ADB

Technical Assistance Consultant's Report

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India: Support to Jawaharlal Nehru National Solar Mission

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Asian Development Bank

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Glossary

“ADB" means Asian Development Bank.

“**BOP**” means Balance of Plant.

“**CAPEX**” means Capital expenditure.

“CSP” means Concentrated Solar Power and addresses the solar thermal concentration only.

“Discom” means an electricity distribution company.

“**DNI**” means Direct Normal Irradiation.

“**EPC**” means Engineering, Procurement and Construction

“**HTF**” means Heat thermal fluid

“IPP” means Independent Power Producers.

“**IRR**” means Internal Rate of Return

“**MNRE**” means Ministry of New and Renewable Energy

“**PPA**” means Power Purchase Agreement

“**ROE**” means Return on Equity

“**TMY**” means Typical Meteorological Year

“**WACC**” means weighted average cost of capital

Scope

As a part of JNNSM, MNRE has proposed some pilot projects on CSP based on the following fundamentals:

- India is a large country with a booming economy and requires Indian adapted solutions of all products and services. Indigenization is desirable for CSP as well.
- Experience on CSP technologies not covered under NVVN projects and having relevance in the Indian context including hybridization needs to be expedited.
- CSP projects must be scalable and replicable throughout India, disseminating know-how and expertise
- CSP projects must reach early cost competitiveness with the conventional power generation
- CSP projects require water as all thermal power plants do, but ways to reduce the water consumption are required, since the good DNI areas may not blessed with large water resources.

The following projects, which emerged through discussions of the MNRE with various stakeholders, will be analysed in this document regarding their scope, technical requirements, applicable financial conditions as well as ways to structure the bidding process for their implementation.

1 – CSP project with storage (> 10 hours up to base load)
2 – CSP project with high operating temperature (>=500ºC)
3 – CSP project with hybrid cooling (usage of water <= 30%)
4 – CSP project with gas support (Gas usage <= 30%)
5 – CSP project with biomass support (Solar >= 60%)
6 – CSP project using Stirling Engines
7 - CSP project augmenting a coal fired power plant

All CSP pilot projects must be innovative by nature and do not fall on the category of commercial proven CSP solutions, though early commercialization is very

much expected, if successful. It is clear that a risk is being taken by MNRE to promote such projects

International projects and trends in CSP

The current CSP projects under operation in the world, with significant sizes, are of the following types

- Parabolic troughs without storage using oil as HTF – less than 400 ºC - a heat exchanger to a water/steam cycle and using superheated steam to feed a conventional steam turbine
- Parabolic troughs with storage (usually 7 or 8 hours) using oil as HTF – less than 400 ºC - and molten salts as the storage medium, a heat exchanger to a water/steam cycle, a heat exchanger from oil to molten salts and using superheated steam to feed a conventional steam turbine
- Parabolic troughs for steam generation to provide steam in lower pressures – acting as economizer – to existing gas combined cycle power plants.
- Linear Fresnel mirrors without storage using water as HTF for saturated steam generation and feeding to a saturated steam turbine
- Linear Fresnel mirrors to generate steam in lower pressure to be coupled with coal fired plants and increase electricity generation of the existing power plant.
- Power tower using water as HTF for saturated steam generation – 40 bar, 250ºC - and feeding to a saturated steam turbine
- Power tower using molten salts as HTF and storage medium – over 500 ºC – for base load operation
- Stirling dishes with single and double piston to generate electricity directly in relatively smaller capacities

The trend in the CSP industry is to get a lower LCOE and provide base power or at least storage capacity to meet dispatchability requirements from utilities and so become a real player for utility-scale generation. Several areas for cost reduction are being targeted

- decrease costs in the solar field: mirrors, frames, evacuated tubes, HTF

- decrease costs in transmission and in the BOP – per unit of electricity generated - by increasing the solar field and store heat
- increase efficiency of the solar field operation by optimising it, develop new HTF, merge HTF and storage medium, develop new solar collectors
- decrease costs in installation and commissioning
- develop new technologies that are cheaper: Fresnel for example
- look for new and better – cheaper - ways to finance the projects
- decrease OPEX to meet projects IRR and ROE
- be able to bring projects on-line that are not based on parabolic troughs and introduce new concepts and technologies: power towers, Fresnel and Stirling

The current market outlook is the following:

Country	**Implemented**	**Advanced**	**Planned**	**Technology**
Spain	700 MW			Trough
Spain	48 MW			Tower
Spain	1,4 MW			Fresnel
Spain		850 MW		Troughs
Spain		1 MW		Stirling
Spain		30 MW		Fresnel
Spain			1522 MW	Troughs
Spain			70 MW	Stirling
USA	433.8 MW			Troughs
USA	1,5 MW			Stirling
USA	3 MW			Fresnel
USA	5 MW			Tower
USA		2602 MW		Troughs
USA		1875 MW		Tower
USA		750 MW		Stirling
Italy	5 MW			Troughs
Argentina		150 MW *		Troughs
Egypt		140 MW *		Troughs
Morocco		470 MW *		Troughs

Abu Dhabi		100 MW	Troughs

Sources: Protermosolar, NREL, SunBD, private. Data may not be updated.

* - Augmentation projects where the power rating is from the power plant and not the solar field.

Troughs dominate worldwide and are considered the proven technology for banks and financial institutions. Scientifically speaking all technologies mentioned are proven. Towers come behind in the planned projects and Fresnel is still to reach some market size. Stirling though being the most efficient technology and with the advantage of no water needs has failed to become a serious player yet.

CSP pilot projects

This chapter is so constructed that it meets a normal due-diligence analysis of a project. It is divided into Technical, Technological, Financial and Legal issues and each sub-chapter being analysed for the mentioned projects above. It should be mentioned that this "due-diligence" approach is not a detailed one and will address the main issues and requirements for projects to be well defined, sound, meeting the objectives set by MNRE and also providing enough information to support any bidding exercise by developers.

To make sure projects are sound from a technical point of view as well as project development clear requirements for qualification and criteria for evaluation are developed in this document. As basic features we have the following:

Projects	**Size (MW)**	**Priority**
1 – CSP project with storage (> 10 hours up to base load)	10 ~ 100	2
2 – CSP project with high operating temperature (>=500ºC)	20 ~ 100	2
3 – CSP project with hybrid cooling (usage of water <= 30%)	20 ~ 100	2
4 – CSP project with gas support	> 1	1

(Gas usage <= 30%)		
5 – CSP project with biomass support (Solar >= 60%)	< 10	1
6 – CSP project using Stirling Engines	< 50	1
7 - CSP project augmenting a coal fired power plant	> 1	1

Prio 1 – easy implementation

Prio 2 – require a technical and financial dedicated framework

Technical issues

Technically speaking the site and the data on a site are of essential interest for any solar project. A suitable site requires that it meets some requirements, namely:

- suitable soil and geological conditions
- suitable radiation for the project to be viably economically
- suitable environmental characteristics to make engineering, procurement, construction and O&M possible and within the budget
- water availability in the vicinity
- power evacuation in the vicinity
- access infra-structures

Coupled with these technical requirements the site also needs not to be:

- too near to populations and settlements
- in such areas that environment – fauna, flora, and landscape - will be damaged by the project
- sensitive areas where resources are scarce – land, water

Site

Site specific, not site specific
Location, general data, available land

Two possibilities are considered: site specific and non-site specific. In the former sites have been selected and in the latter developer shall choose a site. In both cases the mentioned requirements must be fulfilled. As guidelines for site selection, a suitable site should have:

- already approved power evacuation facilities – which will be on-line within less than a year and within less than 5 km
- it is owned by the applying party or is in the process and it will be fully owned in less than 6 months
- soil evaluation is done or can be done in 3 months – soil is suitable, geologic hazards are low, not in flooding area, not in natural disasters prone areas – by a company with experience in the market – more than 50 soil evaluations conducted and concluded up to date.
- water is available within 10 km – the quantity available should be mentioned and approved by the competent authorities
- access roads exist or they are being built – on-line in less than 1 year
- solar radiation is measured and data available in TMY series – global horizontal, direct normal radiation and diffuse – or data from different sources and models has been properly analysed. (Data from NREL/MNRE can be used for screening purposes)
- environmental data is available with statistical sense – 10 years minimum in TMY format – ambient temperature, humidity, wind speed, wind direction and rainfall.
- populations are not nearby – less than 5000 people in a 1 km radius – or at least land issues should be handled very carefully
- not within endemic species habitat or sensitive wildlife – fauna and flora

The first five – exception for the projects with Stirling engines in the case of water - should provide clear selection cases – only if met are the following criteria to be evaluated.

The site specific projects are:

1 – CSP project with storage (> 10 hours up to base load)

2 – CSP project with high operating temperature (>=500ºC)

3 – CSP project with hybrid cooling (usage of water <= 30%)

The non-site specific are:

4 – CSP project with gas support (Gas usage <= 30%)

5 – CSP project with biomass support (Solar >= 60%)

6 – CSP project using Stirling Engines

7 - CSP project augmenting a coal fired power plant

For the non-site specific the request for a clear notion of where the projects are to be located is desirable, but not binding. For evaluation purposes to such clear commitments will be awarded points.

