water pumping, biomass gasifiers, biogas plants, etc.
- Organization of awareness programs on the use of renewable energy and energy conservation and efficiency for different sections of the public, for example, seminars, exhibitions and business meet, mobile exhibition vans and renewable energy parks.
- Enabling energy recovery from agro, industrial, and municipal solid waste.
- For creating awareness among school children, TEDA has also developed a short video film. Besides, a Green Energy Campaign was organized by TEDA in 2011–2012 to promote ideas and business plans in renewable energy all over the state.
- Two mobile exhibition vans fitted with working models of renewable energy gadgets travel throughout Tamil Nadu on request from educational institutions (colleges and schools), NGOs, exhibitions, seminars etc., to spread the awareness about renewable energy as per MNRE guidelines.

4.4 Tamil Nadu Electricity Board

The Tamil Nadu Electricity Board is constituted under the Electricity (Supply) Act, 1948 and authorized to function as the state transmission utility and a licensee as notified by the Government of Tamil Nadu under the Electricity Act, 2003. Tamil Nadu Electricity Board is engaged in activities related to generation, transmission, and distribution of electricity. It has a total installed capacity of 15800 MW, which includes 5586 MW of renewable energy sources like wind, biomass, and cogeneration.

The transmission network expansion is aimed at raising the transmission voltage from 230 kV to 400 kV. Tamil Nadu Electricity Board has taken up the indigenous erection of 400 kV substations and lines. Establishment of 765 kV transmission lines is also under investigation.

To augment the power supply, the Government of Tamil Nadu has also permitted third party sale of power produced by IPPs, captive power producers and other private power producers through short-term intra-state open access to high tension consumers within Tamil Nadu as it will provide an incentive to the generators within the state to produce at their fullest capacity.

The success of wind power in Tamil Nadu underlines the crucial role played by TNEB, especially in the formative years of wind power development. This was a clear departure from other states where renewable energy activities are normally looked after by the state energy development agencies.

4.5 Power Purchase Agreement

Section 61 of the Electricity Act, 2003 (Central Act 36 of 2003) stipulates that the State Electricity Regulatory Commission (SERC) shall specify the terms and conditions for the determination of tariff. In accordance with the above stipulation, the Commission notified the "Power Procurement from New and Renewable Sources of Energy Regulations 2008" in February 2008.

The salient clauses of the existing PPA for wind are as follows:

- The distribution licensee (DL) agrees to establish the interface lines up to the interconnection point in the case of sale of entire power to the DL by the wind energy generator (WEG). If the WEG decides to use such agreed power to be sold to DL, for his captive use or for sale to third party or to another DL, before wheeling of such power to his captive use or sale to third person or to other DL, then the WEG agrees to reimburse the entire cost of interfacing lines to DL.
- The WEG agrees to minimize drawal of reactive power from DL (there will be a reactive power charge of 25 paise per kilo volt amps reactive hour [kvarh] for up to 10% of net power and 50 paise per kvarh for more than 10%)
- The interfacing lines will be maintained by the DL at its own cost.
- The DL shall make payment to the WEG within 30 days of receipt of the bill. Payment delayed beyond 30 days is liable for interest at the rate of 1% per month.
- The agreement will be valid for 20 years from the date of execution.

The salient points of the existing PPA for solar energy are as follows:

- The DL agrees to establish the interface lines up to the interconnection point. The solar power generator (SPG) agrees to pay the infrastructure development charges (IDC) of Rs 25.75 lakh per MW to DL for establishing, operating, and maintaining the line/sub-station.
- The SPG shall be treated as MUST RUN power plant and shall not be subjected to merit order dispatch principles.
- The SPG agrees to minimize drawal of reactive power from DL's grid as stipulated in the Indian Electricity Grid Code/Tamil Nadu Electricity Grid Code/Commission's orders in force.
- The interface lines shall be maintained by DL at its own cost.
- The State Load Despatch Center (SLDC) may instruct the SPG to schedule its power.
- The generation-based incentive (GBI) will be payable to the DL by IREDA (Programme Administrator) for the energy sold by the generator. The GBI shall be equal to the difference between the tariff determined by the Central Commission and the base rate, which was Rs 5.50 per kWh for the financial year 2010–11 and thereafter escalated at 3% per year.
- Reactive power charges are recoverable as per the regulation/code in force.
- Distribution licensee shall make payment to the SPG for the solar energy purchased (including deemed purchase corresponding to captive consumption met from solar generation) within 30 days of receipt of the bill. Payment delayed beyond 30 days is liable for interest at the rate of 1% per month.
- The agreement shall remain valid for 25 years.
- A key feature of the solar PPA is that if the partial completion of the project is more than 100kW, SPG can feed this to the grid and the partly commissioned capacity shall be considered to be eligible for GBI subject to conditions.

4.6 Renewable Purchase Obligation

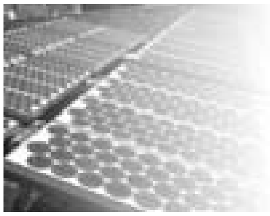
Renewable Purchase Obligation (RPO) is mandated by SERC for power utilities. Under Electricity Act, 2003, SERCs set targets for distribution companies, captive consumers, and open access customers to purchase certain percentage of their total power requirement from renewable energy sources. This target is termed as renewable purchase obligation. The RPO for Tamil Nadu is presented in Table 4.2.

Table 4.2 RPO as a Percentage of Total Power Consumption for Tamil Nadu

Period		2011-2012	2012-2013
RPO	Solar	0.05%	0.05%
	Total	9%	9%

Source: Draft Notification in 2012, Tamil Nadu Electricity Regulatory Commission. Available at http://tnerc.tn.nic.in/regulation/draft%20regulations/2012/RPO%20Amendment-24-08-2012.pdf, last accessed on 27 August 2012.

Distribution companies, open access consumers, and captive power plants have RPOs to purchase a minimum level of renewable energy from the DL in their area (else the option of purchasing renewable energy certificates [RECs] to meet the RPO also exists).



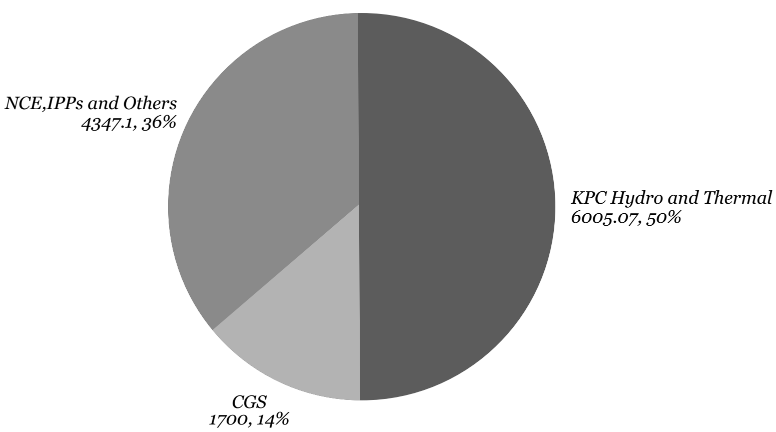
5

Power Scenario in Karnataka

Karnataka stands fifth in the total installed capacity of power generation and third among the state-owned installations in the country.[1] It consumes around 6.64% of the power generated in the country (2010–11 figures).[2] The rapid growth of the state has necessitated the investment in development of better and more reliable power demand in the state of Karnataka. Within the state, about 50.2% of installed capacity is under public sector and rest is owned by private sector.[3] By December 2011, state owned power generating plants were about 80% of this share.[4] The power generation scenario in Karnataka is a mixed lot of renewable and conventional sources. In fact, Karnataka is one of the pioneering as well as self-initiating states to promote renewable energy. Around 30% of the total power generation is supplied from renewable energy sources, with maximum share of wind power.[5]

By July 2012, Karnataka had total installed capacity of 12052. MW with maximum contribution from state-based thermal power plants, followed by non-conventional energy and independent power producers and central government. Karnataka successfully encourages private sector investments for power generation through both, conventional as well as non-conventional resources. Figure 5.1 illustrates the installed capacity and their shares by various sectors. Figure 5.2 illustrates source-wise power generation in the state.

Figure 5.1 Installed Capacity in Karnataka as on July 2012



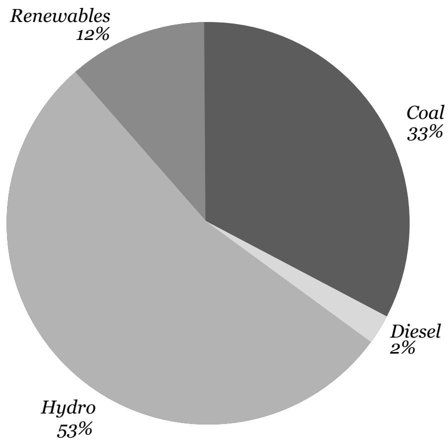
Total installed capacity = 12052.17 MW
Capacity in MW

Source: http://www.kptcl.com/kptclstatistics.htm. These statistics have now been updated up to October 2012. Available at http://110.234.115.69/Statistics/KPTCL%20at%20a%20Glance.pdf

[1] http://www.advantagekarnataka.com/images/sector-profiles/Energy-Profile.pdf [Accessed on 24 August 2012]
[2] http://www.advantagekarnataka.com/images/sector-profiles/Energy-Profile.pdf [Accessed on 24 August 2012]
[3] *Economic Survey of Karnataka*, 2011-12 from Ministry of Planning Commission, Government of India.
Available at http://planning.kar.nic.in/sites/planning.kar.nic.in/files/Economic_Survey/2011-12/Economic%20Infrastructure.pdf [Accessed on 24 August 2012]
[4] Footnote 3.
[5] Footnote 3.

Table 5.1 shows the current installation against the potential. Karnataka Renewable Energy Development Limited (KREDL), which is the state's nodal agency in the state that looks after the development of renewable energy in the state. Table 5.2 summarizes the off-grid and stand alone systems installed in the state under various central and state programs.

Figure 5.2 Resource-wise Installed Capacity



Total installed capacity = 12052.17 MW

Source: http://www.advantagekarnataka.com/images/sector-profiles/Energy-Profile.pdf, last accessed on 24 August 2012.

Table 5.1 Renewable Energy Installation in Karnataka by 2012

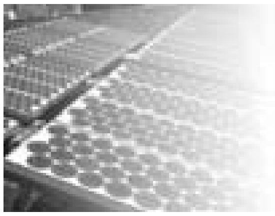
Renewable source	Potential[1] in MW	Current installation[2] in MW
Wind	12950	2112.26
Hydro	3000	646.85
Biomass	1000	88.5
Waste to energy	135	
Co-generation	1500	948.66
Grid connected solar	5.1 - 6.4 kWh/m^2	14

Source: 1. Data for "Potential" is drawn from Karnataka Renewable Energy Policy 2009-14. www.ireda.gov.in/solar/DATA/Policy/7%20Karnataka%20RE.pdf
2. Data for "Current installation" is drawn from http://www.kredltest.in/Reprogressreport.aspx, last accessed on 24 August 2012.

Table 5.2 Off-grid Installations up to 31 March 2011

No. of biogas plants	No. of water pumping wind mills	No. of SPV pumps	Solar Photo Voltaic				Solar water heaters	Aerogen hybrid system (KW)	Solar cooker (Nos.)	Biomass gasifiers (MW)	Waste to energy		Villages/ hamlets under the Remote Village Electrification Program
			SLS (Nos.)	HLS (Nos.)	SL (Nos.)	PP (Nos.)					Industrial (MW)	Biogas (Mwe)	Hamlets
433223	28	551	2694	36134	7334	225.41	1,100,000	39.15	253	7454	3	16	14

Note: 1. SLS: Street light system; HLS: Home lighting system; SL: Solar lantern; PP: Power plants
2. Data for solar water heaters pertains to capacity of 100 litres per day only and is dated November 2010
Source: 1. www.indiastat.com last accessed on 24 August 2012.
2. Data for solar water heaters is sourced from http://kredl.kar.nic.in/ProgressReport.htm last accessed on 24 August 2012.



6

Institutional Framework and Policies on Renewable Energy in Karnataka

Karnataka Renewable Energy Development Ltd. (KREDL) is an organization devoted entirely to the promotion of non-conventional energy sources in Karnataka. On its part, KREDL has attempted to promote renewable energy in the state in a number of ways. These include:

- Encouraging the private sector to identify and develop small capacity projects in wind, mini-hydel, biomass and cogeneration
- Creating an information network for advancing understanding in renewable energy through communication, education, and publicity
- Disseminating information on green energy, harmful effects of global warming, and ozone layer depletion
- Conducting demonstration projects to establish cost effectiveness, economic viability, and the reliability of various technologies
- Engaging in frequent interactions with developers to ensure expeditious capacity additions
- Promoting greater awareness and compliance with energy conservation and energy efficiency issues

6.1 Policies and Programs

With "Karnataka Renewable Energy Policy 2009–14", the state government has articulated its vision "to harness green and clean renewable energy sources in the state for environment benefits and energy security and to initiate energy efficiency measures in all sectors for sustainable growth." The goals of this comprehensive policy range from utilizing renewable energy resources based utility–scale power generation for energy security to renewable energy-based village energization; from effective use of renewable energy technologies (RET) for socioeconomic development of its rural and peri-urban populace to manufacturing RETs for propelling the state's economic growth. The state has recently made public, its draft on solar policy.

With installations of 2986 MW in terms of grid connected renewables-based power and 2300 thousand sq m of solar water heating systems, Karnataka plans to add 4200 MW by 2014 through renewables. Apart from these, under the Solar Karnataka Program the target is to set up 25,000 solar rooftops systems of 5 to 10 kWp capacity with net metering during 2009–14, totaling about 250 MW.

It is mentioned in the policy document that provisions contained in this will be applicable to all the renewable energy projects including those sanctioned prior to the commencement of the policy, which may either have been just commissioned or be at the execution stage. Under the policy, the state government has the right to approve the capacity allotment order essential for availing of the benefits for renewable energy projects. Under this policy, it is obligatory to sell the electricity generated from the renewable energy projects to the respective geographical electricity supply companies (ESCOMs) in which the projects located, at the tariff determined by Karnataka Electricity Regulatory Commission (KERC), under a long term power purchase agreement (PPA). The policy proposed contains some key measures to ease constraints and ensure substantial capacity additions in the next 5 years:

- Renewable energy development is to be classified as an "industry". Land is, therefore, to be made available to the developers by the government through allotment by the Commerce and Industries Department Single Window System. This will obviate the delays developers face in obtaining permission for purchasing land from the Deputy Commissioner of the districts or other modes of purchase.

- A Green Energy cess has been proposed at Rs 0.05 per unit consumed by commercial and industrial consumers to generate Rs 55 crore annually. Ten per cent of the funds raised through cess will be set aside for the Energy Conservation Fund, and a fixed a proportion for renewable energy project financing and strengthening of the evacuation system. The remainder would be dedicated to an integrated information and communication program in the state. (Provision for the same has been made in the tariff proposals filed by the distribution companies.)
- A state-level empowered committee headed by the Chief Secretary has been constituted to co-ordinate departmental issues and clearances in renewable energy projects.
- A time limit of three years from the date of clearance to the date of completion of the project has been set.
- A clear target in terms of future capacity addition has been identified for each renewable energy source and the investment necessary during the policy period also identified (Table 6.2).

Table 6.1 Targets for Capacity Additions, 2009-2014

Renewable energy source	Target (MW)	Year-wise proposed capacity addition					Likely total investment (Rs crore at current prices)
		2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	
Wind power	2969	630	680	530	530	599	15680
Mini and small hydro	600	100	100	150	150	100	2700
Cogeneration in sugar industry	281	56	56	56	56	57	1120
Biomass/bio-gas	300	60	60	60	60	60	2100
Waste to energy	50	10	10	10	10	10	400
Solar PV/GSP/thermal sector	126	6	30	30	30	30	1890
Total	**4326**	**862**	**936**	**836**	**836**	**856**	**23890**

Source: Renewable Energy Policy 2009-2014, by Karnataka Energy Regulatory Commission.

6.1.1 Renewable Energy Project Financing

It is estimated that additional capacity of 4200 MW renewables-based power by 2014 will entail an investment of about Rs 25,200 crore at current prices. During previous years, various renewable energy projects have attracted substantial private investment. During the three years of renewable energy development, in the state (2007–09), on an average annually about 300 MW renewable energy capacity additions brought in about Rs 1,800 crore investment by the private sector. [1] It is expected that the present policy initiative will bring in additional private investment of Rs 1,600 crore annually into renewable energy. With this private sector investment would amount to Rs 17,000 crore during the policy period. The profit making central and state public sector undertakings may also invest in renewable energy projects and lead to greater infusion of funds.

6.1.2 Akshaya Shakthi Nidhi (Green Energy Fund)

In order to facilitate renewable energy project financing and energy conservation and efficiency measures, Green Energy Fund or *Akshaya Shakthi Nidhi* will be established which will draw upon resources raised through the Green Energy cess mentioned above. The Akshaya Shakthi Nidhi will be administered by KREDL for promotion of renewable energy particularly in public–private participation (PPP) mode for decentralized generation and distribution of renewables-based power for the benefit of the rural sector. The funds may also be utilized for land acquisition and land development for renewable energy projects including computation of net present value and compensatory afforestation, soil moisture conservation etc., for forest land clearance.

6.1.3 Land Policy for Renewable Energy Projects

The expeditious availability of suitable land is a major challenge for renewable energy development. To realize the targeted potential of 4200 MW during the policy period about 12000 ha of various categories of lands such as

[1] Frost and Sullivan. 2011. Assessment of Power Sector in Karnataka and the Way Forward. White paper released by Confederation of Indian Industry at the Karnataka Conference on Power held on 25–26 August 2011 in Bangalore.

government barren lands, revenue lands, private lands, panchayat lands, and forest lands have been identified in different districts of the state.