For the site specific projects MNRE received the following sites:

State	location
Rajasthan	Bhadla
Rajasthan	Mathnia
Rajasthan	Ramgarh
Gujarat	Harshad
Gujarat	Charanka
Tamil Nadu	Kulathur
Tamil Nadu	Terkuveerapandiyapuram
Andhra Pradesh	Gadwal
Andhra Pradesh	Ramagundam
Andhra Pradesh	Nennal
Andhra Pradesh	Gurajala
Andhra Pradesh	Rajamundry
Karnataka	Tulasigere

Detailed information has been required to the states as mentioned below. A first screening was done based on the provided information from the states and visits were carried out to the following sites - MNRE setup an official committee – (the official office orders can be found below):

State	location
Rajasthan	Bhadla
Rajasthan	Mathnia
Gujarat	Harshad
Gujarat	Charanka
Tamil Nadu	Kulathur
Tamil Nadu	Terkuveerapandiyapuram

Andhra Pradesh	Gadwal
Andhra Pradesh	Nennal
Andhra Pradesh	Gurajala
Karnataka	Tulasigere

State
Location
Qualification
Nearest city (name and distance in km)
- At least state two GPS coordinates at the borders
Area (hectares)
Ownership of the land
- Options: acquired by the state or private or to be acquired
- If to be acquired, please state the necessary time
Power evacuation facilities
Type of sub-station (voltages)
Distance of the sub-station to site
Soil analysis
- If completed, name of company that did the soil analysis
Water availability
- Quantity (cusec -cubic meter per second)
- If Ground water at what depth?
- If canal, what is the distance to the land?
- Any other source
- Any restrictions in the use of the water
Access roads
- Name of the road, if exists
- Type of road – width
- Type of road - pavement type
- Connection from and to (in km)
Ambient temperature
- Options: ground measured data, no ground measured data
Humidity
- Options: ground measured data, no ground measured data
Wind speed
- Options: ground measured data, no ground measured data
Wind direction
- Options: ground measured data, no ground measured data
Rainfall
- Options: ground measured data, no ground measured data
Populations nearby?
- State the number of people and the distance to the land up to a 5 km radius of the land
- Main ocupation
Endemic fauna in the site
Endemic flora in the site

No.29/5/2010-11/JNNSM (ST)

भारत सरकार/ Government of India

नवीन और नवीकरणीय ऊर्जा मंत्रालय / Ministry of New & Renewable Energy

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Block 14, CGO Complex, Lodi Road,
New Delhi-03, Dated 18th Nov. 2011

Office Order

Subject: Constitution of a Committee to visit the proposed sites to explore suitability for setting up of pilot solar thermal demonstration projects.

As a part of approval for the JNNSM, a provision of pilot demonstration projects was also approved in principle. Pilot demonstration projects are to be closely aligned with the Mission's R & D priorities and designed to promote technology development and cost reduction. The Mission, therefore, envisages the setting up of the following demonstration projects in Phase I, to be commissioned during 12th Plan period.

2. In view of the above, a Core Group was constituted by the Ministry involving experts and policy makers to have consultations with the stakeholders including solar power developers. A number of consultation rounds took place and the following technology configurations emerged to be taken up for pilot projects:--

- CSPs project with large thermal storage
- CSP project with operating temperature of 500ºC
- CSP project with hybrid cooling
- CSP project with biomass support
- CSP project providing base load power
- CSP project using Stirling Engines
- CSP project with natural gas support, and
- CSP project augmenting a coal fired power plant

3. Recently, the States were asked to identify sites for setting up pilot projects, and responses have been received from 5 states (Andhra Pradesh, Gujarat, Karnataka, Rajasthan and Tamil Nadu). For last configuration mentioned above, related to coal fired CSP power plant, a couple of meetings have already been held by Secretary, MNRE with CMD, NTPC with a view to make a proposal to MNRE for such a project at one of their existing coal thermal power stations.

4. Therefore, in order to explore suitability of location, area and availability of infrastructure facilities at the proposed sites where these pilot projects may be set up in the States it has been decided to constitute a Committee with the following composition:-

i) Mr. Agostinho Miguel Garcia, ADB consultant (Chief of Development and Engineering, Sun Business Development Lda, Portugal)
ii) Mr Amit Jain, CCI, New Delhi (for Gujarat, Karnataka and Tamil Nadu sites)
iii) Prof B Ravindra , IIT Rajasthan (for Rajasthan site)
iv) Prof M A Ramaswamy, CSTEP (for Karnataka and Tamil Nadu sites)
v) Mr Ramesh Pawar, Sr. DGM, BHEL Corporate R&D Division, Hyderabad (for Andhra Pradesh sites)
vi) Mr J K Jethani, Scientist 'D', MNRE

PTO.

-:: 2 ::-

6 The terms and objective of the Committee will be to undertake visits to the proposed sites and to explore suitability of location, area and availability of infrastructure facilities where these pilot projects could be set up in the State.

7 Committee members will be provided TA/DA as per entitlement (travel limited to economy class and by Air India wherever available) and a sitting fee of Rs 2000/- per day to the non-official members of the Committee. The expenditure on the visit towards TA/DA for member at Sl. No. (i) above will be borne by ADB; and the expenditure on TA/DA and honorarium etc for the members at Sl.No.(iii) and (iv) above will be borne by MNRE from on-going MNRE projects.

8. The Committee may co-opt any other expert for review of any specific items/work or other tasks, if considered necessary. The term of the committee will be upto 31/03/2012 or till the assignment is completed/closed whichever comes earlier. The Committee will meet as frequently as possible keeping in view the other exigency of work in the Ministry. ST Division will provide Secretarial assistance to this Committee.

9. This issues with the approval of the competent authority.

(Prem Chand)
Under Secretary to the Govt.of India
Ph: 24360707/Extn.1023

To
All Members of the Committee.

Copy is also forwarded for information to:-
(i) PSO to Secretary, MNRE,
(ii) JS(NSM)/ Dir.(AK)/Dir.(Fin.)
(iii) Order Bundle.

Such visits were carried out and more information was gathered which allowed a ranking of the sites to be made:

State	location	Evaluation	Excluded	Reasons for exclusion
Rajasthan	Bhadla	34,7	yes	no gss
Rajasthan	Mathnia	34,6	yes	no water
Rajasthan	Ramgarh	25,3	yes	small size
Gujarat	Harshad	28,7	yes	not ready
Gujarat	Charanka	39,6	0	land to be acquired
Tamil Nadu	Kulathur	34,9	yes	land issues
Tamil Nadu	Terkuveerapandiyapuram	41,0	0	ok
Andhra Pradesh	Gadwal	34,8	yes	big boulders
Andhra Pradesh	Ramagundam	30,6	yes	not ready
Andhra Pradesh	Nennal	40,6	0	ok
Andhra Pradesh	Gurajala	38,5	yes	limestone slabs and river embankment
Andhra Pradesh	Rajamundry	30,0	yes	low DNI
Karnataka	Tulasigere	26,5	Yes	stone and rocky soil

Three sites were qualified and evaluated based on the following criteria:

Topics	Evaluation criteria
Power evacuation	Not constructed = excluded; constructed/on construction = 5
Type	no 110 KV or 132 KV = excluded; otherwise 5
Distance to the site	less than 1 km = 5; <10 km = 4…<20 3 <30 2 <40 1 >50 0
Water availability	Not available = excluded; with limitations 2; no limitations 5
Acquired land	acquired = 5; under acquisition = 3; not acquired/to be acquired = 0
Área	less than 50 hect = excluded; largest: 5 (al the rest proportional)
Access to the site	no access = excluded; otherwise 5
Populations nearby	less than 1000 5, <2000 4, < 5000 3, < 10000 2, < 50000 1
DNI	less than 5 KWh/m2 = excluded; largest: 5 (al the rest proportional)
Solar Park	in existing/construction Solar Park = 5; in solar park being planned = 3

Additionally it was also safeguarded that locations suitable for some of the non-site specific projects would be left for those projects, namely locations where biomass, gas or coal is available.

Badhla in Rajasthan has been included also as there is another substation nearby that can be used until the GSS at Badhla is not commissioned. Like in Charanka in Gujarat the transmission company can provide a temporarily alternative.

For the selected sites letter of comfort will be asked from the States regarding the plots, namely:

- Land will be allotted
- Power evacuation will be available
- Water will be available
- Accesses will be made available, if required

The same comfort letters may also be requested by developers for the non-site specific projects. This is not mandatory and is only advised.

The following chapters address the mentioned issues in a more detailed fashion, but they are not binding for the non-site specific projects.

Power evacuation availability

Sub-stations available, distances, cabling, step transformers

This criterion is the first due to its impact on any project: if there is no grid connection there is no project. Thus only lands within vicinity to power evacuation facilities or to in-construction facilities are suitable to be considered for these projects. Evaluation may be conducted as well based on the age of the transmission systems and the available power.

Land ownership

Land must be owned and clearly in the possession of the government, state government or private owners. If a land acquisition process is on-going, it should be completed within such a time frame that will not compromise the project. Thus only in such mentioned situations will projects be considered. Evaluation will be conducted on the basis of the available size and orientation – south facing areas.

Soil evaluation

Standard penetration test, Laboratory testing, Local geologic setting, Groundwater analysis, geologic hazards, landslides, Flooding and erosion, Subsidence, Poor soil conditions, Primary ground rupture, Strong ground motion, Liquefaction, Foundations, Earthwork

Soil evaluation tests and report must be available or carried out from a reputable company - experience must be the key criteria – and should contain:

- Standard penetration tests with a certain density in the selected plot
- Laboratory testing of samples

- Local geologic setting
- Groundwater analysis
- Geologic hazards, landslides, flooding and erosion
- Subsidence
- Soil condition
- Ground rupture, liquefaction
- Foundations and earthwork

Water availability

Water available, location, accesses, amount, conditions

Water is a crucial asset for any CSP project – exception to Stirling engines – and should be available within a certain distance. The amount to be used should be stated and approved by the competent authorities. For selection purposes the existence of water in the vicinity is the key, for evaluation the amount to be consumed and also availability should be assessed.

For Stirling projects water availability criteria is much less. Needs and usage should still be analysed.

Available infrastructures

roads, accesses, sewage,

CSP projects - as other projects – require good accesses and also infra-structures to support construction and O&M also. Some of the infra-structures can be provided, if not available, but those should be already on-going and should be on-line within a certain time frame. For selection purpose roads will be the key and for evaluation all available infra-structures are to be analysed and assessed.

Solar resource available

DNI, GHI, diffuse – statistical data desirable or at least accepted source for sizing purposes

Solar resource is the “fuel” of a CSP power plant and the meaningful parameter is DNI – Direct Normal Irradiation – but both GHI – Global Horizontal Irradiation - and diffuse are important to be known for a number of reasons. To cope with this, MNRE and NREL have developed a model for solar radiation prediction, which is available online and works on latitude and longitude basis providing DNI and GHI on a time series – TMY – for at least a period of 7 years. Such records can be used for screening purposes.

Other environmental variables

temperature, humidity, wind speed, rainfall, dust, corrosion

For a proper design and engineering of a CSP power plant ambient temperature, humidity, wind loads – speeds and directions – rainfall are required. Other parameters as corrosion and dust analysis are also very important, but not available in India in a comprehensive matter. Projects should provide statistical data – with a minimum time period of measurements – in a TMY series - and data on corrosion will also be of valuable use.

Local communities

brief mentioning of villages, farms and communities

Local communities are to be respected in any project and it should be avoided plots near villages or urban places. A maximum number for a population is to be residing near the proposed land in such a way that there is no possible harm to them. It is also recommended that inclusion and employment policies should be followed by the developers.

Natural flora and fauna

Analysis of existing endemic, endangered or protected species

Places with endemic, endangered or protected species as well as sensitive and wildlife areas are not to be used for such projects. Usually such locations are not private lands, so it is not expected that such lands will be submitted. In any case competent authorities should approve the selected lands. Sites should obtain clearance.

Technology issues

For CSP projects the technology issues are very important and the pilot projects provide fixed configurations that have implications since they will not follow a commercial rational. In any case it is clear that the purpose of such pilot projects are focussed on the solar field, storage, cooling tower and not on, for example, new concepts of turbines, pressure vessels, water demineralization plants or any other components generally designated as BOP – Balance of Plant – or Power block. Thus BOP components will follow the standards of such components and only certified components will be accepted. For the hybrid cooling and the high temperature operation new turbines may be considered as well as cooling towers, but from experienced manufacturers.

In the solar field some components will follow the certificates for the materials, such as: mirrors, aluminium surfaces, piping, evacuated tubes, aluminium frames, foundations, etc. The configuration, sizes and engineering designs are not to be evaluated, but a certain degree of technical soundness of the project is to be assessed and required. The probability of success of such projects is to be raised in that manner. There will some minimum and maximum as well as clear requirements for the projects. For all projects the stated yearly generation will have to be guaranteed by the successful bidder. If larger solar field is required the expenses will have to borne and the land size limitations will still apply. Projects are advised to take into consideration the risk.

Some projects require support or hybridization from other fuels as biomass and gas. In biomass it is advisable to be within the vicinity of the project – less than 50 km -

and proven or approved by the competent authorities. In the biomass no “fuels” that are food products or that may generate social unrest should be considered.

For gas and coal a two stage process will be implemented:

- 1st stage – availability of gas/coal
- 2nd stage – bidding process (only those qualified form the first stage)

Project power yield and rate

To make it simpler and transparent:

Project	Size (MW)	Land size	Min CUF	Max CUF
1 – CSP project with storage (> 10 hours up to base load)	10 ~ 100	400 acre	40%	
2 – CSP project with high operating temperature (>=500ºC)	20 ~ 100	140/150 hect / 400 acre	20%	30%
3 – CSP project with hybrid cooling (usage of water <= 30%)	20 ~ 100	140/150 hect	20%	30%
4 – CSP project with gas support (Gas usage <= 30%)	> 1		20%	40%
5 – CSP project with biomass support (Solar >= 60%)	< 10		20%	40%
6 – CSP project using Stirling Engines	< 50			
7 - CSP project augmenting a coal fired power plant	> 1			

Solar field

Solar field is not particular to any project. The technological requirements are none regarding configuration and engineering design and should all be related to the components used following the Indian and/or international standards. The rational is companies that have certified/tested their products by third parties are better equipped to deliver better products. Typically in all technologies solar field is made of:

- Heliostats, Mirrors or reflective surfaces – tempered float glass with silver mirror or high-reflectivity aluminium mirror
- Receivers – metallic structures with glass enclosures, evacuated tubes, normal steel pipes
- Frames – metallic structures,
- Foundations – cement, metallic poles
- Tracking motors – electrical motors
- Electrical cables - standard
- HTF – highly toxic artificial oils, water, air, molten salts

Each one is analysed below in more detail.

Heliostats, Mirrors or reflective surfaces

Either parabolic troughs, Fresnel mirrors, heliostats or parabolic dishes all are mirror based. The mirrors are either curved or flat and either glass-silver or high-reflectivity aluminium surfaces. The qualification criteria should be international certification of the main components, in this case mirrors or reflective surfaces. The evaluation should be on number of projects deployed with such components.

Heliostats, Mirrors or reflective surfaces	International certificates (IS, ASHRAE SPC 142, ISO 15099, ASTM, etc)	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum volume - 5. Others follow proportionally

Receivers

Receivers are either made of evacuated tubes, normal steel pipes or special cavities. Evacuated tubes should be tested and/or certified by a recognized Indian or international body. Steel pipes should follow ASME or similar standards, special cavities – power towers – should incorporate materials that are also certified and tested. The qualification criteria are the availability of the certifications or tests and the evaluation should be on number of projects deployed with such components.

Receivers (evacuated tubes, steel pipes, cavities)	International certificates (ASME, etc)	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum volume - 5. Others follow proportionally

Frames

Frames for the solar collector are special in parabolic troughs and parabolic dishes, due to the confinement of their shape under working conditions. There are no tested or certified frames, but used materials should be certified – aluminium, steel, alloys. Qualification will be on the basis of certificates and evaluation on the number of projects deployed with such components.

Collector Frames	Materials must be specified and certified	Maximum number of certifications - 5. others follow proportionally
	Number of projects worldwide deployed with the product	Maximum number - 5. Others follow proportionally.

Projects should be advised to take into consideration corrosion.

Corrosion (applicable to any metallic structure)	Coating	maximum coating - 5. Others follow proportionally

Foundations

For all projects foundations are concrete/cement based or metallic poles that can have or not concrete. Cement must be certified and no specification is required regarding the type. Qualification will be on the basis of certificates and evaluation on the number of projects deployed with such components.

Foundations	Materials must be specified and certified	Maximum number of certifications - 5. others follow proportionally
	Number of projects worldwide deployed with the product	Maximum number - 5. Others follow proportionally.

Projects with metallic poles should be advised to take into consideration corrosion.

Corrosion (applicable to any metallic structure)	Coating	maximum coating - 5. Others follow proportionally

Tracking motors

Tracking motors are electrical motors that are tested and certified regarding several parameters. Special interest falls on the tracking algorithm. No particular type of motor or algorithm will be required. Qualification will be on the basis of certificates and evaluation on the number of projects deployed with such motors and using a certain algorithm.

Tracking motors and algorythm	Motor must be specified (Algorithm type must be specified)	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Electrical cables

Only standard and certified electrical cables will be accepted. Qualification will be based on certificates and evaluation on the number of similar cables supplied worldwide.

Electrical cables	Cables (IEC, UL, etc)	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

HTF

HTF are usually artificial oils with altered boiling and/or freezing points, water - deaerated – air, gases and molten salts – phase changing materials that become liquid when heated. On the oils, proper certificates are required, on molten salts, gases, air and water nothing is required. Molten salts are not toxic. Qualification will be on the basis of certificates and evaluation on the number of projects deployed with such components.