6.1.4 Land Identification for Renewable Energy Projects

Inventory of surplus and unused land available with public sector undertakings, the state government, urban local bodies, gram panchayat lands, unproductive single crop agricultural lands, and suitable private waste lands will be undertaken district-wise by the Deputy Commissioners. Care will be taken to exclude archaeological heritage lands, prayer and temple lands, burial grounds and monuments etc. The government will provide such available lands for developing renewable energy projects under the provisions of Section 71 of Land Revenue Act to KREDL. Necessary amendments to Sections 79(a), 79(b), and 80 of the Karnataka Land Reforms Act are to be made to enable the project developers to purchase suitable private land directly from the owners.

For waste to energy renewable energy projects municipal bodies will identify and keep the lands at the disposal of KREDL. The identified lands will be acquired through the Karnataka Industrial Area Development Board (KIADB), under the provisions of the Karnataka Industrial Policy, and made available to the KREDL for renewable energy projects. Non-agricultural conversion for the express purpose will be accorded within a period of one month from the date of applying for the same. The state government will review the applicable stamp duty.

Government barren lands meant for industrial use

Ten per cent of barren government lands reserved as per the industrial planning for industrial use, at declared renewable energy sites will be kept at the disposal of KREDL for developing the land to set up the renewable energy power projects.

Forest land

Wherever forest land is identified for renewable energy projects, the same will be processed and considered by the Karnataka Forest Department under the provisions of the Forest Conservation Act (1980) subject to the guidelines of the Ministry of Environment and Forest within a period of 4 months.

Land development for Renewable Energy projects

The identified revenue, private and forest lands will be developed by KREDL to facilitate setting up of various renewable energy projects expeditiously. The Akshaya Shakthi Nidhi fund will be utilized to develop the lands including the payment towards net present value and compensatory afforestation in case of forest lands. This will enable the state to offer developed land that is ready for renewable energy projects to use. The KREDL will sub-lease the developed lands to the renewable energy developer for a period of 30 years. Thereafter, the project will be renewed for a period of 5 years at a time after the lease period subject to fulfillment of conditions stipulated by the government. Land–lease rent will be determined as per the prime lending rate over current market price as on the date of handing over of the project, subject to land availability and financial limits on case-to-case basis. However, renewable energy developers are not permitted to mortgage the lands to any agency/institution/body.

Consent from departments

Karnataka Renewable Energy Development will obtain consent from the concerned departments such as the Department of Forests that are in charge of wild life sanctuaries, national parks, and eco-sensitive zones. They also need to seek clearances from the irrigation department to establish that the proposed projects do not infringe upon the drinking and irrigation rights of the local inhabitants, and from the revenue department for approval under the Karnataka Land Reforms Act. Consent from the gram panchayat is also required. All departments are expected to offer their points of view within a period of 90 days. The administrative department will monitor the reports in a time bound manner.

Statutory clearances

Various statutory clearances that are essential for the development and commissioning of renewable energy projects will be acquired by KREDL from the concerned departments and agencies. The developers will apply in the formats prescribed to the different departments and furnish a copy to KREDL. The KREDL will pursue the applications with the departments and co-ordinate the process of speedy approvals and clearances within 90 days for all departments/agencies and 120 days in case of forest clearance. The issues pending for longer periods will be placed before the Quarterly Review Meetings held at the level of the Chief Secretary, Government of Karnataka. The KREDL will obtain all statutory clearances before developed lands are offered for renewable energy project development.

6.1.5 Renewable Energy Special Economic Zone

The renewable energy and allied sector requires support from renewable energy equipment manufacturing industries. Renewable energy sources like wind and solar power require considerable land for the setting up of solar PV or wind turbine manufacturing.

Under Industrial Policy 2009 the state has identified Bidar, Belgaum, Bagalkot, Shimoga and Mandya districts for sugar and co-generation of power. Similarly Raichur, Bellary, Bijapur and Chitradurga districts have been identified for industrial development and power generation. It is proposed under this policy that the government will keep 10% of these lands at the disposal of KREDL to develop renewable energy projects and allied industries. Another 10% of the lands will be set apart for renewable energy projects in all future special economic zones (SEZs) to be identified under Industrial Policy 2009 and also in the approved SEZs at Shimoga, Hassan, Bangalore, Udupi, Mysore and Bellary. Ten per cent of all SEZ lands will be kept at the disposal of KREDL to develop renewable energy projects.

Further, steps will be taken to establish Renewable Energy SEZs in line with the Industrial Policy 2009, particularly in the backward areas of Karnataka to promote solar manufacturing units and other allied manufacturing units. Waste lands and surplus unproductive lands of about 2000 ha will be identified for the purpose.

6.1.6 Implementation of Renewable Energy Projects

Various measures will be put in place to facilitate expeditious implementation of renewable energy projects. Wind and mini-hydro projects identified by KREDL will be offered for development on PPP basis within a build own operate transfer framework (BOOT model) on developed lands.

- An allotment committee under the chairmanship of Additional Chief Secretary, Energy Department will consider allotment of capacity of the renewable energy projects to private entrepreneurs.
- Clearance required for renewable energy projects from the concerned department will be given within 90 days of the application submitted. The KREDL will coordinate with the concerned departments.
- A state level empowered committee with the Chief Secretary, Government of Karnataka as chairman will provide single window clearance for developing renewable energy source power plants. The single window will review the issues related to the statutory clearances of various departments. The clearances/approvals which are not accorded within the specified time period will be dealt by the single window empowered committee. Inter-departmental co-ordination will be strengthened to achieve better results. Benefits of supportive policies will be availed of to the maximum possible extent. The composition of the empowered committee will be separately notified.
- Karnataka Power Transmission Company Limited (KPTCL) and KREDL will jointly undertake the survey of low voltage, high voltage and extra high voltage substations and transmission and distribution lines necessary for the renewable energy projects located in remote areas. Karnataka Power Transmission Company Limited will also augment transmission lines by laying new lines and receiving stations as recommended by a committee set up for the purpose of analyzing grid-related issues. Project developers will bear the cost of installing transmission lines from the project site to the substation as per grid norms.
- It is mandatory for the developer to complete the project in all respects and commission it with grid synchronization within to obtain all required statutory clearances within six months.

6.1.7 Regulatory Issues

Power generation from renewable energy sources will be treated as an industry under the provisions of the Industrial policy 2009 and entry tax exemptions and all other incentives available to industrial units under such schemes will also be extended to the renewables-based power projects irrespective of the zone.

6.1.8 Renewable Energy Obligation

The state government is committed to procuring and utilizing renewables-based power as mandated by Government of Karnataka from time to time, subject to KERC guidelines. Due grid strengthening will be undertaken to meet this commitment. The state government reserves the first right of refusal in respect of purchase of power produced by the renewable energy sources which come under this Renewable Energy Policy.

Solar tariff

Karnataka Electricity Regulatory has determined a tariff of Rs 14.50 and Rs 11.35 per unit respectively for solar PV and solar thermal power plants for grid connected power plants.[2]

Roof top solar tariff

Roof top solar PV and other small solar power plants connected to the distribution network at voltage below 33 kV are eligible for a tariff of Rs 14.50 per unit. This tariff will be under the GBI scheme administered by IREDA. The maximum capacity for such projects is limited to 1MW.

Wheeling of electricity

Wheeling charges of 5% will be applicable subject to the KERC norms. For solar power, as a promotional measure, for the third party sales/wheeling through open access within the state, the commission has decided not to charge any transmission or wheeling charges. However, in respect of third party sales/wheeling through open access outside the state, normal transmission and wheeling charges determined by the commission from time to time will be applicable.

Banking of electricity

Banking facility for renewables-based power generated shall be allowed as determined by KERC from time to time for the energy banked with the KPTCL or the distribution licensee (DL). Energy banked beyond the time prescribed will be utilized and paid for by the KPTCL or the DL at tariff fixed by KERC.

Power Purchase Agreement

The sale of electricity by renewables-based power producers to ESCOMs will be governed by PPAs signed in the presence of KERC. The government will assign the PPAs to ESCOMs at the time of allotment.

Settlements

All transactions between the KPTCL/ESCOMs/DL and the producer which involve wheeling or sale of power will be settled on a monthly basis. The KPTCL/ DL will pay interest on payments delayed beyond a month in line with the State Bank of India short term prime lending rate for delayed amount for actual period of delay.

Grid tie policy and net metering

Net metering facility will be extended to solar power systems installed on commercial establishments and individual homes connected to the electrical grid to feed excess power back to the grid with power credits accruing to the PV energy producer.

Exemption from demand cut

Exemption from demand cut to the extent of 50% of the installed capacity assigned for captive use purpose, will be allowed.

Security deposit and royalty

The government will determine suitable security deposit for the renewable energy projects to bring earnestness into project implementation. The quantum of royalty to be levied on energy generation from renewable energy sources will be determined by the government.

[2] Tariff order for solar power, KERC order no S/03/1 dated 13 July 2010.

6.1.9 Financial Incentives to Renewable Energy Projects

Government of India incentives

The various concessions and incentives allowed by the MNRE, GOI regarding detailed survey and investigation or detailed project report, GBIs etc. will *ipso-facto* continue to be passed on by the state government to the project developer through the KREDL.

Entry tax

Entry tax and other fiscal incentives to renewable energy generation units are in accordance with Industrial Policy 2009.

Value-added tax

The value-added tax applicable on renewable energy equipment and instruments as well as the energy efficient and power saving appliances and consumer durables purchased by users will be considered for suitable revision under the provisions of the Karnataka State Sales Act.

Letter of credit

Electricity supply companies (ESCOMs) will extend a letter of credit to the renewables-based power producer for realizing payment for the power within the scheduled period. The cost of the letter of credit shall be reimbursed to the ESCOMS from the Akshaya Shakthi Nidhi by KREDL.

Registration

Various agreements that are executed by the renewable energy project developers with different departments of government regarding capacity allotment, project implementation, revenue and other land lease including forest land lease agreements will be considered for revision of registration fee towards registering the respective agreements under the relevant provisions of Karnataka Stamps and Registration Act by suitable amendment.

6.1.10 Strategy for Wind Projects

Under the policy it is proposed to develop additionally 2969 MW of wind power projects during 5 years up to 2014. This would involve a total investment of Rs 15,680 crore. To facilitate expeditious commissioning of targeted wind projects, various statutory clearances will be facilitated through single window mechanism. KREDL will undertake wind resource assessment and offer the identified windy sites for development on PPP basis within a BOOT model. Further, only three sites will be considered including the ones under the process of development. The government waste lands in windy locations identified for industrial development will be offered to set up wind projects. The capacity of the earlier commissioned wind projects, which are more than 10 years old, will be considered for augmentation or re-powering by replacing older turbines with more efficient higher capacity wind turbine generators. Earlier allotments not commissioned beyond time period will be reviewed. Small wind energy generators will be promoted up to 10 kW for stand-alone systems.

The Karnataka Power Corporation Limited, a state public sector undertaking, is the premier power generating company in the state. A preferential allotment of wind power projects above 500 MW and solar power projects above 100 MW will be considered. The following geographical regions in Karnataka are reserved for the allotment of wind power projects to Karnataka Power Corporation Limited:

- 50 MW at Kappadagudda Extension
- 270 MW at hill ranges of Guledagudda–Gudur
- Hill ranges of Sureban,Yere Kittur, Kallur, Mallur and Basidoni
- Hill ranges of Halolli to Katkol (Godachi, Khanpet, Torgal)
- Hill ranges of Halagatti, Mudakavi, Tadasi, Vasan, Govinakoppa
- Hill ranges of Soudatti to Ugargol
- Hill ranges of Hanumana Hatti to Kakti

6.1.11 Strategy for Solar Thermal/CSP and Solar PV

Grid connected solar projects of 1 MW and above are considered priority projects. Roof-top small scale solar PV installations are being encouraged with net metering facility to feed surplus power to the grid. Solar Karnataka Programme is targeted for 25,000 solar roof tops of 5 to 10 kWp with net metering, totaling 250 MW during next 5 years (2009–2014) with a generation potential of 350 MU.[3] For villages/habitations where grid connectivity is not feasible or not cost effective, off-grid solutions based on stand-alone lighting systems, technologies like solar PV/solar wind hybrid systems, solar lights, and lanterns will be taken up. Solar School and Institution programs are also planned. Gram panchayat and local bodies will be involved in decentralized solar implementation. Solar steam generating systems at institutions and industries will be encouraged. Solar water pumps, water purification systems, milk pasteurization plants, and solar application to cottage industries will be prioritized. Solar passive building technology will be encouraged through legislative measures. To conserve electricity during peak hours, solar water heaters, solar lighting systems, solar hoardings etc will be encouraged in domestic, commercial, and industrial applications. Solar cities will be developed in the state. All city corporations and municipalities will amend their by–laws with due mandatory provisions for providing solar water heating facilities right at planning/building stage, both for residential as well as commercial categories. It will be mandatory for all the public buildings to have solar devises to meet energy requirements and other applications.

Box 6.1 Kolar Solar PV Plant

Karnataka Power Corporation Limited (KPCL) has set up a 3MW capacity solar power project at Yalesandra Village in the state. The primary objectives of the project were to (i) effectively demonstrate the use of solar energy to meet the rising electricity demand in the region, (ii) provide irrigation power to farmers during the day (unlike the conventional electricity that is supplied to the farmers during nights), and (iii) improve the quality of electricity supply. The power generated from the solar power plant is evacuated through single circuit 11KV line to the Bangalore Electricity Supply Company Limited (BESCOM) network connecting to Kamasamudra 66/11 KV MUSS which is 6 km from the site. The total investment of Rs 19.5 crore was made by KPCL at a concessional interest rate of 8.5% provided by Karnataka Bank on the financial strength of KPCL.

The solar power plant that was commissioned in December 2009, generates 13000–14000 kWh per day, which is sold to BESCOM at Rs 6 per kWh (as determined by Karnataka Electricity Regulatory Commission). This was a pioneering effort of KPCL to demonstrate solar power generation at this scale, considering that till that time JNNSM was not launched. That is why the plant did not receive any GBI or capital subsidy. However, along with the accelerated depreciation in the first year (KPCL being a profit making venture), low-interest debt, and revenue from selling the carbon credits, the sustainability of the project is ensured. The clean development mechanism (CDM) of the project is under validation. With an annual reduction of 4,381 tCO_2, it has been estimated that carbon emission reduction certificates (CERs) would generate revenue of around Rs 10 lakh per MW annually.

Notes: JNNSM: Jawaharlal Nehru National Solar Mission; tCO_2: total carbon dioxide; GBI: generation-based incentive
Source: http://mnre.gov.in/file-manager/userfiles/powerplants_241111.pdf.

6.2 Awareness and Promotion

In the recent past, following exhibitions and seminars were organized by KREDL:

- Renewable Energy exhibition in Gulbarga and Hubli.
- A seminar on Solar City was held at Hubli.
- Energy conservation essay competition was organized at district and state level. About 20,000 school children of the state participated. This event was organized in association with education department.
- Energy conservation day was celebrated where energy–efficient industries in dairy, general, government building, pharmaceuticals and steel sectors were awarded with prizes and trophies at Bangalore. A technical seminar was also held.
- Seminar on Clean Development Mechanism (CDM) was organized at Bangalore to create awareness among the developers of renewable energy and also various utilities about the benefits of CDM on account of renewable energy application as well as energy efficiency.
- A seminar was organized by Sainik School at Bijapur on Solar Steam Generating Systems.

[3] Karnataka Renewable Energy Policy 2009-2014, www.ireda.gov.in/solar/DATA/Policy/7%20Karnataka%20RE.pdf

- The workshop on Green Technologies was also organized by KREDL and National Institute of Engineering, Mysore with overall coordination by its Centre for Renewable Energy and Sustainable Technologies.[4]

6.3 Renewable Purchase Obligation

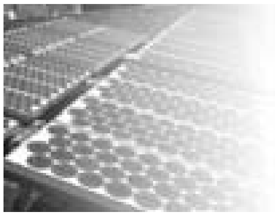
The RPO for Karnataka is presented in Table 6.2.

Table 6.2 RPO as a Percentage of Total Power Consumption for Karnataka

Type of renewable energy	*2011–12*
Solar	0.25%
Non-solar	7%-10%[5]
Total	7.25%-10.25%

Note: RPO for non-solar varies with the distribution company.
Source: KERC (Power Procurement from Renewable Sources by Distribution Licensee and Renewable Energy Certificate Framework) Regulations, 2011. The same data is also available in "All India Renewable Energy Regulatory framework". At http://mnre.gov.in/information/renewable-energy-regulatory-framework. Last accessed on 20 November 2012.

[4] http://www.niecrest.in/index.php?option=com_content&view=article&id=11&Itemid=12 last accessed on 26 August 2012.



7

Solar Technology Assessment and Appropriate Technology Options

The most commonly used solar technologies to convert sunlight to usable form of energy are solar thermal technology and solar photovoltaic (SPV) technology.

Solar thermal technology is of two types—non-concentrating and concentrating. Non-concentrating solar technologies harness heat from the sun to provide hot water or hot air. Concentrating solar thermal (CST) technologies harness heat from the sun to get high temperature fluids/steam by way of concentrators. This high temperature working fluid/steam is then used either for process heating purposes or for generating electricity.

Solar photovoltaic technology converts sunlight directly into electricity. Solar photovoltaic systems can be grid connected or off-grid depending upon the application.

7.1 Solar Thermal Technology

7.1.1 Non-concentrating

There are two types of solar collectors that fall within this technology option—flat-plate, commonly used for residential applications and evacuated-tube, commonly used in commercial buildings.