HTF (water, oils, molten salts, air)	HTF must be mentioned. (Artificial oils or any toxic products have to be certified)	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Stirling Engines

Stirling engines are of various designs and incorporate different materials. The design will not be evaluated. Testing certificates will be evaluated as well as the number of projects deployed with the engine.

Stirling engines	Engines	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Balance of Plant

Balance of plant is considered to be everything besides the boiler in a normal thermal power plant. In CSP it also addresses everything that it is not on the solar field and the power block may also be included under the designation or not. It is considered in this document to address everything. No new components are to be inserted or demonstrated in these projects – exception made to turbines and cooling towers. Current state-of-the-art technologies and solutions are required. The exception goes for the heat exchangers, where new types may be allowed according to the used HTF. For hybrid projects – biomass and gas – the boilers to be used are the standard in the market. We have the following:

- Pressure vessels
- Piping and pumps
- Electrical cables
- Heat exchangers
- Water Tanks or reservoirs
- Demineralization plant

- Heat storage tanks

- Turbine
- Alternator
- Transformer
- Cooling tower

- Biomass boilers
- Gas boilers

For the considered pilot projects Stirling engines do not have BOP and the considerations below do not apply – exception to the step transformer. The hybrid cooling will also be an exception in terms of the cooling tower, which obviously will not be a typical one and new designs will be accepted. For high temperature operation new turbine designs are also to be accepted. All other areas are similar to all other configurations. Each area is analysed in more detail below.

Pressure vessels

Steam drum, expansion vessel, blow-down, deaerator,

The main pressure vessels to be considered are the steam drum, expansion vessels, blow-down tanks and the deaerator. Extensive experience, standards, ASME compliance, certifications exist for the vessels and they will be manufactured for the project – not available on-the-shelf. There will be no opportunity to present certifications before they are manufactured. What can be required is the material in which the vessels will be constructed and relevant compliance standards. Qualification is to be done on the certifications and evaluation on the number of vessels where such materials were used.

Pressure vessels (Steam drum, expansion vessel, blow-down, deaerator)	Main material have to be mentioned (steel, alloys, etc) and certified	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Piping and pumps

Pipes, pumps, feed-heaters

Pipes should be according to ASME or similar standards. Pumps will be for the used HTF and must be certified and/or tested for artificial oils or molten salts as well as any gases or air. They are electrical equipments and should be certified accordingly. Feed-heaters are pressure equipments and are certified accordingly. Qualification will be made on certifications and evaluations on the number of projects where the components/materials were used.

Piping and pumps (pipes, pumps and feed heaters)	Certifications (ASME, CE, etc)	Maximum number of certifications - 5. others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Electrical cables

Only standard and certified electrical cables will be accepted. Qualification will be based on certificates and evaluation on the number of similar cables supplied worldwide.

Electrical cables	Cables (IEC, UL, etc)	Maximum number of certifications - 5. Others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Heat exchangers

HTF to water, HTF to storage medium, storage medium to water
Superheating

Extremely important component, but independently of the mediums they are made of coils and fins. Used materials are to be mentioned, since the exchange heaters will be made on request. Designs and concepts will not be analysed. Qualification will

be made on the basis of certification of the materials used and evaluation will be made on the number of exchange heaters with such materials.

Heat exchanger (if not used this category will not be summed)	Materials used must be mentioned and certified	Maximum number of certifications - 5. Others follow proportionally
	Number of projects worldwide deployed with the product	Maximum number - 5. Others follow proportionally.

Water Tanks or reservoirs

Demineralization plant,

No new concepts or components are expected to be incorporated. Reservoirs are custom made and de-mineralization plants are deployed in all thermal power plants. Certifications of materials and/or systems are required. Same applies for any reservoir that is not at a certain pressure. Qualification is made on the basis of certification and evaluation on the number of systems deployed or vessels using such component.

Water Tanks or reservoirs (demineralization plant)	Materials used must be mentioned and certified	Maximum number of certifications - 5. Others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Heat storage tanks

Medium storage, “hot” and “cold” storage

Tanks are customized and used materials are to be certified. Qualification will be made on such certificates and evaluation on the number of tanks using such materials.

Heat storage tanks (if not used this category will not be summed)	Materials used must be mentioned and certified	Maximum number of certifications - 5. Others follow proportionally
	Sales volume	Maximum number - 5. Others follow proportionally.

Turbine

No new designs are expected and mature turbines are to be used. Since hybrid cooling is required as well as high operating temperatures turbines that have not been used in CSP projects may be required and that will not provide traceable track-record in those projects. Risk has to be accepted on both cases. Manufacturers with tradition in the market will be accepted. Qualification will be made on meeting the requirement of experience and evaluation will be on the number of turbines delivered (MW/MVA range).

For the other projects, which will not require new turbine concepts, only certified turbines are accepted. Qualification will be made on certification and evaluation on the number of similar models delivered worldwide.

New turbines (with alternator and step transformer)	Experience of the manufacturer (years)	Maximum number of years - 5. Others follow proportionally
	Sales volume (MW/MVA size)	Maximum number - 5. Others follow proportionally.

Turbines (with alternator and step transformer)	Number of certifications for the model	Maximum number of certifications - 5. Others follow proportionally
	Sales volume (specific model)	Maximum number - 5. Others follow proportionally.

Alternator

Usually part of the turbine and no special requirements will be issued on the component. For the new concepts – hybrid cooling or high temperature – turbine and alternator will not be analysed separately.

Transformer

Step transformer is required in Stirling and not mandatorily in other projects – it can be also included in the turbine electrical design. For Stirling step transformers shall meet electrical certifications. Qualification will be made on certifications and evaluation on the number of similar models delivered worldwide.

For step transformers included in the turbine design no separate analysis from the turbine will be made.

Transformer	Number of certifications for the model	Maximum number of certifications - 5. Others follow proportionally
	Sales volume (specific model)	Maximum number - 5. Others follow proportionally.

Cooling tower

Specially to be considered for the hybrid cooling project, it will encompass new designs, materials and concepts. Materials will require certification. Electrical equipments will require certification. Heat exchangers or air coolers will require certification. Qualification will be based on the certifications. No evaluation will be made.

For all other projects, except from Stirling, cooling towers will be analysed on the basis of the materials used and certification. Qualification is to be made on certificates and evaluation on the number of similar cooling towers installed worldwide.

Cooling tower	Materials used must be mentioned and certified	Maximum number of certifications - 5. Others follow proportionally
	Sales volume (for MW sizes)	Maximum number - 5. Others follow proportionally.

Biomass boiler

Only experienced manufacturers and standard products will be allowed. Qualification will be made on evaluation of the track record of the manufacturer and the number of similar models delivered worldwide.

Biomass boiler	Number of certifications for the model	Maximum number of certifications - 5. Others follow proportionally
	Sales volume (specific model)	Maximum number - 5. Others follow proportionally.

Gas boiler

Only experienced manufacturers and standard products will be allowed. Qualification will be made on evaluation of the track record of the manufacturer and the number of similar models delivered worldwide.

Gas boiler	Number of certifications for the model	Maximum number of certifications - 5. Others follow proportionally
	Sales volume (specific model)	Maximum number - 5. Others follow proportionally.

Project technical qualification

In addition to all the technical items mentioned above extra points will be awarded to developers that present boiler certifications or solar collector testing documents. For each category that is not included in a certain project, that is to be mentioned and it should not count negatively for the bidder qualification.

The project technical qualification will comprise the sum of the points awarded to each component according to the mentioned criteria above. It is not mandatory to answer all, but it is requested that for each project a minimum number of points is achieved – around 30% of the possible maximum marks – to be qualified. The total marks obtained will count with 10% to the final evaluation.

Projects	**Max marks**	**Min marks**
1 – CSP project with storage (> 10 hours up to base load)	180	60
2 – CSP project with high operating temperature (>=500ºC)	180	60
3 – CSP project with hybrid cooling (<= 30% usage of water)	175	60
4 – CSP project with gas support (Gas usage <= 30%)	210	70
5 – CSP project with biomass support (Solar >= 60%)	210	70
6 – CSP project using Stirling Engines	155	55
7 – CSP project augmenting a coal fired power plant	120	40

Technical tie-ups are not mandatory and may or may not exist. Clearly the risk of the projects to be commissioned is higher than commercial configurations and so special care has been taken to increase the probability of success and demand some technical details from the prospective bidders.

Financial issues

The usual criteria for risk analysis are:

- CAPEX
- OPEX
- Resource versus power yield
- Dispatchability
- WACC (Weighted average cost of capital)
- Debt ratio and coverage

Some issues are clearly for the developers to deal with, but since the CSP projects are of non-commercial nature bankability issues may prevent the projects to access financing easily. Main hurdles lay on the guarantees and the track-record of the developers and of the CSP projects. Internationally the lessons learned have showed that EPC, promoters, technology developers and also project developers should all be in the SPV for a successful financial closure. The main financial issues to be dealt with are financing, debt coverage and the project remuneration and those will be covered in more detail below.

Project Remuneration

CAPEX, Fit or equity share

Project remuneration for CSP projects, and other Renewables, has been based on Fit – Feed in tariffs or RPS driven PPAs. India under the NSM scheme has defined the mechanism to be a FiT based on reverse bidding mechanism and RPOs will drive the market in terms of offer and demand. The nature of these projects is non-commercial but remuneration has to be provided. Two mechanisms were selected:

- GBI – Generation based incentive – through reverse bidding mechanism as in the NSM -> applies to all projects except the coal augmentation
- Grant on CAPEX to be given – through reverse bidding on the amount of grant required per MW thermal

In the GBI driven projects not all CSP pilot projects are of the same nature. Clearly we have to make a distinction between the site specific and non site specific. The site specific projects may require low financing to be viable.

1 – CSP project with storage (> 10 hours up to base load)
2 – CSP project with high operating temperature (>=500ºC)
3 – CSP project with hybrid cooling (usage of water <= 30%)

Project Risk mitigation

As mentioned the major issues are financing and the debt coverage ratio. Financial institutions will be concerned with projects that do not generate enough earnings to meet the debt as well as the O&M. Such analysis will be done and some of the pilot projects have no track-record, resulting into higher guarantees and also high interest rates. A special low cost financing package may be available from a public company, likely to be the Solar Power Corporation. Such low financing should target an interest rate to the successful bidder not higher than 5%. This only applies for the site specific projects.

In all the other projects risk is not considered to be high.

Legal issues

India has already approved legislation regarding solar projects and CSP in particular. NSM as well as state policies are published and available online and many projects are being carried out already. The pilot projects pose no new scenarios in terms of existing legal matters apart from:
- CSP projects are thermal cycles that will yield a concentrate, present in the blow-down tank of the steam cycle and that concentrate should not be damped in the land or anywhere without meeting the existing regulation for thermal power projects
- water used for cooling should also meet the relevant legislation

- gas usage should be according to the legislation pertaining to gas handling and gas fire power plants
- coal fire plants regulations should be complied with by the CSP project – solar field

The guidelines for Procurement of Solar power has also been drafted by PFC and approved by Ministry of Power. There are some concerns on the stated guidelines, either for site specific as well as for the non site specific, namely:

PFC guidelines issues	
Land	Page 7 i)
Radiation	Page 8 V)
Power evacuation	Page 8 3.3
Water	Page 8 iv)
Timelines	150 days for the RFP

- Land has to be acquired prior to the RFP and the whole process of acquisition must be finalised before the PPA becomes effective – comfort letter will be sought from the states to comply
- Solar radiation, hydrological, geological, meteorological and seismological data etc. necessary for preparation of Detailed Project Report (DPR) must be available at least 30 days before RFP submission date – such requisite will have to be relaxed for solar projects.
- Power evacuation should be approved, but it is not a bidding process – comfort letter will also be sought for this matter
- Discoms should be identified for the purchase of the power - a comfort letter should also be sought

As mentioned above regarding the site, land ownership and rights should also be very clear and available, either it is a government or a private land. In case leases are given, the contract should allow for ownership for a number of years that makes the project viable and also meaningful for the developer and the objectives of MNRE. Land allotment should also be clear and without any pending issues or claims from local villagers.

MNRE or nominated company as a stake holder should have a clear role to facilitate such process and avoid any contract issues that may increase the risk of the projects and that applies to all projects. Grants are to be approved and given on a performance basis with a clear mechanism based on milestones achieved.

The permits and deadlines for all the required processes should be supported by MNRE or nominated company in order to make sure the project is not delayed due to any nature that is not directly input to the developer. Deadlines of construction permits are of special concern, since that may endanger the project. The project will follow the usual deadlines for permitting, engineering and construction and if deadlines are not met with an acceptable cause developer may loose the license.

Environmental impact analysis

According to the approved legislation there is no EIA required for CSP projects. Nevertheless and as mentioned above the CSP effluent should be of concern.

Pollution control board

Thermal power plants run-off (blow-down)

According to the regulations of the Central Pollution control board there are rules to be followed for the liquid effluents of thermal power plants and temperature limits for the discharges of condenser cooling temperature. Below are the links and the documents.

http://www.cpcb.nic.in/Industry-Specific-Standards/Effluent/ThermalPowerPlant.pdf

THERMAL POWER PLANT : STANDARDS FOR LIQUID EFFLUENTS

Source	Parameter	Concentration not to exceed, mg/l (except for pH & Temp.)
Condenser Cooling Water (once through higher cooling system)	pH Temperature*	6.5 to 8.5 Not more than 5oC than the higher intake
Boiler Blowdown	Free available Chlorine Suspended solids Oil & grease Copper (Total) Iron (Total)	0.5 100 20 1.0 1.0
Cooling Tower Blowdown	Free available Chlorine Zinc Chromium (Total) Phosphate Other corrosion inhibiting materialon	 1.0 0.2 5.0 Limit to be established on case by case basis by Central Board in case of Union Territories and State Boards in case of States
As pond effluent	pH Suspended solids Oil & grease	6.5 to 8.5 100 20

* Limit has been revised, please see new limit at Sr. No. 66C of the document

Source : EPA Notification
[S.O. 844(E), dt 19th Nov; 1996]

Thermal Power Plant : Emission Standards

Generation Capacity	Pollutant	Emission limit
Generation capacity 210 MW or more	Particulate matter	150 mg/Nm^3
Generation capacity less than 210 MW	Particulate matter	300 mg/Nm^3

* Depending upon the requirement of local situation, such as protected area, the State Pollution Control Boards and other implementing agencies under the Environment (Protection) Act, 1986, may prescribe a limit of 150 mg/Nm^3, irrespective of generation capacity of the plant.

http://www.cpcb.nic.in/Industry-Specific-Standards/Effluent/tpp-Temperature.pdf

TEMPERATURE LIMIT FOR DISCHARGE OF CONDENSER COOLING WATER FROM THERMAL POWER PLANT

A. New thermal power plants commissioned after June 1, 1999.

New thermal power plants, which will be using water from rivers/lakes/reservoirs, shall install cooling towers irrespective of location and capacity. Thermal power plants which will use sea water for cooling purposes, the condition below will apply.

B. New projects in coastal areas using sea water.

The thermal power plants using sea water should adopt suitable system to reduce water temperature at the final discharge point so that the resultant rise in the temperature of receiving water does not exceed 7°C over and above the ambient temperature of the receiving water bodies.

C. Existing thermal power plants.

Rise in temperature of condensor cooling water from inlet to the outlet of condenser shall not be more than 10°C.

D. Guidelines for discharge point:

1. The discharge point shall preferably by located at the bottom of the water body at mid stream for proper dispersion of thermal discharge.
2. In case of discharge of cooling water into sea, proper marine outfall shall be designed to achieve the prescribed standards. The point of discharge may be selected inconsultation with concerned State Authorities/NIO.
3. No cooling water discharge shall be permitted in estuaries or near ecologically sensitive areas such as mangroves, coral reefs/spaning and breeding grounds of acquatic flora and fauna.

Source : EPA Notification
[GSR 7, dated Dec. 22, 1998]

More over certain states may have additional requirements to be obeyed and such requirements should be known prior to starting the project.

Land lease and rights

Land lease contracts should be issued according to the central legislation as well as states specific land rules. Allotments should be all ready and done or in the phase of being finished – within less than 6 months.

PPA signature and grants

PPAs templates are already issued by the central government and also by the states. In the pilot projects no new items are required besides the communication of the price to be paid by KWh. Utilities will have to buy the electricity at a market price and MNRE or nominated agency shall pay the difference. The PPA should be clear and transparent providing a bankable document.

On the grants it shall also be very clear the requirements and the amount to be given.

Permits and deadlines

Permits and deadlines are to be clearly stated and met. Developers should know the deadlines and MNRE – under nominated public company –should facilitate all permits in terms of maximum timeframes for answers from the relevant agencies. All required permits are to be listed and a maximum time frame for it is to be provided, based on a deadline is to be defined. Developers that fail to obey the deadlines and if no proper reasoning is presented are to loose the licenses and second bidder is to be called.

The guidelines for procurement of Solar Power require that the whole RFP process to be done within 150 days.

Penalties

Penalties have to be defined for all projects and in such way that if a certain project comes online and does not comply with the stated configuration and

performance by the developer other developers that were not selected and would have done it also should be entitled to indemnification.

It is also noteworthy that the penalties for execution phase and after commissioning are distinct.

Penalties	
Execution phase	Less one paisa per kWh for each week of delay based on each established deadline
After commissioning	1 INR less per Kwh per each non-conformity*

* The bid documents from the successful bidder will be used to determine the non-conformities.