Flat plate collectors may be unglazed, liquid flat plate solar collectors (FPC) and solar air heating collectors. The unglazed collectors (for 35–40°C) are used for low heating application viz. swimming pool heating etc. A typical cross sectional view of this type of collector is shown in Figure 7.1.

Figure 7.1 Schematic Diagram of Flat Plate Solar Collector

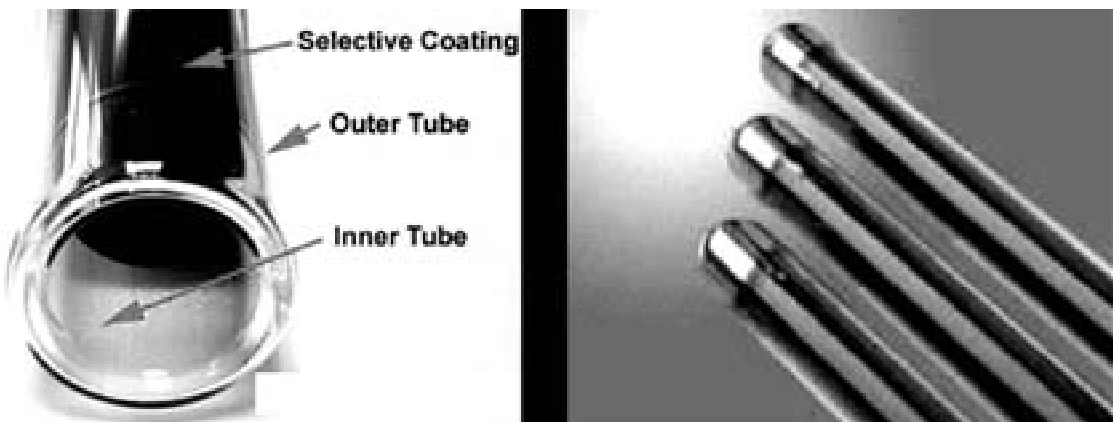
Source: http://www.solarfeeds.com/solar-cooling-and-heating-market-trends

An FPC is a widely used solar energy collection device for applications that require heat at temperatures below 80°C. A typical liquid FPC consists of a selectively black-coated absorber plate of high thermal conductivity (such as copper or aluminum), one or more transparent covers, thermal insulation, heat removal system, and outer casing. The transparent cover reduces the convective and radiative heat losses from the absorber plate to the surrounding. To achieve operating temperatures higher than 80°C, two glass covers may also be used. The heat collected by the absorber plate is extracted by circulating a working fluid through the riser tubes attached to the absorber plate, which are further connected to a larger pipe called header at both ends as shown in Figure 7.1.

The working fluid, usually water or an anti-freeze mixture flows through these tubes to carry away the heat. An outer casing houses all the components. This is finally placed on a stand so that the collector properly inclined to receive maximum solar radiation.

An evacuated glass solar tube (EGT) is the key component of EGT solar water heaters and solar water heating systems. The EGTs allow sunlight to pass through freely but reduce the convective heat loss from the absorber due to the evacuated space around it. An EGT is configured by two concentric borosilicate glass tubes; the outside surface of the inner tube is coated with selective coatings to increase the absorptivity in the solar spectral region and low emissivity in the infra-red region. The jacket between cover glass tube and the inner glass tube is evacuated and sealed. In order to maintain vacuum in the jacket between the two tubular glass tubes, a barium getter (gas absorbent) is used inside the bottom of the cover tube. During manufacturing this getter is exposed shortly to high frequency magnetic fields, which create high temperatures in one second and consequently the bottom of the evacuated tube gets coated with a pure layer of barium. Figure 7.2 presents a cross sectional view along with the glass based vacuum tubes, while Figure 7.3 presents various components of the vacuum tube system.

Figure 7.2 Cross-sectional View of EGT Collectors



Source: http://www.solardirect.co.nz/solar_heating_how_does_it_work_xidc25507.html

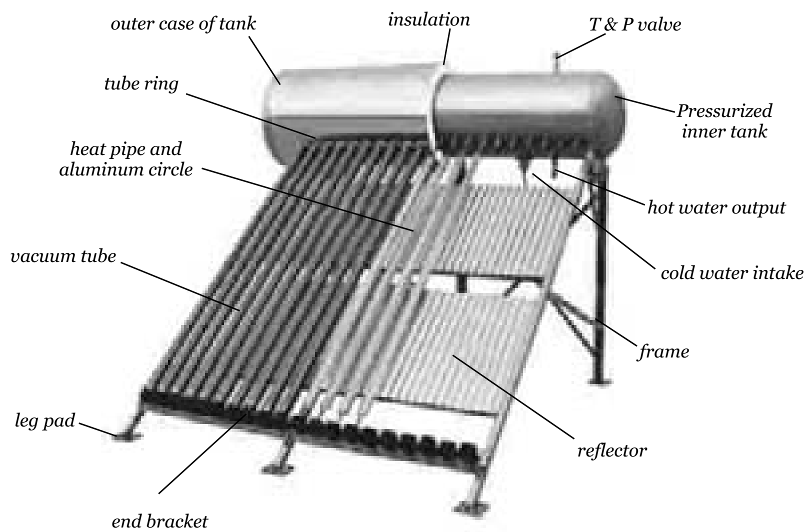
7.1.2 Various Components of EGT Collectors-based Water Heating System

Concentrating solar thermal power plants produce electricity by converting solar radiation into high-temperature heat using various mirrors/reflectors and receiver configurations. In CST plants solar radiation is converted to high-temperature heat source which, in turn, is used to produce steam or hot gas for power production through turbine generator combination where as in concentrated solar photovoltaic (CPV) technologies electricity is produced directly through semiconductor based converter/solar cell. The overall generic arrangement in a typical CST power plant is shown in Figure 7.4. The main subsystems of a CST power plant are described in the subsequent sections

Solar field

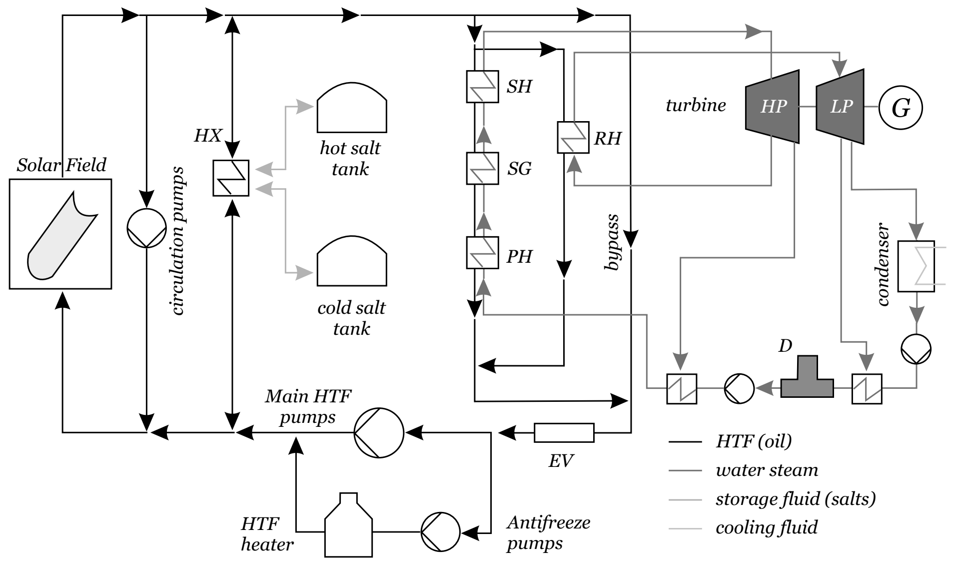
Solar field is essentially an array of the mirrors/reflectors that collects the solar radiation and focuses it on the solar receiver. The focusing mechanism depends on the type of solar collector and the tracking mechanism (one-axis or two-axis). The solar field is also known as solar concentrator or heliostat field. It is the major part of any CST power plant.

Figure 7.3 Various Components of EGT Collectors Based Water Heating System



Source: http://greenterrafirma.com/evacuated_tube_collector.html. Last accessed on 24 November 2012.

Figure 7.4 Generic Arrangement of a CSP Plant



Source: http://www.sciencedirect.com/science/article/pii/S0038092X11002441 (Research paper titled: 'Performance model for parabolic trough solar thermal power plants with thermal storage: Comparison to operating plant data' Isabel Llorente García, José Luis Álvarez, and Daniel Blanco)

Receivers/absorbers

Receivers/absorbers are part of the system that transforms solar radiation to heat. Sometimes the receiver is an internal part of the solar collector field. A heat transfer medium, usually water or oil is used in the solar receiver to transport the heat to the thermal energy storage and/or conversion system.

Energy conversion system

The energy conversion system converts heat in to usable forms of energy which could either be electricity or thermal heat for process heating. This is done in two stages:

- heat energy is converted to mechanical power using steam/gas turbine or
- electricity is generated through generator/alternator.

The output of the energy conversion system can be thermal heat for process heating/cooling applications or electricity. Typically in CST power plants waste heat can be used for other applications.

Thermal energy storage

Thermal storage can be for few minutes to few hours. Size of storage system influences the size of the solar field, area required for solar field and eventually the capital cost of CST power plant.

Fossil fuel back-up system

Fossil fuel back-up system is provided to improve the capacity utilization factor and / or smooth out variation due to sudden drop in solar radiation levels.

7.1.3 Classification of Concentrating Solar Thermal Technologies

Concentrating Solar Thermal technologies are categorized based on the types of solar collectors used or the method of concentration. Following four major CST technologies have reached commercialization stage or are near it:

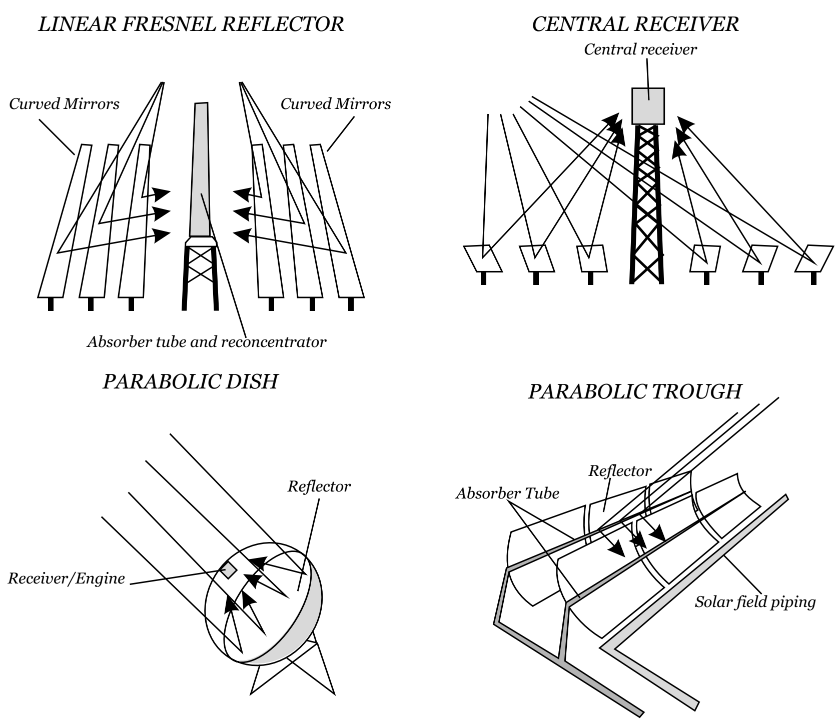
- Parabolic trough collectors (PTC)
- Power towers or central receivers
- Parabolic dishes (dish-engine system)
- Compound linear fresnel reflectors (CLFR)

The brief discussion of all CST technologies is covered in next section. Figure 7.5 presents a schematic diagram of these CST technologies.

7.1.4 Parabolic Trough Collector System

Parabolic trough technology is currently the most proven CST technology and therefore the most developed and standardized system. Parabolic trough-shaped mirror reflectors are used to concentrate electromagnetic radiation onto

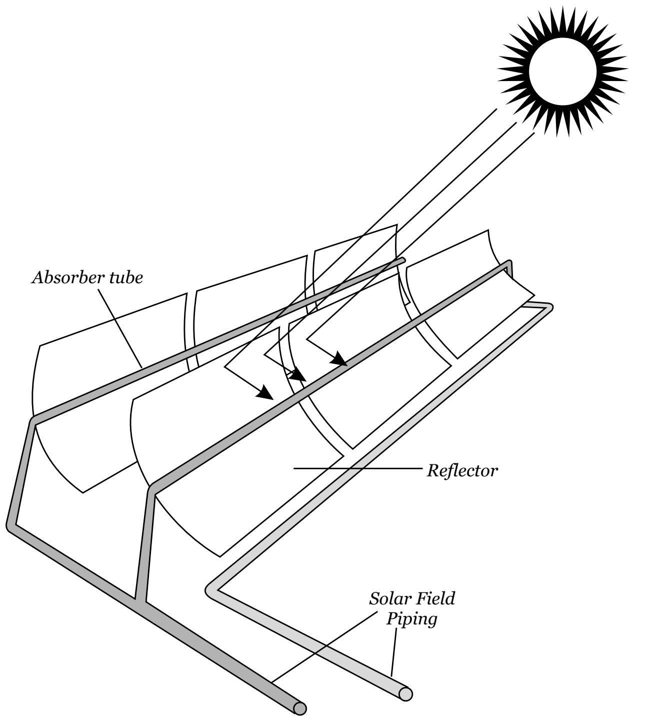
Figure 7.5 Schematic Diagram of CST Power Technologies



Source: Compiled by authors.

thermally efficient receiver-tubes placed in the trough's focal line. The PTCs are usually designed to track the sun along one axis, predominantly north–south. A thermal transfer fluid, such as synthetic thermal oil, is circulated in these tubes. The fluid is heated to approximately 400°C by the sun's concentrated rays and then pumped through a series of heat exchangers to produce superheated steam. The steam is converted to electrical energy in a conventional steam turbine generator, which can either be part of a conventional steam cycle or integrated into a combined steam and gas turbine cycle. This is the first CST technology to be commercialized. Figure 7.5 presents schematic diagram of a PTC system.

Figure 7.6 Schematic Diagram of Parabolic Trough Collector System



Source: http://www.yale.edu/ynhti/curriculum/units/2010/4/10.04.09.x.html. Last accessed on 24 November 2012.

PTC projects worldwide

The parabolic trough projects currently in operation are between 14 and 80 MWe in size, and existing plants are producing well over 500 MW of electrical capacity. In southern California, nine plants named solar electricity generating systems (SEGS) of about 2 million sq m of mirror area were developed from 1984–1989 by Luz Company. Further development of new plants stopped in 1990s in USA due to unfavorable tax policies. However, technology development and innovations continued. Recent changes in policies and incentives have seen resumption of commercial CST plants in the US. In US, commercial construction of PTC plants has resumed with the 64 MW project called Nevada One, which will produce 130 GWh of electricity annually.

In Spain, the Andasol I, II and III and Solnova projects which are under construction will together provide 250 MW capacity (five projects of 50 MW capacity each), and more than 14 more projects based on PTC technology are being developed worldwide. The largest single parabolic trough installation yet proposed is called Solana, and is planned for a site in Nevada, US. Parabolic trough systems are also being studied to integrate them with conventional coal fired power plants in a hybrid operation called Integrated Solar Combined Cycle (ISCC), where the steam generated by solar is fed into a thermal plant that also uses fossil-fuel generated steam, generally natural gas.

Major sub-components of the PTC system

Collector field. The collector field comprises reflectors (mirrors), structure and control/tracking of the collector. Usually, low iron single piece glass mirrors are used which are parabolic in shape. Presently for PTC technology the operating reflector of 4 mm low iron glass mirrors are in use (SEGS plants in Mojave Desert in California).

Tracking system. Tracking is particularly important in solar energy collection systems that operate under concentrated solar radiation. As the earth–sun angles changes continuously hence to align the collector with the position of sun, tracking is essential with concentrating collectors. PTC comprises single-axis tracking; the frequency of tracking depends on various factors including tracking axis orientation and accuracy of tracking required which in turn depend on concentration ratio.

Thermal storage. The thermal energy storage (TES) systems are incorporated into CST installations and allow them to convert the heat collected during times of high insolation to power during times of low insolation. The kind of storage system used for solar energy storage depends upon the CST technology. Molten salt, concrete storage, phase change materials, saturated steam or pressurized air are some of the storage mediums used in CST power plants. Currently, storages for 30 minute to 7.5 hour operations are being tested and studied.

Suppliers of PTC technology. Parabolic trough collector is the most proven and mature CST technology. The major suppliers of the PTC technologies are Acciona Energia, Solel Solar System, Solar Millennium AG, Abengoa Solar: Solucar Energia, S.S., SENER Ingenieria, Sky Fuel, etc. These industries have announced more than 5400 MW capacity CST projects for the next 10 years.

Investment cost of CSP power plant based on PTC technology. Parabolic trough power plants consist of large fields of PTC collectors, a heat transfer fluid/steam generator, a Rankine steam turbine/generator cycle, and optional thermal storage and /or fossil-fired backup systems.

For investment cost analysis, recently commissioned Andasol-I CST power plant, 50 MW, PTC technology has been taken as reference. Table 7.1 presents the cost break up of CST power plant based on PTC technology along with 7.5 hour heat storage.