EPC company qualification

Companies bidding for the project will have to be also evaluated and the projects are different in nature and some are new in the world. Previously the technical qualifications for the plants – components - were analysed, but the selected EPC company must be solid and able to carry out the project. Since these are not commercial projects the financial solidity of the developer should count more than the technical experience, which ultimately can be properly outsourced. The evaluation criteria are:

EPC company qualification	Evaluation
Financial criteria – company worth - counts with 80%	Project value < 20% yearly sales volume of the EPC
Technical with 10% (except for Stirling)	Minimum is 10 points
number of CSP plants constructed	max - 5. Others proportionally
number of CSP plants designed	max - 5. Others proportionally
number of countries with CSP plants constructed	max - 5. Others proportionally
number of countries with CSP plants designed	max - 5. Others proportionally
number of plants with storage constructed	max - 5. Others proportionally

number of plants with storage designed	max - 5. Others proportionally
Stirling Engines –> the evaluation will be 90% based on financial criteria (no EPC technical evaluation)	Project value < 20% yearly sales volume of the EPC

In this fashion for all projects except Stirling:

- Project technical evaluation = 10%
- EPC technical evaluation = 10%
- EPC financial strength = 80%

For Stirling:

- Project technical evaluation = 10%
- EPC financial strength = 90%

Official Committee

A committee was setup officially by MNRE to make the site visits as expressed in the documents below:

No.29/5/2010-11/JNNSM (ST)

भारत सरकार/ Government of India

नवीन और नवीकरणीय ऊर्जा मंत्रालय / Ministry of New & Renewable Energy

***

Block 14, CGO Complex, Lodi Road,
New Delhi-03, Dated 18th Nov. 2011

Office Order

Subject: Constitution of a Committee to visit the proposed sites to explore suitability for setting up of pilot solar thermal demonstration projects.

As a part of approval for the JNNSM, a provision of pilot demonstration projects was also approved in principle. Pilot demonstration projects are to be closely aligned with the Mission's R & D priorities and designed to promote technology development and cost reduction. The Mission, therefore, envisages the setting up of the following demonstration projects in Phase I, to be commissioned during 12th Plan period.

2. In view of the above, a Core Group was constituted by the Ministry involving experts and policy makers to have consultations with the stakeholders including solar power developers. A number of consultation rounds took place and the following technology configurations emerged to be taken up for pilot projects:--

- CSPs project with large thermal storage
- CSP project with operating temperature of 500°C
- CSP project with hybrid cooling
- CSP project with biomass support
- CSP project providing base load power
- CSP project using Stirling Engines
- CSP project with natural gas support, and
- CSP project augmenting a coal fired power plant

3. Recently, the States were asked to identify sites for setting up pilot projects, and responses have been received from 5 states (Andhra Pradesh, Gujarat, Karnataka, Rajasthan and Tamil Nadu). For last configuration mentioned above, related to coal fired CSP power plant, a couple of meetings have already been held by Secretary, MNRE with CMD, NTPC with a view to make a proposal to MNRE for such a project at one of their existing coal thermal power stations.

4. Therefore, in order to explore suitability of location, area and availability of infrastructure facilities at the proposed sites where these pilot projects may be set up in the States, it has been decided to constitute a Committee with the following composition:-

i) Mr. Agostinho Miguel Garcia, ADB consultant (Chief of Development and Engineering, Sun Business Development Lda, Portugal)
ii) Mr Amit Jain, CCI, New Delhi (for Gujarat, Karnataka and Tamil Nadu sites)
iii) Prof B Ravindra , IIT Rajasthan (for Rajasthan site)
iv) Prof M A Ramaswamy, CSTEP (for Karnataka and Tamil Nadu sites)
v) Mr Ramesh Pawar, Sr. DGM, BHEL Corporate R&D Division, Hyderabad (for Andhra Pradesh sites)
vi) Mr J K Jethani, Scientist 'D', MNRE

PTO.

6 The terms and objective of the Committee will be to undertake visits to the proposed sites and to explore suitability of location, area and availability of infrastructure facilities where these pilot projects could be set up in the State.

7 Committee members will be provided TA/DA as per entitlement (travel limited to economy class and by Air India wherever available) and a sitting fee of Rs 2000/- per day to the non-official members of the Committee. The expenditure on the visit towards TA/DA for member at Sl. No. (i) above will be borne by ADB; and the expenditure on TA/DA and honorarium etc for the members at Sl.No.(iii) and (iv) above will be borne by MNRE from on-going MNRE projects.

8. The Committee may co-opt any other expert for review of any specific items/work or other tasks, if considered necessary. The term of the committee will be upto 31/03/2012 or till the assignment is completed/closed whichever comes earlier. The Committee will meet as frequently as possible keeping in view the other exigency of work in the Ministry. ST Division will provide Secretarial assistance to this Committee.

9. This issues with the approval of the competent authority.

(Prem Chand)
Under Secretary to the Govt.of India
Ph: 24360707/Extn.1023

To

All Members of the Committee.

Copy is also forwarded for information to:-

(i) PSO to Secretary, MNRE,
(ii) JS(NSM)/ Dir.(AK)/Dir.(Fin.)
(iii) Order Bundle.

Appendix – Cost Estimates

Topics	Hybrid cooling	High temp operation	Large storage	Solar Biomass	Gas hybridization	Stirling engines
Size (MW)	20 - 100	20 - 100	10 - 100	< 10	20 - 100	< 10
Number	1	1	1, 2	Total < 30 MW	Total < 100 MW	Total < 30 MW
Maximum area available	140 hect/150 hect	140/150 hect /400 acre	400 acre/400 acre	0	0	0
Minimum CUF	20%	20%	40%	20%	20%	
Maximum CUF	30%	30%	100%	40%	40%	
Tariff (INR/KWh)	10.2	11.2	9.2	7.2	7.2	12.8
1st period						
INR/KWh	12	13	11	9	9	14
Years	10	10	10	10	10	10
2nd period						
INR/KWh	9	10	8	6	6	12
Years	15	15	15	15	15	15
Efficiency loss	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%
Likely Hect/MW	4	4.5	6			
Minimum budget (Cr)	1487.3	1451.7	1788.7	899.9	2999.6	1199.9
Maximum budget (Cr)	2390.3	2488.6	10221.0	1799.8	5999.3	1999.8

Approach Paper on Biomass & Biogas Tariff Regulations

Rajasthan Electricity Regulatory Commission

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1 Technology Specific Parameters: Biomass Plants

1.1 Eligibility Criteria

Norms for Biomass power project would be applicable for grid connected system based on the Rankine Cycle technology and using biomass fuel sources, provided use of the fossil fuel is restricted only up to 15% of the total fuel consumption on annual basis.

1.2 Capital Cost

Biomass based power plant based on the Rankine cycle employs two type of condensers, namely the water cooled condenser and the air cooled condenser.

1.2.1 Capital cost for Biomass Power Plants- Water Cooled Condensers

1.2.1.1Capital Cost norms as approved by CERC and other SERCs

CERC in its RE Tariff Regulation, 2012 has specified the normative capital cost for the Biomass based power projects employing water cooled condensers as Rs.445 Lakh/MW for the FY 2012-13. For arriving at this Capital Cost, CERC reduced the Capital cost of Rs.5.0 Crores/MW by Rs.0.20 Crore/MW on account of evacuation infrastructure cost beyond point of connection and Rs.0.35 Crores/MW on account of difference between Air Cooled Condenser (ACC) and Water Cooled Condenser (WCC).

CERC in their Statement of Objections and Reasons dated 06.02.2012 for the above referred regulation, observed that the generic norms for determination of the tariff may be differentiated based on project-specific factors. These factors for the biomass based power plants with Rankine Cycle are: technology type, the fuel type (rice husk, straw, stalks), the size of the project (to account for economies of scale), the quality of the resources at that particular site and the specific location of the project. In order to specify generic norms for a biomass based power projects, the CERC considered a representative project size of 10 MW.

Thereafter, CERC under its regulatory dispensation issued the CERC RE Tariff Order 2013-14 wherein the capital cost for such plants was linked to the indexation mechanism specified in the above referred regulation and subsequently determined as Rs.463.33 lakh/MW for FY 2013-14.

Various SERCs have issued the Tariff Orders for biomass based generation projects employing water cooled condensers. The latest cost data approved by the various States Commissions are as under:

SERCs	Capital cost (Rs.Cr/MW)	Indexation Mechanism	Order/Regulation	Remark
GERC	4.68 : Water Cooled	Not Provided	Order on determination of tariff for procurement of power from biomass based power projects, 2013	Took note of the capital cost for water cooled condensers as determined by CERC during FY 2012-13
MERC	4.03 (FY 10-11)	As per CERC	Regulations as on 7.6.2010	As per CERC
TNERC	4.45	Not Provided		TNERC Comprehensive Tariff Order for Biomass Plant, 2012
HERC	4.50 (FY 10-11)	As per CERC	HERC (Terms and Conditions for determination of Tariff from Renewable Energy Sources) Regulations, 2010	As per CERC
PSERC	4.45	As per CERC	PSERC Suo Moto generic RE tariff order based on CERC RE regulations 2012	As per CERC

UERC	4.45	Not provided	UERC (Tariff and Other Terms for Supply of Electricity from Renewable Energy Sources and non-fossil fuel based Co-generating Stations) Regulations, 201	Took note of the capital cost for water cooled condensers as determined by CERC
JSERC	4.90 : Water cooled (FY 12-13)	As per CERC	Tariff Order on Determination of Generation Tariff for (RPL)-Project Specific	

1.2.1.2 Actual Project Cost Approach

Capital cost information for RE projects as provided by IREDA in its annual report and capital cost information submitted by the project developers to Executive Board of United Nations Framework Convention for Climate Change (UNFCCC) in the Project Design Document (PDD) for projects to get registered under CDM activity have been considered for the analysis.

The capital cost data for around 10 projects which translates into 101.3 MW have been analysed under this approach. The table below summarises the average capital cost for the projects during various years.

Source	2009-10			2010-11			2011-12		
	No	Capacity (MW)	Capital Cost (Rs.Cr/MW)	No	Capacity (MW)	Capital Cost (Rs.Cr/MW)	No	Capacity (MW)	Capital Cost (Rs.Cr/MW)
IREDA				2	19.90	4.79	2	19.90	4.01
UNFCC	4	36.8	4.74	2	24.5	5.39			
Total	4	36.8	4.74	4	44.4	5.12	2	19.90	4.01

Also, it was observed that IREDA[1] uses following benchmark capital cost norm for financing the biomass based power projects during FY 2011-12:

Pressure configuration (ata)	Biomass Power Project (Rs.Cr/MW)		
	6MW	7.5MW	10MW
44	4.03	3.93	3.79
66	5.38	5.19	5.03
86	5.59	5.37	5.15
102	5.93	5.77	5.61
110	6.05	5.89	5.72

Further, during the recent haring of TNERC on 'Determination of Comprehensive Tariff for Biomass Power Plants, 2012', IREDA stated that the cost ceiling benchmark for Biomass project employing water cooled condensers ranges from Rs.5-6 Crore/MW depending upon boiler pressure configuration.

1.2.2 Capital cost of Biomass Power Projects- Air Cooled Condensers

1.2.2.1 Capital Cost norms approved by other SERCs

Various SERCs have issued the Tariff Orders for biomass based generation projects employing air cooled condensers. The latest cost data approved by the various States Commissions are as under:

SERCs	Capital cost (Rs.Cr/MW)	Indexation Mechanism	Order/Regulation	Remark
GERC	4.98 : Air Cooled	Not Provided	Order on determination of tariff for procurement of power from biomass based power projects, 2013	Took note of the capital cost for water cooled condensers as determined by CERC

[1] As per the Explanatory Memorandum of CERC RE Tariff Regulations, 2012

				during FY 2012-13
JSERC	5.34 : Air cooled (FY 12-13)	As per CERC	Tariff Order on Determination of Generation Tariff for (RPL)-Project Specific	

1.2.2.2 Actual Project Cost Approach

The Cost Breakup for 9.9 MW project financed by IREDA having total project cost of around Rs.50.0 Cr. (Including evacuation infrastructure cost beyond point of connection and with Air Cooled condenser) as confirmed by the project developer are as under:

Particulars	Cost (Rs.Cr)
Civil Works	7
Plant & Machinery	34
IDC	3.5
Pre-operative charges	4
Margin money for W/C	1.5
Total Cost	**50**
Cost/MW (Rs.Cr/MW)	**5.05**

Further, during the recent haring of TNERC on 'Determination of Comprehensive Tariff for Biomass Power Plants, 2012', IREDA stated that the cost ceiling benchmark for Biomass project employing air cooled condensers are 4-5% higher than project costs of biomass power projects employing water cooled condensers (project cost for water cooled condensers ranges from Rs.5-6 Crore/MW depending upon boiler pressure configuration).

1.2.3 Approach adopted by RERC

The Commission while issuing its Explanatory Memorandum on the Sixth Amendment in RERC Tariff Regulations, 2009 (March, 2013) stated that biomass power plants in Rajasthan generally bring in use mustard husk as their feedstock. Further, it is mentioned that Mustard Husk is high in silica content and other components that causes corrosion and erosion in boiler and boiler grate, which entails higher cost and requires consideration in arriving at the capital cost. Moreover, the sizes of Mustard Husk based Bio-mass plants in the State come in the range 6 MW to 10 MW. Hence, while deliberating the normative capital cost of biomass power projects, representative project size of 8 MW was considered as against 10 MW adopted by CERC.

In the view of above, the Commission while issuing 'Statement of Objects and Reasons' for the above referred regulation, specified the capital cost of the biomass power plants based on water cooled condensers as Rs.5.05Cr/MW.

With regards to the transmission related cost for biomass power projects, the Commission observed that such projects are usually located near the load centers and generally require shorter evacuation transmission system lines. Considering the above , the Commission specified a transmission system cost of Rs 15 Lakh/MW for evacuation of power and Rs.2lakh/MW towards connectivity charges for biomass power projects.

Considering the position discussed above, the Commission while finalising the Sixth Amendment in RERC Tariff Regulations, 2009 (March, 2013) determined the capital cost of projects employing water cooled condenser as Rs. 5.22 Cr./MW. Further, on considering a difference of Rs 0.35 Cr/MW from plants employing water cooled condenser as compared to air cooled condenser, same as considered by CERC, Commission in the aforementioned amended regulation has adopted a capital cost of Rs 5.57 Cr/MW for Biomass projects employing air cooled condenser for FY 2013-14.

Based on aforementioned

1.3 Plant Load Factor

The Plant load factor (PLF) being a critical performance parameter for any power plant installation and since it is dependent on factors such as reliable and quality fuel supply, plant availability and unconstrained power off-take arrangement.
CERC in its RE Tariff Regulation, 2012 has specified the threshold plant load factor for biomass power plants based on the rankine cycle as follows:

- During Stabilisation: 60%
- During the remaining period of the first year (after stabilisation): 70%
- From 2nd Year onwards: 80%

However, RERC in its RERC Tariff Regulations, 2009 determined the plant load factor for biomass based power plants employing air-cooled and water-cooled condensers as following:

Particulars	Water Cooled condenser	Air cooled condenser
Plant Load Factor	60% (during stabilisation), 70% (first yr after stabilisation), and Yr-2 onwards 75%	60% (during stabilisation), 70% (first yr after stabilisation), and Yr-2 onwards 75%

As per the information provided by IREDA/UNFCC in respect of the biomass power projects, most of them assume capacity utilization at 60-70 % during the 1st year of operation, and 75 % to 80 % from the 2nd year onwards. The Commission proposes to retain the norms specified by CERC for threshold plant load in its RE Tariff Regulations, 2012 which is as under:

- During Stabilisation: 60%
- During the remaining period of the first year (after stabilisation): 70%
- From 2nd Year onwards: 80%.

Considering the above, the Commission is of the view to retain the norms regarding the PLF same as specified by CERC.

1.4 Auxiliary Consumption

RERC in its RERC Tariff Regulations, 2009 specified the auxiliary consumption levels for biomass power plant employing air-cooled and water-cooled condensers. The stipulations in this regard were as follows:

Particulars	Water cooled condenser	Air-cooled condenser
Auxiliary Consumption Factor	10.5% (during stabilisation) 10% (after stabilisation)	12.5% (during stabilisation) 12% (after stabilisation)

The auxiliary consumption factor is one of the key performance factors and is in dependent of the size of the plant. Further, it may vary according to the need of pre-processing requirement of the biomass fuel. The Commission also notes that the auxiliary energy consumption is a function of plant efficiency and the energy conservation methods adopted by the developers.

Auxiliary power consumption in a power plant influences the net power available for export from any power plant. Lower the auxiliary consumption, higher will be the power that can be exported. The major power plant auxiliaries in the power plant contributing to the auxiliary power consumption are,

- Boiler Feed water Pump
- Condensate Extraction Pump
- Cooling Water Pumps
- ID Fans
- FD Fans
- Cooling Tower Fans
- Air Compressor
- Fuel Handling Equipments
- Losses in the transformers

The auxiliary consumption also depends on the plant availability and loading on the plant. Greater the plant availability & higher the plant loading, the lower will be the auxiliary consumption. The plant availability is

largely dependent on the quality of fuel while the loading on the power plant is greatly influenced by the grid conditions.

According to the study carried out by NPC[2] it varies between 10% & 18%. They suggested that power plants should strive to maintain auxiliary consumption within 12**%**, which can be achieved if operated under stable conditions.

The Commission proposes to retain the norm as it is for the next control period.

1.5 Feedstock Cost

MNRE in its letter dated 23rd September, 2011 to CERC submitted their findings on evaluation report on biomass price wherein prices(Rs./T) of different types of biomass in different States prevailing in the same period was specified. The excerpts of the finding have been tabulated below:

State	Rice Husk(Rs./T)	Mustard residue (Rs./T)	Stalks (Cotton/Maize) (Rs./T)	Wheat Straw (Rs./T)	Paddy Straw (Rs./T)	Julifora (Rs./T)	Wood Shavings (Rs./T)
Haryana	3000	2200	2000	2500	1500		3500
Maharashtra	2400		1600	2000	1400		3500
Punjab	3200	2500	2000	2500	1500		4000
Rajasthan		1900	1800	2500		1900	
Odisha	2000				1500		2500
West Bengal	2400			2000	1400		3000
Chattisgarh	2000				1500		3500

CERC in its RE Tariff Regulation, 2012 has specified the biomass fuel price for Rajasthan during first year of the Control Period (i.e. FY 2012-13) as Rs. 2300 /Tonne. Further, in the above referred regulation, CERC specified that for each subsequent year of the Tariff Period, the normative escalation factor of 5% per annum would be applicable and accordingly, the biomass fuel price for FY 2013-14 arrives at Rs. 2415/Tonne.