Table 7.1 Cost Break up of CST Power Plant based on PTC Technology

S. No.	*Particulars*	*Cost (million US$)*	*Cost (Rs in crore)*
1	Labor cost: Site and solar field	62.4	347.57
2	Equipment: Solar field and HTF and system	140.3	781.47
3	Thermal storage system	38.4	213,89.00
4	Conventional plant components and plant system	52.0	289.64
5	Others	71.0	395,4.00
	Total	**364.0**	**2027.97**

Note: 1US$ = Rs 55.7, as on 2 September 2012
Source: IRENA working paper on: Renewable Energy Technologies: Cost Analysis Series, Volume 1: Power Sector Issue 2/5 Concentrating Solar Power. Available at http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-CSP.pdf, last accessed on 2 September 2012.

The cost break up reference has been taken from the European roadmap prepared by ECOSTAR in which the capital cost is segmented broadly into five categories.[1] The investment breakdown of reference PTC power plant is presented in Figure 7.7.

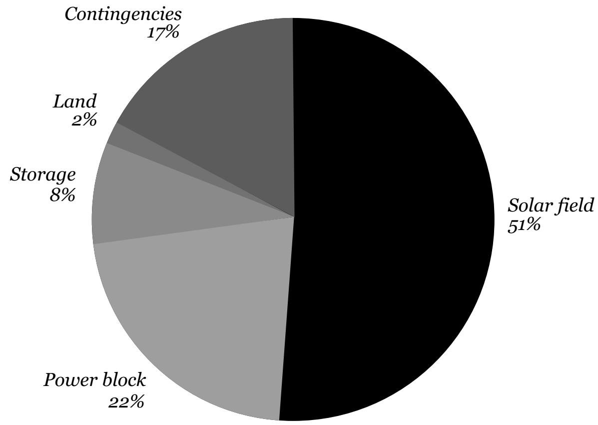
It can be seen that solar field which consist of solar collectors, balance of system, and tracking comprise 51% of the cost followed by power block at 22% which comprises turbine, generator, heat exchangers etc.

7.1.5 Central Receiver System (Power Tower)

Central receiver systems use a field of distributed, circular array of mirrors that is, heliostats which individually track the sun and focus the sunlight on the top of a tower. By concentrating the sunlight 600–1000 times, they achieve temperatures from 800°C to well over 1000°C. Solar energy is absorbed by a working fluid and then used to generate steam to power a conventional turbine. The high temperatures available in solar towers can be used

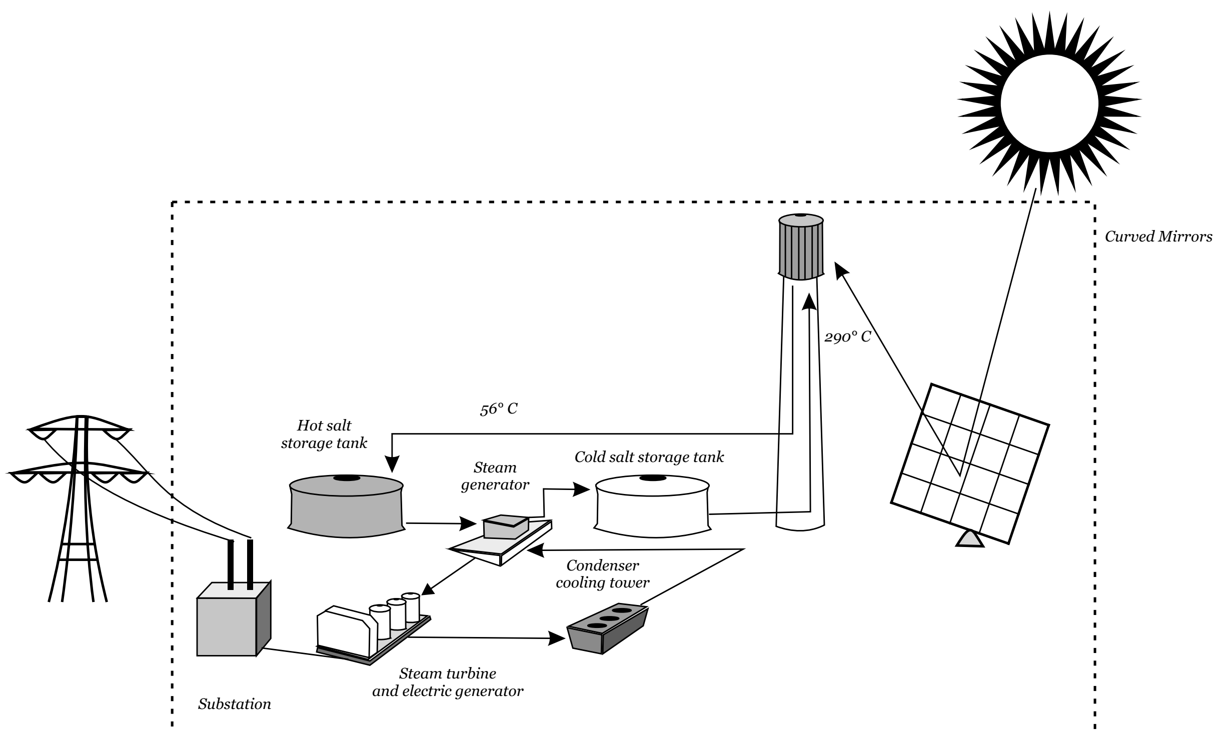
[1] European Concentrated Solar Thermal Road-Map (ECOSTAR SES6-CT-2003-502578), DLR.

Figure 7.7 Cost Break up of Parabolic Trough Based CST Power Plant



Source: European Concentrated Solar Thermal Road-Map (ECOSTAR SES6-CT-2003-502578), DLR

Figure 7.8 Schematic Diagram of Central Receiver CST System with Molten Salt Storage



Source: www.solarpaces.org.

not only to drive steam cycles, but also for gas turbines and combined cycle systems. Such systems can achieve up to 35% peak and 25% annual solar electric efficiency when coupled to a combined cycle power plant. Figure 7.8 presents a schematic diagram of a central receiver CST power plant.

There are some landmark operational projects running in Spain, notably the Sanlúcar Solar Park, the PS-10 solar tower of 11 MW and the PS-20 that has a 20 MW capacity. In India ACME Solar has invested in the start-up company e-Solar, USA which has developed saturated steam-based 5 MW capacity tower systems. The company has announced projects in Rajasthan and Gujarat.

Major sub-components of central receiver system

Heliostat field. The heliostat field comprises a large heliostat, structure, and control/tracking. The heliostat typically utilizes a mirror, which can be oriented throughout the day to redirect sunlight along a fixed axis toward a stationary target or receiver.

Storage. Central tower based systems typically use Molton salt, hot concrete storage, phase change materials, saturated steam or pressurized air as storage media.

Receivers/absorber and power block. This includes the receivers, absorbers including heat collection elements, and Power Block.

Technology suppliers

Central receiver technology is the second CST technology which is well-proven and mature. Manufacturers/suppliers of this technology include Abengoa Solar, Bright Source Energy, Solar Reserve, e-Solar, etc. Solar Reserve had installed a power plant based on this technology named Solar Two in 1980 in California which is now decommissioned. The Brightsource Energy has announced CST power project of the capacity of 400 MW in USA (California). More than 300 MW capacity CST power projects have been announced by various companies which will be commissioned in the next 10 years.

Investment cost of CSP power plant based on central tower technology

Recently commissioned PS10 power plant of 11 MW capacity in Andalusia, Spain, based on central receiver technology has been taken as reference case. Table 7.2 presents the cost break-up of CST power plant based on central receiver technology.

Table 7.2 Cost Break-up for Central Receiver Based Solar Thermal Power Plant

S. No.	Particulars	Cost (in million Euros)	Cost (Rs in crore)
1	Solar field	12.60	86.11
2	Power block	8.40	57.41
3	Receiver	5.25	35.86
4	Tower	1.05	7.17
5	Storage	1.05	7.17
6	Land	0.70	4.78
7	Indirect cost	5.95	40.64
	Total	**35.00**	**239.14**

Note: €1 = Rs 68.325, as on 10 July 2012.
Source: Abengoa Solar.

The cost break-up reference has been taken from the European roadmap prepared by ECOSTAR in which the capital cost is segmented broadly into seven categories.[2] The cost breakdown of reference central tower power plant is presented in Figure. 7.9.

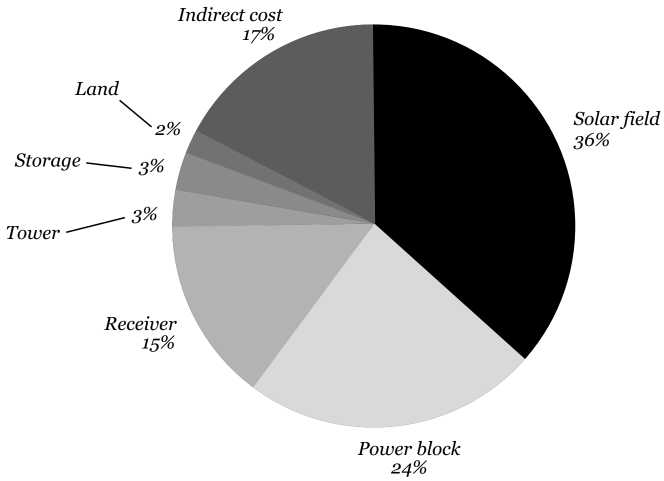
The solar field which consists of solar collectors, balance of system, and tracking constitutes 36% of the cost followed by the power block at 24% which comprises the turbine, generator, heat exchangers etc. The receiver is also a major component of this technology comprising 15% of the cost.

7.1.6 Parabolic Dish

A parabolic dish-shaped reflector concentrates sunlight on to a receiver located at the focal point of the dish. The concentrated beam radiation is absorbed into a receiver to heat a fluid or gas (air) to approximately 750°C. This fluid or gas is then used to generate electricity in a small piston or Stirling engine or a micro turbine, attached to the receiver. The dishes are usually designed to track the sun along two axes to reflect the sun beam on to point of focus. Figure 7.10 presents the schematic diagram of parabolic dish-Stirling system.

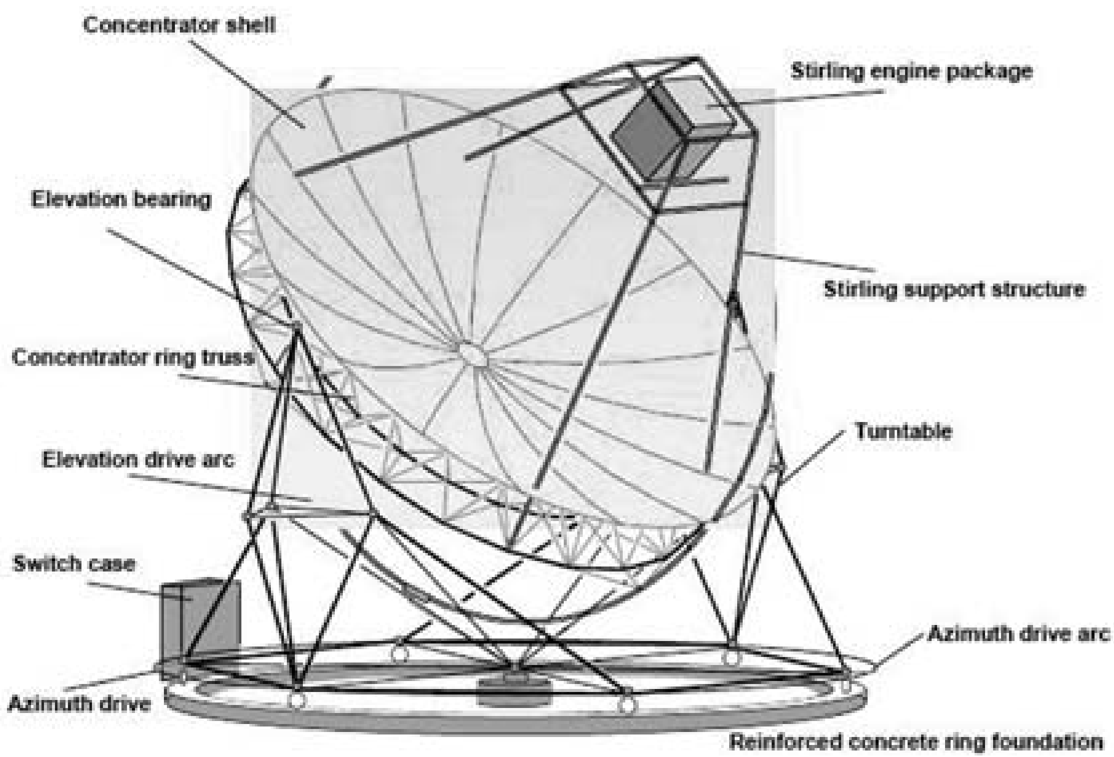
[2] Footnote 1.

Figure 7.9 Cost Break-up of CST Power Plant Based on Central Tower Technology



Source: European Concentrated Solar Thermal Road-Map (ECOSTAR SES6-CT-2003-502578), DLR

Figure 7.10 Schematic Diagram of Parabolic Dish-Stirling System



Source: Sourced from internal TERI research by authors.

Several dish/engine prototypes have successfully operated over the last 10 years, ranging from 10 kW (Schlaich, Bergermann and Partner design), 25 kW (SAIC) to over 100 kW (the 'Big Dish' of the Australian National University). Because of their size, they are particularly well-suited for decentralized power supply and remote, stand-alone power systems. The technology promoted by Stirling Energy Systems (SES), called 'Solarcatcher', is a 25 kW system. In 2008, Stirling Energy Systems claimed a new solar-to grid system conversion efficiency record by achieving a 31.25% net efficiency rate in New Mexico.

The Australian Big Dish technology is being brought to market by Wizard Power and has a surface area of 500 sq m. In Australia, Wizard Technology, which has commercialized the 'Big Dish', is proposing a project near Whyalla, Australia with applications in steel processing, of 40 MW in size was proposed to be started in 2009. The $230 million project had to use Wizard Power technology to generate 66GWh of solar electricity each year; enough electricity to power 9,500 average Australian homes and reduce greenhouse gasses by 60,000 tons per annum, equivalent to taking 17,000 cars off the road each year. The project was delayed due to the financial problems but this got some go- ahead node during March 2012, after the Solar Oasis consortium signed a funding deed with the Australian government for a $A60 million grant. The deed was crucial for the project to move forward and finalize funding arrangements with equity partners and financiers. Initial grant was awarded nearly two years ago under the Australian government's Renewable Energy Demonstration Program.[3] In India Infinia Solar Systems, USA has proposed solar power plant with 3kW dish stirling system through its Indian partners, though no project with this system has come in ground in India till now.

Major sub-components of central receiver CST system

Stirling engine. The Stirling or hot gas engine is worked with a pressurized gas in a closed thermodynamic cycle. Because the Stirling engine is independent from the heat source, it is possible to use gas or oil burners as well as solar energy. Mounted on a parabolic dish, the Stirling engine transforms the concentrated solar radiation to electric energy. Presently Infinia Solar Systems is manufacturing typical Stirling engines.

Parabolic dish. Parabolic dish uses a modular mirror system that approximates a parabola and incorporates two-axes tracking to focus the sunlight onto the receiver located at the focal point of each dish. The mirror system is typically made from a number of mirror facets, either glass or polymer mirror. It could also consist of a single stretched membrane using a polymer mirror. The concentrated sunlight may be used directly by a Stirling, Rankine, or Brayton cycle heat engine at the focal point of the receiver or to heat a working fluid that is piped to a central engine. The primary applications include remote electrification, water pumping, and grid-connected generation.

Tracking mechanism. The parabolic dish-Stirling system comprises a two-axes tracking mechanism as it works on direct normal incidence.

Technology suppliers

The parabolic dish-Stirling CST technology is modular and best suited for decentralized energy supply. World-wide demonstration projects have been successfully implemented by the manufacturers but the technology has not yet commercialized to the extent of a parabolic trough and central tower system. Presently there are three major manufacturers of parabolic dish–Stirling system namely Stirling Energy Systems, Infinia Solar System, and Brayton Energy. The Stirling Energy Systems has announced the projects of 1750 MW capacity in the US.

Cost of parabolic dish–Stirling CSP technology

Figure 7.11 shows the detailed cost decomposition of the CST power plant based on the parabolic dish–Stirling technology. It has been observed that the solar field comprises 38% of the cost followed by power block at 37%.

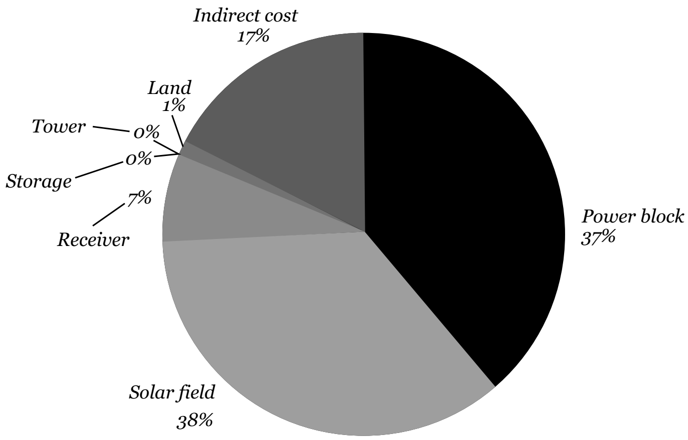
As the power block is inbuilt with the parabolic dish system, storage is not possible with this technology. However, the efficiency of this technology is higher than other CST technologies.

7.1.7 Linear Fresnel Reflector

This system, similar to the parabolic trough collector system, consists of an array of nearly-flat reflectors concentrating solar radiation onto an elevated inverted linear receiver. Water flows through the receiver and is converted into the steam. This system is line-concentrating, similar to a parabolic trough, with the advantages of low costs structural support and reflectors, fixed fluid joints, a receiver separated from the reflector system, and long focal lengths that allow the use of flat mirrors. The technology is seen as a potentially low-cost alternative to

[3] http://social.csptoday.com/emerging-markets/csp-down-under-cost-busting-thermal-storage-and-rooftop-options and http://www.wizardpower.com.au/index.php?option=com_content&view=article&id=36&Itemid=35

Figure 7.11 Cost Break-up of Parabolic Dish based CST Power Plant



Source: TERI estimates

Figure 7.12 LFR Technology based CST Power Plant

Source: http://www.csp-world.com/news/20120411/0094/areva-build-250mw-csp-plant-rajasthan-india

trough technology for the production of solar process heat and electricity. Figure 7.12 presents the photograph of a working LFR technology-based solar system.

LFR collectors are being mainly developed by the Australian company Ausra (now acquired by AREVA) in the USA. It built a test plant of 1 MW in the east of Australia in 2003, which feeds steam directly into an existing coal-fired power station. The capacity of this plant is currently being doubled. The company has one 5 MW plant operating and one 177 MW planned in the US. The Fresnel design uses less expensive reflector materials and absorber components. It has lower optical performance and thermal output but this is offset by lower investment and operation and maintenance costs. The 1.4 MW PE1 Fresnel plant from Novatec has recently started grid connected operation in Calasparra, Murcia, Spain.

7.1.8 Requirements of Concentrating Solar Thermal Power Plants

Solar direct normal irradiance

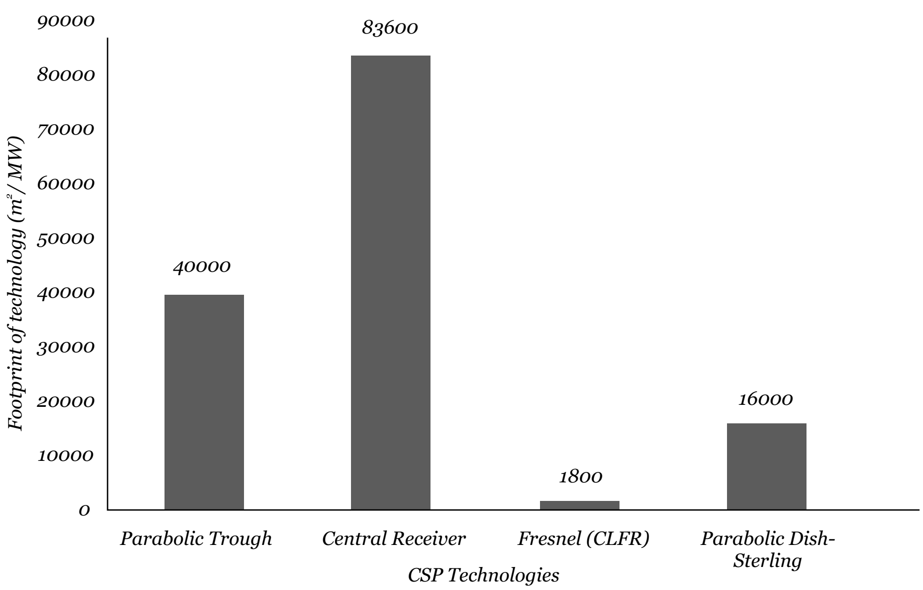
Concentrating solar power (CSP) technologies require direct solar radiation, which can be focused along a line or point through concentrating collectors. Global solar irradiance consists of direct and diffuse irradiance. Using tracking mechanism (single or two-axes) the cumulative direct solar radiation over any surface can be increased. Direct normal irradiance (DNI) is the optimal value of direct solar radiation at any location. Locations receiving less than 1700kWh per sq m annual DNI are not recommended for CSP projects.

Essentially the locations in between the latitudes 15–35°N are suited for CSP projects as the annual variation of the sun–earth angles is not extreme.

7.1.8.2 Land requirements

Concentrating solar power plants require a significant stretches of land that typically cannot be put to other uses simultaneously. The CSP project also requires the land to be graded level, except for solar dishes. The optimal area requirement for any CSP technology is estimated through shade analysis taking into account the realistic coordinates of geography and technology.

Figure 7.13 Footprint of Various CSP Technologies



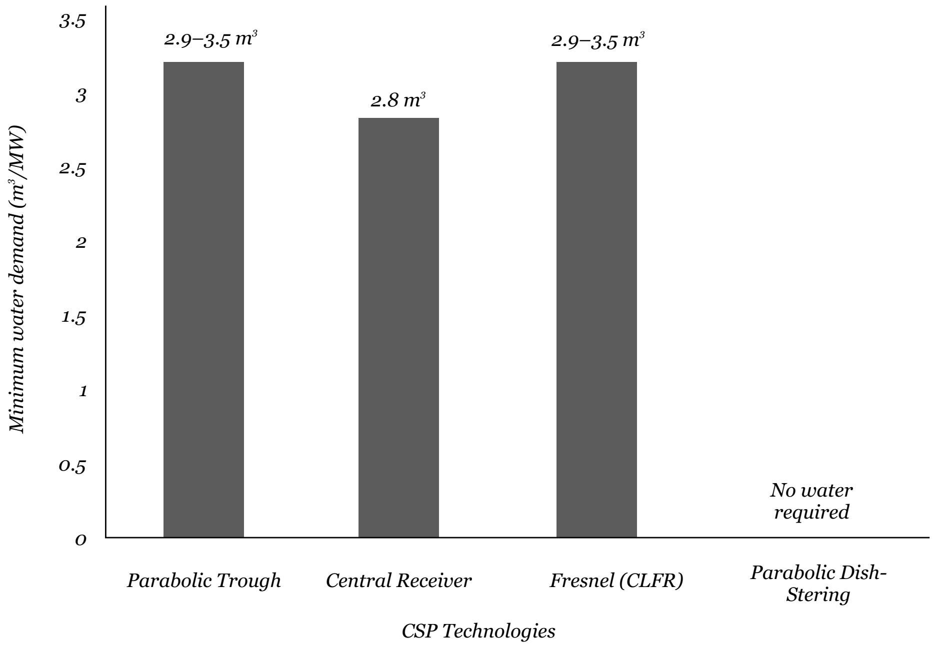
Source: Global Concentrated Solar Power Industry Report 2010-11 by CSP Today (http://www.csptoday.com/globalreport/index.shtml)

From the study of commissioned CSP plants it has been observed that the land requirement for parabolic trough plants of 50 MW is about 200 ha (2 sq km). Figure 7.13 gives an idea about the foot print of various CST technologies.

Water requirement

Water is also an essential requirement of CSP plants. The highest demand of water in a CSP plant is mainly on account of evaporative losses in cooling towers. In addition water is required for cleaning of the reflectors. A summary of minimum water consumption for different CSP technologies is presented in Figure 7.14.

Figure 7.14 Water Requirements of Various CSP Technologies



Source: Global Concentrated Solar Power Industry Report 2010-11 by CSP Today (http://www.csptoday.com/globalreport/index.shtml)

Inter-comparability of CST technologies

Based on application, advantages, and limitations a performance matrix for CST technologies has been developed and presented in Appendix V whereas Appendix VI summarizes the installed capacity and the maturity levels of various CST technologies.

Appendix VII shows the capacity of CST plants based on technology, which are (a) operational by the end of 2009 and (b) under installation and/or planned. It can be seen that the parabolic trough technology is currently the most proven CST technology and therefore the most developed and standardized. The parabolic trough projects currently in operation are between 14 and 80 MWe in size, and existing plants have a cumulative capacity of over 500 MW.

7.1.9 Solar PV Technology

Solar PV technologies can be classified broadly as conventional PV and concentrating solar PV. Figure 7.15 provides detailed classification of solar cell technologies.

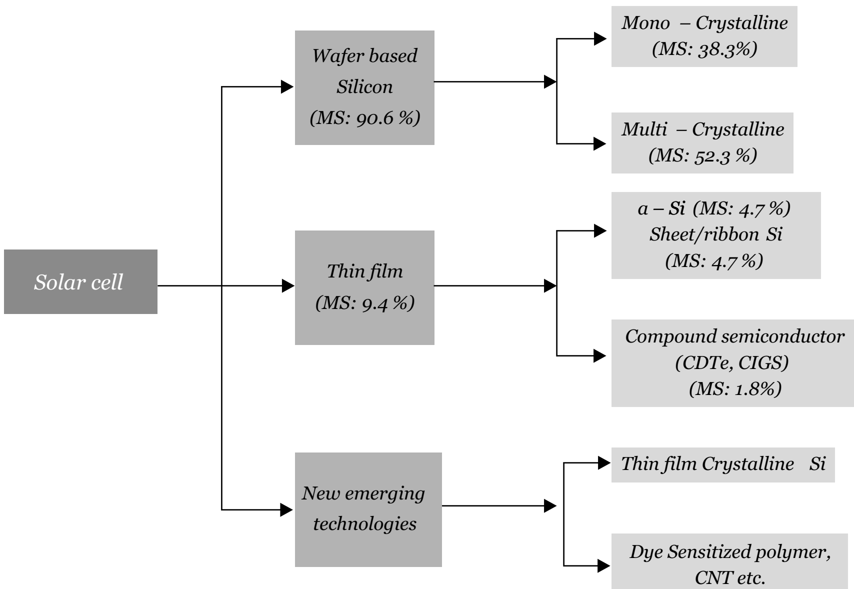
Conventional solar PV

Solar cells represent the fundamental power conversion unit of a photovoltaic system, which has much in common with other solid-state electronic devices, such as diodes, transistors and integrated circuits. Solar cells are usually assembled into modules. Its operation is based on the ability of semiconductors to convert sunlight directly into electricity by exploiting the photovoltaic effect. In the conversion process, the incident energy of light creates mobile charged particles in the semiconductor, which are then separated by the device structure resulting in electricity generation.

Single/mono-crystalline silicon (C-Si)

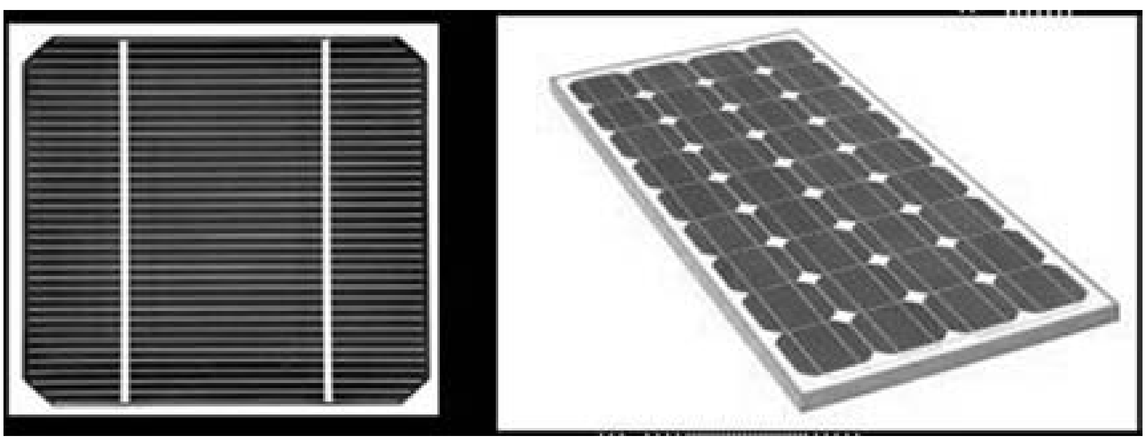
This is the most established and efficient solar cell technology till date, which has a module efficiency of 15-18%. The cell and module fabrication technology is well developed and reliable. These cells are manufactured from single silicon crystal. During manufacturing, Si crystals are cut from cylindrical ingots (Figure 7.16).

Figure 7.15 Classification of Solar Cell Technologies



Source: http://sovoxglobal.com/cell_classification.html

Figure 7.16 Mono-crystalline Silicon Solar Cell and Module



Source: http://sovoxglobal.com/cell_classification.html

Polycrystalline silicon solar (poly-Si or mc-Si)

The production of polycrystalline cells is more cost-efficient. These are manufactured by cooling a graphite mould filled with molten silicon. In this process, liquid silicon is poured into blocks that are subsequently sawed into plates. During solidification of the material, crystal structures of varying sizes are formed. These cells have module efficiency of around 12-14% (Figure 7.17).

Thin film solar cell technology

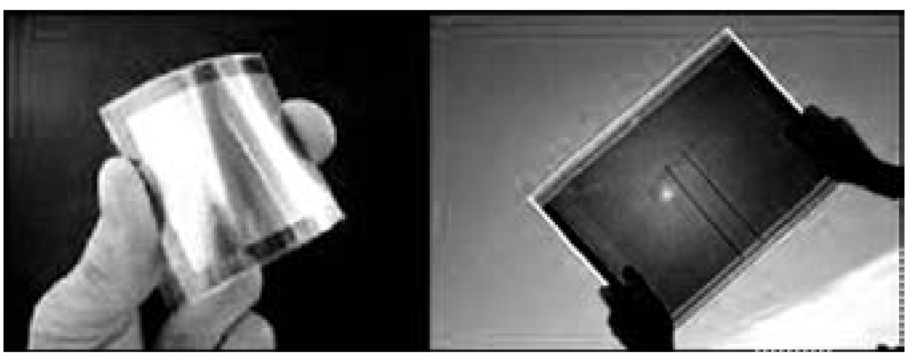
In this approach thin layers of semiconductor material are deposited onto a supporting substrate, such as a large sheet of glass. Typically, less than a micron thickness of semiconductor material is required, a hundredth or thousandth part of the thickness of a silicon wafer (Figure 7.18). Some of the thin film solar cells in use are as follows:

- a – Si
- CdTe
- CIS, CIGS (copper indium gallium di-selenide) Figure 7.18: Thin film solar cell and module
- Thin film crystalline silicon.

Figure 7.17 Polycrystalline Silicon Solar Cell and Module

Source: http://sovoxglobal.com/cell_classification.html

Figure 7.18 Thin Film Solar Cell and Module



Source: http://sovoxglobal.com/cell_classification.html

A comparison of CSP and SPV technology is presented in Appendix IX.

7.1.10 Concentrating Solar Photovoltaic

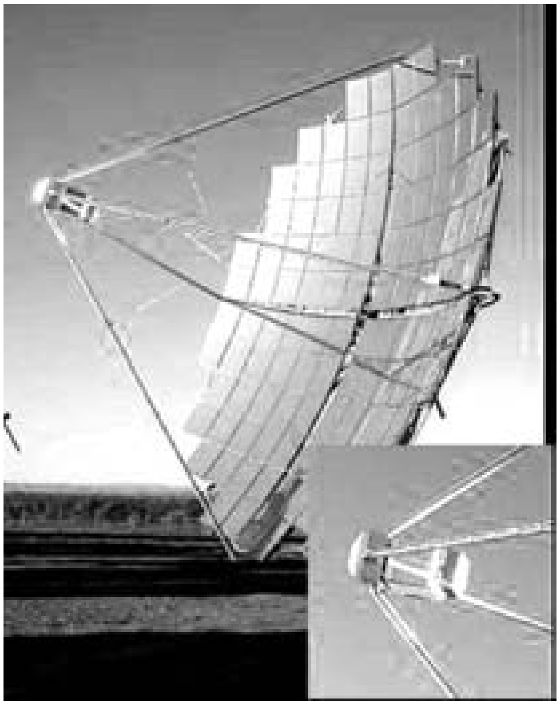
Concentrating solar photovoltaic systems employ solar radiation concentrated onto photovoltaic cells for electricity production. Due to concentrated radiation on a small surface, solar cell size reduces drastically. Concentrators of all varieties (such as parabolic trough or parabolic dish) with tracking mechanism may be used. Additionally, increasing the concentration ratio improves the performance of photovoltaic materials. There are four types of CPV technologies:

- Dish CPV
- Lens CPV
- Low concentration CPV and
- Non-Tracking CPV

Dish CPV

The parabolic dishes are now being coupled with photovoltaic in dish CPV systems. Dish CPV systems are available in a range of sizes and configurations from large systems that resemble dish-engines with the engines replaced with a CPV receiver to several small dishes combined together in a tracking panel (Figure 7.19).

Figure 7.19 Large Parabolic Dish CPV

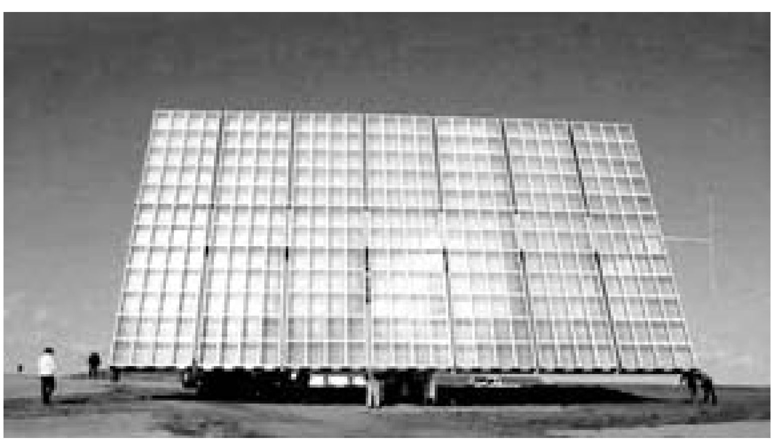


Source: www.solarsystem.com

Lens CPV

Lens CPV technology is gaining popularity as it promises lower costs than standard PV. The technology comprises full tracking panels of lens-CPV assemblies, and arrays of individually tracking facets (Figure 7.20).

Figure 7.20 Lens CPV



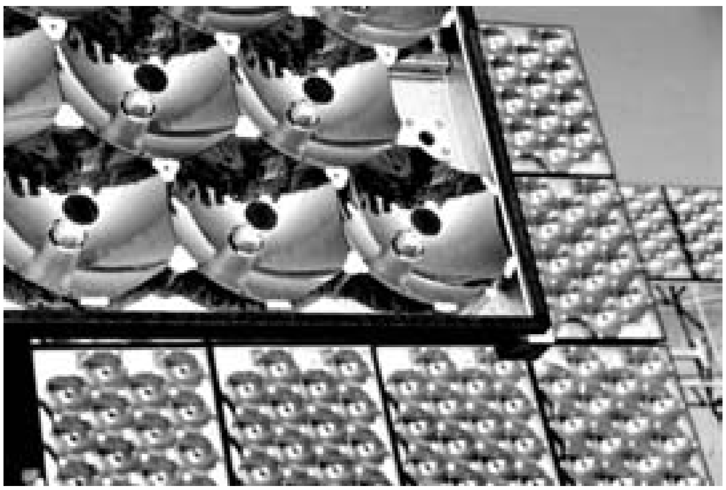
Source: www.solareis.anl.gov.

Lens CPV modules with individual tracking facets have a lower profile than Lens CPV tracking panels as the panel is mounted on a flat plane and only the small assemblies are used to track. This results in many moving parts and high potential for mechanical failure and consequently ballooning O&M costs. The tight packing of the facets within one panel can also lead to shading between the facets as they track the sun.

Low concentration PV

Low concentration PV is the most accessible CPV technology presently which applies simple flat reflective surfaces to concentrate light onto conventional solar panels. These systems require single-axis tracking with much lower accuracy as compared to higher concentration CPV/CST technologies. Different configurations of LCPV systems have been developed and deployed, but all are based on the same basic principle of combining low-cost and low-precision reflectors and trackers with a PV panel to improve performance (Figure 7.21).

Figure 7.21 Low Concentration PV



Source: www.news.cnet.com.

Non-tracking CPV

This technology is an approach to develop a product at a lower cost than conventional PV. This type of CPV panel looks and acts almost exactly like a conventional PV panel, but contains a third to half of the PV used in a conventional PV panel. Non-tracking CPV technologies use a variety of internal optical devices that can accept light at a range of angles and direct it towards a small amount of PV. Non-tracking CPV offer promising market application as they can be installed and operated like conventional PV panels, with low O&M costs, with a fraction of the PV material used to create PV panels. Furthermore, because these technologies accept light from a range of angles, they are not limited to DNI, but can take advantage of a greater range of the solar radiation.

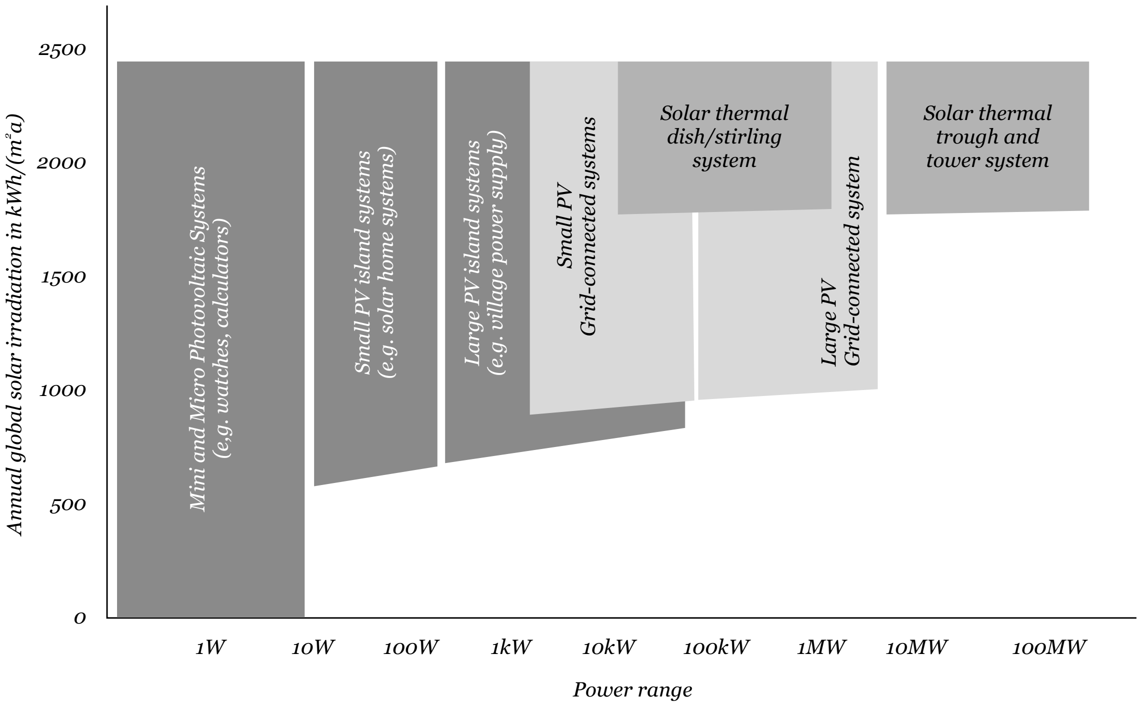
7.2 Appropriate Selection of Solar Technology

From the entire range of solar technologies available, it is very important to select appropriate technology determined by the solar resources availability, type of applications, and space available for installations etc.

For water heating, industrial process heating, and drying application, the solar thermal technology is very appropriate. For instance, for low temperature applications with clear sky conditions, flat plate collector is appropriate whereas during overcast conditions, evacuated tube collectors may be more useful as they facilitate more efficient absorption of solar radiation, combined with excellent insulation provided by the evacuated tube. For applications where high–temperature process heat or steam is required, concentrating solar thermal technologies would be needed.

In the case of solar electricity generation, selection of appropriate technology is very important not only from the point of view of proper functioning but also from the point of view of maximizing economic benefits. Global solar radiation consists of direct and diffuse solar radiations. It is important to note that while solar thermal power plants can only use direct irradiance for power generation; photovoltaic systems can convert the diffuse irradiance as well. That means they can produce some electricity even with cloud-covered skies. The areas where photovoltaic systems and solar thermal power plants can operate overlap only in a narrow range.[4] Figure 7.22 illustrates the suitability of technology with respect to global solar radiation and power plant size.

Figure 7.22 Operational Areas for Solar Thermal Power Plants and Photovoltaic Systems Depending on the Installed Capacity and the Annual Global Solar Irradiation



Source: Contribution of *Concentrated Solar Thermal Power for a Competitive Sustainable Energy Supply* by Volker Quaschning; Norbert Geuder, Christoph Richter, Franz Trieb. http://www.volker-quaschning.de/downloads/CleanAir2003.pdf

Due to their modularity, photovoltaic operation covers a wide range from less than one watt to several megawatts. Moreover, photovoltaic systems can operate in stand-alone as well as in grid-connected mode. As explained earlier, there are different PV technologies but c-Si and thin film are most common. On the other hand in case of CPV, a few plants are under operation as pilot projects only.

Some of the factors for selection of c-Si or thin film are listed in Tables 7.3 and 7.4.

Table 7.3 Selection of Appropriate PV Technology

Sl. No.	Description	Crystalline technology	Thin film technology
1	Technology	Pure silicon wafers are converted into PN junction, which is called a solar cell. These cells are laminated into solar modules and these are then framed into aluminium channels, which generate 12 volts or 24 / 30 volts DC.	A thin film of silicon is deposited onto a glass and then another glass is laminated onto this. This is called a thin film module. It is double glass module and is used as a building integrated photovoltaic module (BIPV). This generates a voltage of 80 volts DC.

[4] Volker Quaschning et al. Solar Power–Photovoltaic or Solar Thermal Power Plants. Brussels: VGB Congress Power Plants 2001. 10-12 October 2001.

Sl. No.	Description	Crystalline technology	Thin film technology
2	Usage	• These are being commonly used as hybrid systems with mains, DG, wind and hydro. • These are also used for pumping power to the grid as voltage support or load support systems as grid tied systems.	These are only used for pumping power to the grid as grid tied SPV systems for load support or voltage support systems.
3	Advantages/ disadvantages	• These are more efficient systems and installations occupy less space. • The power of the system reduces with increase in the ambient temperature. • Overall cost of the system is more.	• These are less efficient systems and occupy around 50% more space than crystalline systems. • The power reduction with the rise in ambient temperature is negligible. • Overall cost of the system is less.
4	Installations	These are installed either on the roof -top or ground on the supporting structures.	• These are also installed on the ground or the roof-top onto the supporting structure. • When used as BIPV, these form part of the building and could be installed with the facade, window shades, roof, walls etc.
5	Efficiency	13%–13.5%	6.5%–7%

One of the important factors in favor of thin film technologies is that they have better efficiencies with diffuse radiation. Therefore, where diffuse radiation component is high and skies are overcast, or if the PV is to be integrated with buildings with partial shading (or not facing the sun throughout the day), one can expect better annual energy output with thin film-based systems.

Concentrated solar technologies are more dependent on the DNI levels, hence the output and the profitability of solar thermal power plants is related to DNI levels of the locations. For economically viable systems, a minimum DNI of 5 kWh per sq m has been suggested. [5] Dish-Stirling systems are best suited for decentralized application with small capacity power requirements whereas the parabolic trough and solar tower power plants are best suited in the megawatt range.

For the CST plants, the selection of appropriate technology based on the application is listed in the following table.

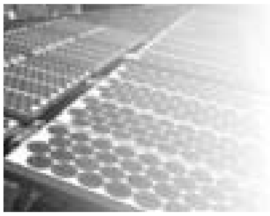
Table 7.4 Selection of Appropriate Technology-based Application

	Parabolic trough	Central tower power plant	Parabolic dish	Fresnel linear reflector
Applications	Grid-connected plants, mid to high-process heat (Highest single unit solar capacity to date: 80 MWe)	Grid-connected plants, high temperature process heat (Highest single unit solar capacity to date: 20 MWe under construction)	Stand-alone, small off-grid power systems or clustered to larger grid connected dish parks (Highest single unit solar capacity to date: 100 kWe)	Grid-connected plants, or steam generation to be used in conventional thermal power plants. (Highest single unit solar capacity to date is 5MW)

As of now, the parabolic trough-based power plant technology has proved to be a mature technology, with the largest share in the installations among CSP worldwide. Even the first phase of Jawaharlal Nehru National Solar Mission (JNNSM) appears to have more parabolic trough-based CST plants coming up.

For the industrial heat application, compact LFR technology can be used because it is modular and its indigenization too could be faster.

[5] Siting guidelines for concentrating solar power plants in the Sahel: Y. Azoumahb et al. 2010. Case study of Burkina Faso. *Solar Energy 84(8)*. Pp. 1545–1553. http://www.sciencedirect.com/science/article/pii/S0038092X10002100.



8

Recommendations

As part of this study, a number of interactions were held with various stake holders in both Karnataka and Tamil Nadu, to understand (a) why certain technologies have developed faster than others and (b) key issues faced in renewable energy projects. Two very successful programs, to develop wind energy in Tamil Nadu and solar water heating in Karnataka, were analyzed in detail through extensive stakeholders' engagement.

The key reasons for the success of wind energy program in Tamil Nadu are as follows:

- Good wind resources are available in the state
- Tamil Nadu Electricity Board (TNEB) has played a crucial role in promoting the wind, especially in the formative years of wind power development in the state (since the utility itself was behind the wind program, it facilitated settlement of issues such as those related to grid-connection, evacuation, wheeling, and banking).
- Potential sites are mostly non-agricultural and privately-owned making them relatively easy to access and acquire.
- There is good grid network in the wind potential areas.
- A favorable policy and regulatory environment prevails with good wind power purchase tariff, renewable purchase obligations, tax incentives, tax holidays, and easy clearances along with accelerated depreciation benefits.

In the same way, the success of solar water heating program in Karnataka, particularly in the capital city of Bangalore, can be attributed to the following reasons:

- There is year round demand for hot water.
- There is good solar radiation availability.
- Policies and regulations are conducive.
  - Rebate in electricity bill for those domestic consumers who have solar water heating systems installed in their houses.
  - Mandatory use of solar water heating systems.
- Awareness generation by the state agencies and manufacturers is an ongoing exercise.
- There is a good manufacturing base along with established supply chains, especially in Bangalore leading to good after-sales service and better client satisfaction.

Availability of solar and wind energy resources is very location specific. While there are some common barriers pertaining to higher investment cost and grid integration etc, others depend not only on specific technology and its application, but also on the geographic location. In the following section, barrier analysis is carried out for specific technological applications such as solar water heating, solar, and wind power generation.

8.1 Solar Water Heating

8.1.1 Barriers

- In many of the northern cities in India, solar radiation is greatest in summer, when there is no demand for heating, and lowest in winter, when the demand is highest. Hence there is a mismatch in demand and supply.

- In case of industrial or commercial systems, proper integration of the solar water heating system with the conventional system is required to ensure quality services and optimized energy delivery.
- Consistent quality, especially for large systems, is difficult to ensure.
- State-of-the-art controllers are required for better energy management in case of larger, forced-flow systems.
- There is hardly any emphasis on research and development for (a) design improvements, cost optimization, and better aesthetics and (b) for other applications, including solar space heating, large- and small-scale cooling and air conditioning, and industrial process heating.
- There is a need for better quality components for the solar collector systems like high quality low-iron glass, non-polluting selective coatings, and more efficient absorbers.
- Solar thermal systems require high upfront costs. Payback period is often used as a criterion for decision-making; however, payback period does not account for the entire lifetime of the system and excludes long-term savings.
- Non-realistic pricing of competing energy sources presents an important challenge to solar thermal development. Alternate fuels like gas, kerosene, electricity are comparatively cheaper, which is a setback for the development of solar thermal industry. For instance, environmental externalities are not internalized in the prices of fossil fuels and electricity is generated from fossil fuels, thereby keeping these costs artificially low.
- "Split incentives" issue when the one who pays is separate from the one who benefits. For example, in organizations, the decision-making administrator may not recognize the benefits of savings of fuel and electricity if the funds for capital cost and for running costs are handled separately. Split incentives are also an obstacle for apartment buildings with multiple-rented flats.
- Lack of awareness among the public about the maturity, reliability, and potential energy savings of current solar thermal technology poses a significant challenge. Many still labor under the misconception that the intermittence of solar technology will not be able to provide adequate water or space heating.
- Lack of properly trained professionals for design, installation, building integration, and post-installation service is also a serious drawback.
- There is lack of suitable space for solar water heating system installation.
- Emphasis on compliance of regulatory provisions such as mandatory installation of solar water heating systems in buildings is inadequate.

8.1.2 Recommendations

These barriers can be lowered through strategies around research and development, support for market development, and government regulations.

- Mandatory regulations would pave the way for greater penetration of solar water heating systems. The state government, in consultation with the municipalities/municipal corporations could prioritize certain cities and start the process.
- The state should also facilitate, through suitable incentives and financial assistance, development/strengthening of complete supply chain for the solar systems.
- Public awareness and education are central to successful programs; it is imperative for Tamil Nadu Energy Development Agency and Karnataka Renewable Energy Development Limited to engage the public through sustained awareness campaigns and communicate the benefits of renewable energy and in particular solar water heating to different user-groups including local elected representatives.
- A focused and sustained campaign may be mounted encompassing all media—print, radio, and television. Apart from specific recommendations, such campaigns must inform the general public about the places from where solar energy devices and services can be procured.
- A key component of the awareness creation campaign would be to capture the attention of school children towards energy-efficiency and a clean future. Thus, the campaign for the school children may include the following elements:
    - Inter-school essay and drawing competitions
    - Inter-school quizzes

  - Workshops and seminars
  - Exhibitions and demonstrations
  - Field trips to prominent solar plants
- A policy framework that incentivizes research and development to improve technology, reduce costs, and increase ease of installation and use would be desirable. Current policies regarding research and development of solar thermal energy are insufficient.
- In order to tackle public ignorance about the current state of solar thermal technology, outreach programs and extensive media publicity may be resorted to.
- Professionals should be properly trained to deliver services all along the value-chain to eliminate installation/ post-installation problems. The training should encompass technical features, the economics and marketing of solar heaters.
- Capacity building of the architects may be initiated in passive solar design so that heating and cooling loads are greatly reduced and solar thermal systems can be incorporated into the building.
- Likewise, relevant organizations, government agencies, and financial institutions may receive training to promote and assess solar thermal systems.
- Certification of solar collectors and systems instills a sense of confidence in potential customers. For certification programs to be successful, criteria for certification need to be uniform, and the private sector needs to voluntarily recognize the certification as legitimate.
- In order to address the split incentives problem, energy service companies can finance the upfront costs and recover the same from the fuel and electricity savings until the investment and profit margin are compensated.
- Financial and fiscal incentives help support the growth of solar technologies. Since these help decrease capital costs, potential customers will be more willing to invest in solar systems. However, such incentives, especially the capital subsidy must incorporate a sunset timeframe right from the beginning. Fiscal incentives like tax exemptions, property tax rebates and electricity bill rebates may be more useful.
- Since manufacturing and installation of solar systems is labor intensive, creation of domestic capacity resulting in more employment opportunities in the solar energy industry, may be encouraged along side creating a competitive environment.
- Cooperative procurement of solar thermal technology by governments or private firms can lower costs on one hand and minimize risks for producers on the other.
- An appropriate policy framework and user-friendly financing mechanisms may be developed in close coordination with the Ministry of New and Renewable Energy, Ministry of Power, Ministry of Urban Development, state power utilities, and financial institutions.
- Another important focus area is to enhance the competitiveness of the Indian solar thermal industry through continuous investment in research and development.
- It is also important to focus beyond solar water heating in terms of other solar thermal applications to expand the market scope and horizons for constituent players.
- Governments need to pinpoint and eliminate the legal barriers that hinder the growth of solar thermal technology. The approvals and clearances process must be simplified.
- Provisions to protect "solar rights" (the right for a building to receive sunlight without obstruction by neighboring structures) may be incorporated in the building by-laws.
- RPO may have a component on solar water heating systems as these systems act as a demand side management measure.
- The electricity distribution companies may become vehicles to promote solar water heating systems and incentives such as rebate on electricity bill may be routed through them. This would also help reduce transaction costs.
- The state may also design a scheme to promote renewable energy service companies (ReSCOs) to act as one–stop shops for solar energy based solutions.

8.2 Solar Power

Development of a large market for solar power technologies faces many challenges.

8.2.1 Barriers

- Very high upfront investment requirements
- Relatively immature technology in case of Concentrated Solar Power (CSP)/Concentrated Photovoltaic (CPV)
- Lack of indigenous experience in CSP/CPV
- Non-standardization of technologies leading to reliability issues
- Non-despatchable power supply, unless there are storage/backup facilities, which add to the costs
- High demand for water in case of CSP technology (dry cooling or sea water desalination remain costly options)
- Low peak coincidence factor (electricity demand peaks in morning and evening whereas the solar power has maximum output in the noon, hence this poses a challenge in the absence of appropriately designed storage)
- Non-existent value-chain, including non-availability of trained professionals
- Perceived technological risk among the financing community, hence difficulty in getting financing at favorable terms, especially for large projects
- Large pre-investment risks associated with the costs of marketing, contracting, and information collection
- Subsidy on fossil fuels, non-internalization of socio-environmental externalities, and irrational electricity tariff structures rendering solar power non-competitive
- High transaction costs in technology commercialization
- Challenges of developing sustainable business plans for ensuring accelerated up-scaling

8.2.2 Recommendations

- Solar energy should be treated as a national resource and exploitation of the same accorded priority (there may be a central organization for solar energy on the lines of Nuclear Power Corporation).
- To bring down the costs, partial risk guarantee funds could be set up in collaboration with multilateral development banks and/or through international funding for propagation of clean technologies.
- Solar power programs need to be integrated with regional development and rural electrification programs.
- Technology transfer should be enabled through removal of trade barriers within the framework of the proposed global clean technologies fund.
- Favorable policies should be formulated to promote indigenous manufacturing of solar systems, thereby bringing down the costs. Towards this, the state may consider setting up a "Solar Manufacturing Hub" for manufacturing solar systems and their components. Apart from (a) servicing the domestic markets with standard equipment and devices and (b) bringing down the costs of solar systems through economies of scale (and therefore ease of introduction of the latest technologies/processes); this Hub could cater to the growing export markets as well. Another option is to set up "Solar Park" in the state. A "Solar Park" is a concentrated zone of solar development targeting 3,000 to 5,000 MW of generation capacity over time, with a solar manufacturing and technology hub, and research and development facilities. It is believed that a Solar Park could facilitate the cost reduction of solar power significantly, due to economies of scale and sharing of common transmission and infrastructure.
- Market infrastructure including strong sales and services networks for providing the energy service may be set up
- Local financiers should be encouraged to assume part of the credit risk to ensure post project sustainability and replication.

8.3 Wind Power

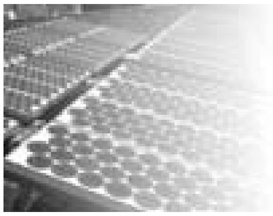
8.3.1 Barriers

- High investment requirements
- Intermittency of wind resource, leading to problems in scheduling the wind power
- Dispersed nature of resource posing difficulties in tapping wind energy resource from far–flung areas, especially from the point of view of load centers

- Low peak coincidence factor that leads to problems in matching wind power availability with demand
- Power off-take problems due to grid instabilities
- Grid up-gradation required to tap the full potential of wind power in Tamil Nadu
- High reactive power requirements for start-up
- Non-availability of high efficiency wind turbines for low wind regimes
- Subsidy on fossil fuels, non-internalization of socio-environmental externalities, and irrational electricity tariff structure
- Non-availability of proven short-term wind power forecasting tool for India
- Inadequate infrastructure facilities and poor access to transmission and distribution networks
- Complexity of land acquisition in resource-rich areas, especially forest areas
- Long delays in payment by distribution utilities.

8.3.2 Recommendations

- The state needs to ensure (a) evacuation facilities at the potential sites, (b) grid access at nominal charges, if any, and (c) grid stability for reliable power off-take and better capacity utilization.
- To encourage private participation, the state-level policy and regulatory regime (e.g. third-party sale, tariff setting, wheeling, and banking of power) should be long-term and stable.
- The renewable purchase obligation should be adequate to incentivize the state utilities/designated consumers to procure wind power. This also includes a mechanism to ensure timely compliance.
- Wind power supply option needs to be included in utility's unit commitment approach.
- Investment in development of comprehensive wind energy forecasting models suitable for Indian climate and grid conditions is an urgent requirement. It would be necessary to test the model on wind farms in India, which require a day ahead forecasting with 15 minute time interval to meet the conditions of Indian Electricity Grid Code 2010.
- Measures need to be taken for better operation and maintenance of wind power systems and better technological performance leading to improved capacity utilization.
- Baseline projections need to be redefined in the light of investment requirements and a preparedness plan developed for accelerated penetration under carbon mitigation scenarios.
- Clear policy from government on re-powering for wind turbines may be worked out so that wind power output in Tamil Nadu could be enhanced.
- Tamil Nadu too might levy a green cess to create a 'clean energy fund' that can be utilized for infrastructure strengthening for solar and wind power projects.
- Apart from developers, local manufacturing of components related to solar and wind should be promoted by giving special benefits and tax breaks. Taxes and duties on balance of systems should be reduced so that cost of the overall system can be brought down.
- The State Electricity Regulatory Commissions should look in to the issue of late payment of dues the generators by the distribution utilities in order to devise a suitable mechanism for the timely payments.



Appendices

Appendix I List of Projects under Off-Grid Solar Applications of JNNSM as on 31 August 2010

S. No.	State	Implementing agency	Sanctioned systems	Location	Date of sanction/ date of completion	Capacity (kWp)
1	Andhra Pradesh	NEDCAP	Power plants 2x100kWp 1x80kWp 1x60kWp 2x30kWp 1x1.94kWp 1x1.3kWp 1x1kWp	Educational institutions	16.07.2010	404
2		NEDCAP	Power plants 1x25kWp 1x3kWp 8x1kWp	MPDO offices / commercial organizations	13.08.2010	36
3	Chhattisgarh	CREDA	Power plants 1222kWp	Branches of rural bank, hospitals, temples, govt. institutions and PWD guest houses	24.08.2010	1222
			Power plants 1x50kWp 7x25kWp 1x10kWp	Branches of State Bank of India	24.08.2010	235
4	Haryana	HAREDA	SPV street lighting systems (6660 nos.)	330 villages in Sirsa district	15.07.2010	493
5		HAREDA	Power plant 1x50kWp	TERI Retreat Gwal Pahari	15.07.2010	50
6		HAREDA	Power plants 1x30kWp 7x10kWp	BPDO offices in Sisrsa district and hospital at Rewari	15.07.2010	100

(Contd.)

S. No.	State	Implementing agency	Sanctioned systems	Location	Date of sanction/ date of completion	Capacity (kWp)
7		Gurgaon Gramin Bank	Power plants 20x1.6kWp	Rural branches of the bank	25.08.2010	32
8	Himachal Pradesh	CEL	Power plants 4x100kWp	SSB training centers	13.08.2010	400
9	Karnataka	KSRTC	Power plants 20x2kWp	Bus stations	31.08.2010	40
10	Lakshadweep	LD Administration	Solar power plants 1x660kWp 1x220kWp 2x110kWp		09.08.2010	1100
11	Madhya Pradesh	MPUVN	Power Plants 19x10kWp 18x8kWp 33x5kWp 10x2kWp	Tribal hostels/ police stations	16.07.2010	521
12		Forest department	Solar power plants/power packs	Forest check posts	28.07.2010	900
13		MPUVN	Solar power Plants 28x10kWp	CHC s	06.08.2010	280
14	Maharashtra	TMC	SPV power plant 1x50kWp	Thane Municipal Corporation	15.07.2010	100
15		SEZ	SPV power Plants 1x75kWp 1x25kWp	SEEPZ SEZ	15.07.2010	50
16	Manipur	MANIREDA	SPV power plants 4x25kWp	Hospitals, jail and state training academy	19.08.2010	100
17	Mizoram	ZEDA	SPV power plants 4x25kWp 2x10kWp 1x1kWp	Charitable institutions, hospital	26.08.2010	121
18	Punjab	PEDA	SPV power plants 1x100kwp 1x5kWp	Educational institutions	16.07.2010	105
19	Rajasthan	REIL	Power plants 9168x1.12kWp	Gram panchayats in the state	04.06.2010	10268
20	Tamil Nadu	TEDA	Power plants 1x60kWp 1x25kWp 1x10kWp 1x1.8kWp	Schools/ commercial organizations	20.08.2010	97

(Contd.)

S. No.	State	Implementing agency	Sanctioned systems	Location	Date of sanction/ date of completion	Capacity (kWp)
21	Uttarakhand	UREDA	SPV street lighting systems 1645 nos.	316 villages in eight districts	12.08.2010	122
22	Uttar Pradesh	UPNEDA	Street lighting systems (2798 nos)	230 villages in Nine districts	13.07.2010	207
23		UPNEDA	Power plants 57x4,8kWp Street Lighting Systems (342 nos.)	57 Ashram Schools	15.07.2010	299
24		UPNEDA	Street lighting systems (10430 nos.)	2086 villages in 46 districts	28.07.2010	772
25		UPNEDA	Street lighting Systems (5957nos.)	648 villages in 37 districts	13.08.2010	441
26		Allahabad UP Gramin Bank	Power Plants 120x1.5kWp 130x2kwp 39x3.5kWp 5x4.6kWp	294 branches of the bank	30.08.2010	599
27	Others	CEL	Power plants 2x100kWp 1x50kWp 1x30kWp	Charitable Institutions, engineering college and IOCL R&D Center	19.08.2010	280

Appendix II List of Projects Proponents Registered for GBI under Guidelines for RPSSGP Connected to Distribution Network (Below 33 kV) as on 28 December 2010

Project code	Project proponent	Project state/ UT	Capacity allocated as per state (in MW)
RPSSGP_GBI/001	Noel Media & Advertising Pvt Ltd	Tamil Nadu	1
RPSSGP_GBI/002	Premier Solar Systems Pvt Ltd	Jharkhand	2
RPSSGP_GBI/003	Saimeg Infrastructure Pvt. Ltd	Jharkhand	2
RPSSGP_GBI/004	New Era Enviro Ventures Pvt. Ltd.	Jharkhand	2
RPSSGP_GBI/005	Andromeda Energy Technologies Private Limited	Andhra Pradesh	0.75
RPSSGP_GBI/006	Kijalk Infrastructure P. Ltd.	Jharkhand	2
RPSSGP_GBI/007	Chandraleela Power Energy Private Limited	Haryana	0.8
RPSSGP_GBI/008	Singhal Forestry Private Limited	Chhattisgarh	2

(Contd.)

Project code	Project proponent	Project state/ UT	Capacity allocated as per state (in MW)
RPSSGP_GBI/009	Aew Infratech Pvt. Ltd	Rajasthan	1
RPSSGP_GBI/010	Gemini Geoss Energy Pvt. Ltd.	Tamil Nadu	1
RPSSGP_GBI/011	Gajanan Financial Services Pvt Ltd	Andhra Pradesh	1
RPSSGP_GBI/012	Asian Aero-Edu Aviation Private Limited	Rajasthan	1
RPSSGP_GBI/013	B&G Solar Private Limited	Tamil Nadu	1
RPSSGP_GBI/014	Basant Enterprises	Rajasthan	1
RPSSGP_GBI/015	Rays Power Private Limited	Rajasthan	1
RPSSGP_GBI/017	Sovox Renewables Private Limited	Rajasthan	1
RPSSGP_GBI/018	Sovox Renewables Private Limited	Punjab	1
RPSSGP_GBI/019	KVR Constructions	Jharkhand	2
RPSSGP_GBI/020	Photon Energy Systems Ltd.	Andhra Pradesh	1
RPSSGP_GBI/021	Tayal & CO	Haryana	1
RPSSGP_GBI/022	Zamil New Delhi Infrastructure Private Limited	Rajasthan	1
RPSSGP_GBI/023	Zamil New Delhi Infrastructure Private Limited	Haryana	1
RPSSGP_GBI/024	Sri Power Generation (India) Private Limited	Andhra Pradesh	1
RPSSGP_GBI/025	RV Akash Ganga Infrastructure Ltd.	Uttarakhand	2
RPSSGP_GBI/026	Andhra Pradesh Industrial Infrastructure Corporation Limited	Andhra Pradesh	1
RPSSGP_GBI/027	Adora Energy Private Limited	Madhya Pradesh	2
RPSSGP_GBI/028	Harrisons Power Private Limited	Tamil Nadu	1
RPSSGP_GBI/029	Navbharat Buildcon Pvt Ltd	Rajasthan	1
RPSSGP_GBI/030	Abacus Holdings Private Limited	Odisha	1
RPSSGP_GBI/031	Amrit Jal Ventures Pvt. Ltd.	Andhra Pradesh	1
RPSSGP_GBI/032	Priapus Infrastructure Private Limited	Uttar Pradesh	2
RPSSGP_GBI/033	MGM Minerals Ltd.	Odisha	1
RPSSGP_GBI/034	Dante Energy Private Limited	Uttar Pradesh	2
RPSSGP_GBI/035	AKR Construction Limited	Jharkhand	2
RPSSGP_GBI/036	Sunedison Energy India Private Limited	Rajasthan	1
RPSSGP_GBI/037	Shiv-Vani Energy Limited	Madhya Pradesh	2
RPSSGP_GBI/038	RL Clean Power Pvt Ltd	Tamil Nadu	1
RPSSGP_GBI/039	G S Atwal & Co. (Engineers) Pvt. Ltd	Punjab	1.5
RPSSGP_GBI/040	Bhavani Engineering	Andhra Pradesh	1
RPSSGP_GBI/041	Enterprise Business Solutions	Punjab	1.5
RPSSGP_GBI/042	JSR Developers Pvt Ltd	Madhya Pradesh	1.25
RPSSGP_GBI/043	PCS Premier Energy Pvt Ltd	Jharkhand	2
RPSSGP_GBI/044	Great Shine Holdings Pvt. Ltd.	Tamil Nadu	1

(Contd.)

Project code	***Project proponent***	***Project state/ UT***	***Capacity allocated as per state (in MW)***
RPSSGP_GBI/045	Chhattisgarh Investments Ltd.	Chhattisgarh	2
RPSSGP_GBI/046	SDS Solar Private Limited	Haryana	1
RPSSGP_GBI/047	Dr.Babasaheb Ambedkar Sahakari Sakhar Karkhana Ltd.	Maharashtra	1
RPSSGP_GBI/048	Jay Ace Technologies Limited	Uttarakhand	2
RPSSGP_GBI/049	Ganges Enterprises Private Limited	Rajasthan	1
RPSSGP_GBI/050	Andhra Pradesh Power Generation Corporation Ltd	Andhra Pradesh	1
RPSSGP_GBI/051	Raajratna Energy Holdings Private Limited	Odisha	1
RPSSGP_GBI/053	Enertech Engg Pvt. Ltd	Jharkhand	2
RPSSGP_GBI/054	Sukhbir Solar Energy Private Limited	Haryana	1
RPSSGP_GBI/055	Soma Enterprise Limited	Punjab	1
RPSSGP_GBI/056	Amson Power Private Limited	Tamil Nadu	1
RPSSGP_GBI/057	Kishore Electro Infra Pvt Ltd	Andhra Pradesh	1
RPSSGP_GBI/058	S N Mohanty	Odisha	1
RPSSGP_GBI/059	Technical Associates Ltd	Uttar Pradesh	2
RPSSGP_GBI/060	VKG Energy Pvt.Ltd.	Haryana	1
RPSSGP_GBI/061	Molisati Vinimay Pvt. Ltd.	Odisha	1
RPSSGP_GBI/062	Sepset Constructions Limited	Maharashtra	2
RPSSGP_GBI/063	Solar Semiconductor Pvt Ltd	Andhra Pradesh	0.75
RPSSGP_GBI/064	Reliable Manpower Solutions Ltd	Haryana	1
RPSSGP_GBI/065	Pantime Finance Company Pvt Ltd	Odisha	1
RPSSGP_GBI/066	Ramakrishna Industries	Andhra Pradesh	1
RPSSGP_GBI/067	H.R.Minerals And Alloys Pvt Ltd	Haryana	1
RPSSGP_GBI/068	Metro Frozen Fruits & Vegetables Pvt. Ltd.	Uttarakhand	1
RPSSGP_GBI/069	Jay Iron & Steels Limited	Odisha	1
RPSSGP_GBI/070	Lanco Solar Private Ltd	Rajasthan	1
RPSSGP_GBI/071	Carlill Energy Private Limited	Punjab	1.5
RPSSGP_GBI/072	Citra Real Estate Limited	Maharashtra	2
RPSSGP_GBI/073	Bharat Petroleum Corporation Ltd	Punjab	1
RPSSGP_GBI/074	Dhruv Milkose Pvt. Ltd.	Uttar Pradesh	1
RPSSGP_GBI/075	Conflux Infratech Private Limited	Rajasthan	1
RPSSGP_GBI/076	Econergy Inc	Punjab	1
RPSSGP_GBI/077	Eastern Bearings Pvt. Ltd.	Uttar Pradesh	1
RPSSGP_GBI/078	Shri Mahavir Ferro Alloys Pvt Ltd	Odisha	1
RPSSGP_GBI/079	C&S Electric Ltd.	Haryana	1
RPSSGP_GBI/080	Vivek Pharmachem (India) Limited	Rajasthan	1

Note: * Two projects of 1 MW each are kept in abeyance subject to the final order of Hon'ble High Court of Judicature at Madras.

Appendix III List of Projects for Migration under JNNSM

S. No	Name of applicant	State	Capacity (MW)	Solar PV or solar thermal
1	Maharashtra State Power Generation Co. Limited, (MAHAGENCO), Mumbai	Maharashtra	4	Solar-PV
2	Clover Solar Pvt. Ltd., Mumbai	Maharashtra	2	Solar-PV
3	Videocon Industries Ltd, Mumbai	Maharashtra	5	Solar-PV
4	Enterprise Business Solutions, USA	Punjab	5	Solar-PV
5	Azure Power (Punjab) Pvt. Ltd., Amritsar	Punjab	2	Solar-PV
6	ACME Tele Power Limited, Gurgaon	Rajasthan	10	Solar-Thermal
7	Comet Power Pvt. Ltd., Mumbai	Rajasthan	5	Solar-PV
8	Refex Refrigerants Limited, Chennai	Rajasthan	5	Solar-PV
9	Aston Field Solar (Rajasthan) Pvt. Ltd.	Rajasthan	5	Solar-PV
10	Dalmia Solar Power Limited, New Delhi	Rajasthan	10	Solar-Thermal
11	Entegra Ltd, Ansal Bhawan, New Delhi	Rajasthan	10	Solar-Thermal
12	Entegra Ltd, Ansal Bhawan, New Delhi	Rajasthan	1	Solar-PV
13	AES Solar Energy Pvt. Ltd., Gurgaon, Haryana	Rajasthan	5	Solar-PV
14	Moser Baer Photo Voltaic Ltd., New Delhi	Rajasthan	5	Solar-PV
15	OPG Energy Pvt. Ltd., Chennai, Tamil Nadu	Rajasthan	5	Solar-PV
16	Swiss Park Vanijya Pvt. Ltd.	Rajasthan	5	Solar-PV
	Total		**84**	

Appendix IV List of Projects Selected for NVVN for Phase 1, Batch 1

S. No	Bidder	Solar project type	Project capacity (MW)	Location	State
1	Camelot Enterprises Private Limited	PV	5	Kalhe	Maharashtra
2	Khaya Solar Projects Private Limited	PV	5	Dist:Naguar, Tehsil:Naguar, Vill:Mundwa	Rajasthan
3	DDE Renewable Energy Limited	PV	5	Dist:Nagaur, Tehsil:Khinvsar, Vill:Bhojas	Rajasthan
4	Electromech Maritech Pvt Ltd	PV	5	Dist:Nagaur, Tehsil:Khinvsar, Vill:Bhojas	Rajasthan
5	Finehope Allied Energy Private Limited	PV	5	Dist:Nagaur, Tehsil:Khinvsar, Vill:Bhojas	Rajasthan
6	Vasavi Solar Power Pvt Ltd	PV	5	Nagaur, Khinvsar, Bhojas	Rajasthan
7	Karnataka Power Corporation limited	PV	5	Mandya,Malavalli,Bel akavadi	Karnataka
8	Newton Solar Private Limited	PV	5	Dist:Nagaur, Tehsil:Khinvsar, Vill:Bhojas	Rajasthan
9	Greentech Power Private Limited	PV	5	Jodhpur, Phalodi, BAP	Rajasthan
10	Saidham Overseas Private Limited	PV	5	Nagaur, Khinvsar, Bhojas	Rajasthan

(Contd.)

S. No	Bidder	Solar project type	Project capacity (MW)	Location	State
11	Mahindra Solar One Private Limited	PV	5	District: Jodhpur , Tehsil: Phalodi, Village: Amla	Rajasthan
12	Azure Power (Rajasthan) Pvt Ltd	PV	5	Nagaur, Jayal, Kathali	Rajasthan
13	Rithwik Projects Private Limited	PV	5	Anantapur, Kadiri, Kutagulla	Andhra Pradesh
14	Sai Sudhir Energy Limited	PV	5	T.Veerapuram, Rayadurg Taluk, Anantapur Dist., AP.	Andhra Pradesh
15	Maharashtra Seamless Limited	PV	5	Jaiselmer, Pokaran, Pokaran	Rajasthan
16	Viraj Renewables Energy Private Limited	PV	5	Jodhpur District, Phalodi tehsil, Rawre village	Rajasthan
17	Northwest Energy Private Limited	PV	5	Village-Kantia,District Nagaur	Rajasthan
18	Sun Edison Energy India Private Limited	PV	5	Bikaner, Kolayat, Deh	Rajasthan
19	Electrical Manufacturing Co. Ltd.	PV	5	Allahabad,Naini	Uttar Pradesh
20	Alex Spectrum Radiation Private Limited	PV	5	Gajner, Kolkayat, Bikaner	Rajasthan
21	Indian Oil Corporation Limited	PV	5	Barmer, village Marudi	Rajasthan
22	Coastal Projects Limited	PV	5	Chitradurga, Molakalmur, Murudi	Karnataka
23	Welspun Solar AP Private limited	PV	5	Anantapur District, Amadgur Mandal, Thummala Village	Andhra Pradesh
24	CCCL Infrastructure Limited	PV	5	Tuticorin District, Kombukaranatham Village	Tamil Nadu
25	Alex Solar Private Limited	PV	5	Khurda, Khurda	Odisha
26	Punj Lloyd Infrastructure ltd	PV	5	Jodhpur, Bap, Phalodi	Rajasthan
27	Bhaskar Green Power (P) Ltd.	PV	5	Village Pareware, Distt. Jaisalmer	Rajasthan
28	Amrit Animation Pvt Ltd	PV	5	Jaisalmer, Pokran	Rajasthan
29	Oswal Woolen Mills ltd.	PV	5	Jodhpur, Phalodi, Natisara	Rajasthan
30	Precision technik Pvt ltd.	PV	5	Jaisalmer, Pokhran, Nokh	Rajasthan
31	Lanco Infratech Limited	Thermal	100	Jaisalmer, Nachna, Chinnu	Rajasthan
32	KVK Energy Ventures Private Limited	Thermal	100	Jaisalmer,Nachana- 1,Chinnu	Rajasthan
33	Megha Enginnering and Infrastructure Ltd.	Thermal	50	Anantapur, Pamidi, Virannapalle	Andhra Pradesh
34	Rajasthan Sun Technique Energy Private Limited	Thermal	100	Bikaner, Kolayat, Ladkan	Rajasthan
35	Aurum Renewable Energy Private Limited	Thermal	20	Jamnagar, Dwarka, Mojap	Gujarat
36	Godawari Power and Ispat Limited	Thermal	50	Jaisalmer, Jaisalmer, Parewar	Rajasthan
37	Corporate Ispat Alloys Limited	Thermal	50	Jaisalmer, Pokhran, Nokh	Rajasthan
	Total		620		

Appendix V Comparison between Various CST Technologies

	Parabolic trough	*Central tower power plant*	*Parabolic dish*	*Fresnel linear reflector*
Applications	Grid-connected plants, mid to high-process heat (highest single unit solar capacity to date: 80 MWe. Total capacity built: over 500 MW and more than 10 GW under construction or proposed)	Grid-connected plants, high temperature process heat (Highest single unit solar capacity to date: 20 MWe under construction, Total capacity ~50MW with at least 100MW under development)	Stand-alone, small off-grid power systems or clustered to larger grid connected dish parks (Highest single unit solar capacity to date: 100 kWe, Proposals for 100MW and 500 MW plants in Australia and US)	Grid connected plants, or steam generation to be used in conventional thermal power plants. (Highest single unit solar capacity to date is 5MW in US, with 177 MW capacity installations under development)
Advantages	Commercially available over 16 billion kWh of operational experience; operating temperature potential up to 500°C (400°C commercially proven) Commercially proven annual net plant efficiency of 14% (solar radiation to net electric output) Commercially proven investment and operating costs Modularity Good land-use factor Lowest materials demand Hybrid concept proven Storage capability	Good mid-term prospects for high conversion efficiencies, operating temperature potential beyond 1,000°C (565°C proven at 10 MW scale) Storage at high temperatures Hybrid operation possible Better suited for dry cooling concepts than troughs and Fresnel Better options to use non-flat sites	Very high conversion efficiencies – peak solar to net electric conversion over 30% Modularity Operational experience of first demonstration projects only Easily manufactured and mass-produced from available parts No water requirements for the cooling cycle	Readily available Flat mirrors can be purchased and bent on site, lower manufacturing costs Hybrid operation possible Very high space efficiency around solar noon.
Limitations	The use of oil-based heat transfer media restricts operating temperatures today to 400°C, resulting in only moderate steam qualities	Projected annual performance values, investment and operating costs need wider scale proof in commercial operation	No large-scale commercial examples Projected cost goals of mass production still to be proven Lower dispatchability potential for grid integration Hybrid receivers still an R&D goal	Recent market entrant, only small projects operating

Appendix VI Technological Maturity Level of CST Technologies (Globally)

CSP technology type	*Installed capacity (MW) till 2009*	*Electricity produced up to 2009 (GWh)*	*Appropriate capacity under construction and proposed (MW)*
Parabolic trough	> 500	> 16000	> 10,000
Central receiver	> 40	80	> 3,000
Parabolic dish-stirling	< 1	NA	> 1500
CLFR	> 5	8	> 500

Appendix VII CST Installation Statistics (Global)

	Trough	Power tower	CLFR	Dish
Operating plants at the end of 2009 (MW)	633.8	49.4	32.78	0.24
Plants under construction (MW)	1500	10	28.4	0
Plants under planning stage (MW)	7730.18	660.15	935	2450

Appendix VIII Key Characteristics of the Various CSP Technologies

	Trough	Power tower	CLFR	Dish
Concentration ratio	70–80	300–1,000	25–100	1,000–3,000
Current operating temperatures	400° C (750° F)	250° C (482° F) – 500+°C (1,000+°F)	316° C (600° F)	800° C (1,472° F) - 900° C (1,652° F)
Average net conversion efficiency	11% – 14%	15% – 22%	9% – 11%	24% – 27%
Area requirements (MW / sq mile)	100 – 128	60 – 80	180	100
Heat transfer fluids	Near term: Oil future: steam, molten salt	Near term: steam, molten salt	Near term: steam future: molten salt	Near term: - Future: -
Tracking method	1 dimension rotational tracking	2 dimension rotational tracking	1 dimension rotational tracking	2 dimension rotational tracking
Water usage (cooling & washing) (m3/MWh)	2.940	2.800	-	0.019
Wind resistance (mph)	Staw speed: 23 Damage: 50–84	Staw speed: 22.5 Damage: 87	Staw speed: - Damage: 150 mirrors, 100 receiver array	Staw speed: 35 Damage: 90–100
Parasitic loss	10% – 14%	2% – 5%		3% – 5%
Operating plants at the end of 2009 (MW)	633.8	49.4	32.78	0.24
Plants under construction (MW)	1500	10	28.4	0
Plants under planning stage (MW)	7730.18	660.15	935	2450
Key developers	Acciona Energia, Solel Solar System, Solar Millennium AG, Abengoa Solar: Solucar Energia, S.S., SENER Ingenieria, Sky Fuel etc.	Abengoa Solar, Bright Source Energy, Solar Reserve, eSolar etc.	Ausra, No vatic, Biosol Skyfuel, Solar Power Group	Stirling Energy Systems / Tessera Solar, Infinia, Abengoa

Appendix IX Technology Matrix of SPV, CPV, and CSP

Technology type	System	Concentration technology	Power conversion	Concentration ratio	Tracking required	Insolation required	Footprint (acres/ MW)	Efficiency	Status of commercialization
Conventional photovoltaic	Mono-crystalline	Not used	Silicon	1	Stationary	Global	6	15-18 %	Commercialized
	Poly-crystalline	Not used	Silicon	1	Stationary	Global	7	12-14 %	Commercialized
	Thin Film	Not used	a-Si, CIS, CdTe, CIGS	1	Stationary	Global	8	6-8 %	Commercialized
Concentrating Solar Photovoltaic	Dish CPV	Parabolic dish	Multi-Junction or Silicon PV	500-1500	Double-axis	Direct normal incidence	8.0	28–36% (d) 31–42% (p)	Prototype/commercial
	Lens CPV	Lens or Fresnel Lenses	Multi-Junction PV	500-1000	Single / Double-axis	Direct normal incidence	8.0		Prototype/commercial
	LCPV	Low concentration reflectors	Silicon PV	1.5 – 3.0	Single / Double-axis	Global	11.0		Commercial
	Non-tracking CPV	Non-tracking concentrators	Multi-Junction or Silicon PV	> 2	Stationary	Global	NA		Early manufacturing
Concentrating Solar Thermal	Trough	Parabolic trough	Rankine cycle	> 80	Single-axis	Direct over Single axis	7.0	10-15% (d) 17-18 % (p)	Commercial since 1985
	LFR	Linear fresnel reflectors	Rankine cycle	> 80	Single-axis	Direct over Single axis	4.0	10-12 % (p)	Prototype
	Tower	Heliostat solar field	Rankine/ Brayton cycle	500-1500	Double-axis	Direct normal incidence	14.0	8-10 % (d) 15-25 % (p)	Commercial since 2006
	Dish-Engine	Parabolic dish	Stirling/ Brayton Cycle	500-1500	Double-axis	Direct normal incidence	9.0	16-18 % (d) 18-24 % (p)	Demonstrated 1980s

Appendix X Photographs of Solar Installations Visited

Figure A1(a) Solar Hot Water System Installed at Hotel Sai Renaisence, Bangalore

Figure A1(b) Solar Hot Water System Installed at Hotel Sai Renaisence, Bangalore

Figure A2(a) Solar Cooking System Installed at Bosch Limited, Bangalore

Figure A2(b) Solar Cooking System installed at Bosch Limited, Bangalore

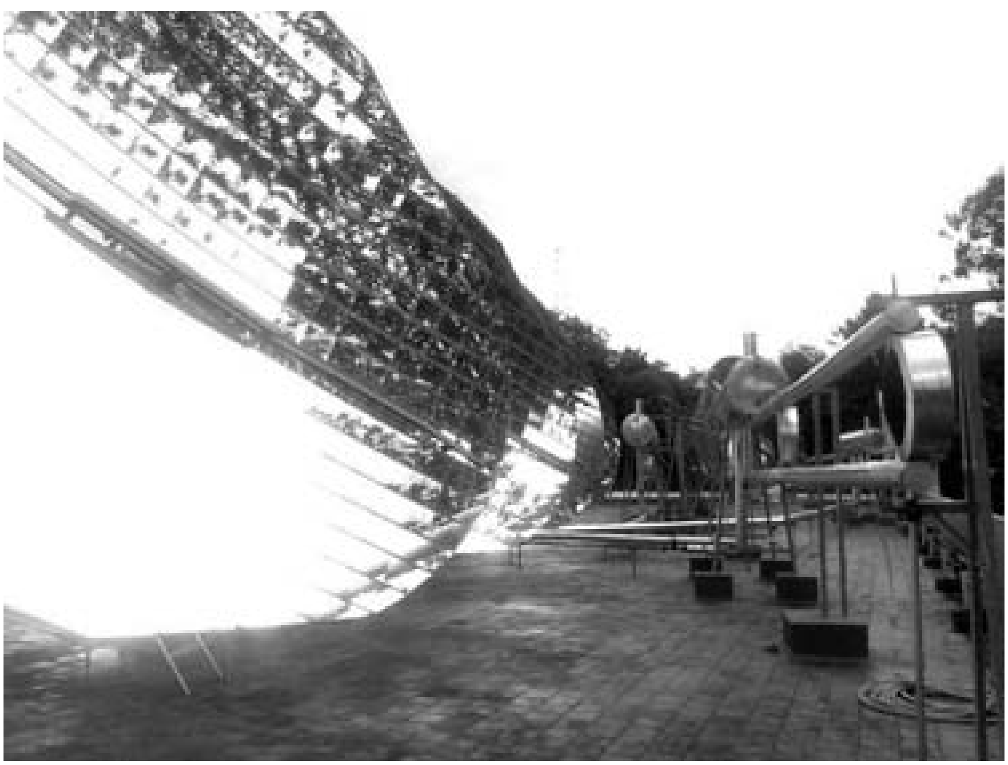


Figure A3(a) Grid Connected Solar PV Power Plant (3 MWp) at Kolar, Karnataka

Figure A3(b) Switch Yard and Control Room of Solar PV Power Plant at Kolar, Karnataka

Figure A4(a) Off Grid Solar PV Power Plant (10 kWp) at M. S. Swaminathan Foundation, Chennai

Figure A4(b) Off Grid Solar PV Power Plant (10 kWp) at M. S. Swaminathan Foundation, Chennai

Development of Solar and Wind Power in Karnataka and Tamil Nadu

This publication analyzes the performance of two states in India— Karnataka and Tamil Nadu— in their efforts toward installing solar and wind energy. It attempts to distill the reasons for their success, albeit in two very different renewable energy programs. It covers the major initiatives taken by the country in the form of policy and regulations including the formation of a full-fledged Ministry of New and Renewable Energy.

The report focuses on lessons learned from these states so that a supportive environment can be created in other states to promote and adopt renewables-based power. The report also covers specific recommendations to create such an environment. Apart from the program and policy dimensions, the report deals in detail with the Indian solar industry and carries out an assessment of solar technology from the point of view of their applications in the country.

This study will help policy makers and academia in further strengthening knowledge solutions for renewable energy across other countries in Asia.

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