However, CERC in its RE tariff 2013, dated Feb 28,2013 specified the biomass fuel price for Rajasthan for FY 2013-14 as Rs. 2464.48 /tonne.

Also, RERC in its third amendment to RERC Tariff Regulation in 2011 specified the base biomass fuel price as Rs.1830/MT for FY2011-12. The above referred amendment, mentioned that in order to determine the fuel price for the subsequent years of control period, normative escalation of 5% would be adopted. Considering the above norm, the Commission vide its order dated April 28, 2013 on 'Determination of Tariff for biomass power plants in Rajasthan' specified the fuel price as Rs.2017/MT.

M/s Dalkia Energy Services Limited (DESL), for a study conducted by RREC, studied/surveyed the prices and prices trend of main Biomass fuels across Rajasthan particularly in respect of Mustard crop and Juliflora Biomass and the findings were recommended in the report dated March 18, 2011 which are as follows:

- The average landed cost of Biomass at factory gate for the 8 running biomass power plants (S. M. Environmental technologies Pvt. Ltd., Surya Chambal Power Ltd., Kalpataru Power Transmission Ltd-Uniara, Kalpataru Power Transmission Ltd- Ganganagar, Sambhav Energy Ltd., Sathyam Power Pvt. Ltd., Transtech Green Power Pvt. Ltd., Amrit Environmental Technologies Pvt. Ltd.) for FY 2010-11 was assessed at Rs 2077/Tonne. However, the report also suggested that the price was higher than anticipated as a result of some market distortion, likely reason being drought of last year and panic buying by the power plants.
- Biomass traders were also interviewed for all districts to gather information on biomass being traded, exported, imported and the prices were estimated.

	Traders Selling Rate (Rs. /Tonne)		
Average across 26	Minimum	Maximum	Average

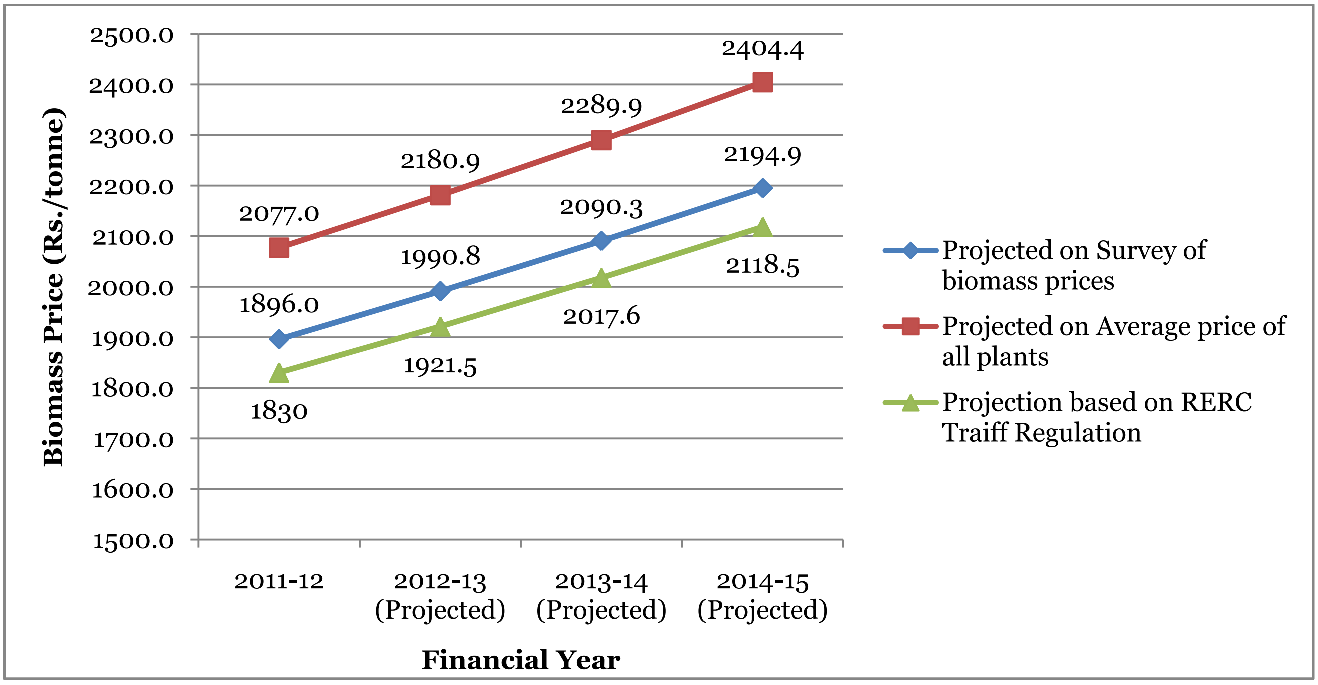
[2] As per the Explanatory Memorandum of CERC RE Tariff Regulations, 2012

districts	1754	1979	1823

Based on the price estimated across districts and efficient logistics management, the price of biomass for FY 2011-12 was reported as Rs. 1896/tonne.

The following illustration depicts the trajectory of feedstock prices projected over the stipulated period from FY 2011-12 to FY 2014-15. The below mentioned projections are based on the data sourced from:

- Survey of the feedstock prices by M/s.Dalkia
- Average price of feedstock as reported by industries
- Price of the feedstock specified by RERC



Considering the above, the Commission proposes the price of biomass for FY 2014-15, at Rs. 2200/tonnes.

1.6 Station Heat Rate

Gross station heat rate or GHR means the heat energy input in kCal required to generate one kWh of electrical energy at generator terminals of a thermal generating station. Gross Station Heat Rate (GHR) is a key performance parameter for a power plant. The GHR depends on several factors such as plant capacity, plant design and configuration, technology (boiler type and pressure levels etc.), plant operation and maintenance practices, quality of fuel received, and operational performance over varying load conditions.

RERC in its RERC Tariff Regulations, 2009 specified the station heat rate for biomass power plant employing air-cooled and water-cooled condensers. Subsequently the Station Heat Rate values were continued in the Draft Rajasthan Electricity Regulatory Commissions (Terms and Conditions for determination of tariff)(Sixth Amendment) Regulations 2013. The stipulations in this regard were as follows:

Particulars	Water cooled condenser	Air-cooled condenser
Station Heat Rate	4300 kCal/kWh (during stabilisation) 4200 kCal/kWh (after stabilization)	4540 kCal/kWh (during stabilisation) 4440 kCal/kWh (during stabilization)

CERC in its RE Tariff Regulation, 2012 has specified the station heat rate for the Biomass based power projects employing water cooled condensers as 4000 kCal/kWh for FY 2012-13. Various SERCs have issued the Tariff Orders for biomass based generation projects employing water cooled condensers. The station heat rates approved by various State Commissions are as under:

SERCs	Water Cooled/Air Cooled	Station Heat rate (kCal/kWh)	Order/Regulation
AERC	Water Cooled	4000	AERC Term and Conditions for RE TARIFF Regulations, 2012
CSERC	Water Cooled	4000	CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2012
GERC	Water Cooled	3800	Order on determination of tariff for procurement of power from biomass based power projects, 2013
MERC	Water Cooled	3800	Regulations as on 7.6.2010
HERC	Water Cooled	3800	HERC (Terms and Conditions for determination of Tariff from Renewable Energy Sources) Regulations, 2010
PSERC	Water Cooled	4000	PSERC Suo Moto generic RE tariff order based on CERC RE regulations 2012
JSERC	Water Cooled	3800	Tariff Order on Determination of Generation Tariff for (RPL)-Project Specific

Various SERCs have issued the Tariff Orders for biomass based generation projects employing air cooled condensers. The latest Station Heat Rate data approved by the various States Commissions are as under:

SERCs	Water Cooled/Air Cooled	Station Heat rate (kCal/kWh)	Order/Regulation
GERC	Air Cooled	3950	Order on determination of tariff for procurement of power from biomass based power projects, 2013
JSERC	Air cooled	3800	Tariff Order on Determination of Generation Tariff for (RPL)-Project Specific

The Central Electricity Authority (CEA) came out with a report on operation norms for biomass based power plant in September 2005, wherein norm of 4500 kCal/kWh was suggested based on the analysis of data furnished by the 16 projects most of them having capacity ranging from 4 MW to 6 MW. From the design data provided by the biomass power plants, CEA calculated Turbine heat rate at 3094 kCal/kWh. Weighted Average Gross heat rate of 16 projects was arrived at 4033 kcal/kWh based on the design steam parameters and efficiency of the boiler derived from the performance curve adjusted based on the moisture content in the biomass fuel which is in the range of 77%.

Biomass such as cotton stalk, chilly stalk and mustard stalk etc., create problem in the boiler tubes, thus affecting the performance of the boiler. Therefore, CEA suggested allowing 5% allowance over average gross heat rate. Further, noted that since biomass is stored in open, it is affected by climate changes. Certain percentage weight will get loss due to loss of moisture and degradation due to weather changes and loss during the strong wind. Therefore, CEA also suggested allowing additional 5% over 4234.65 to take care of fuel related losses like qualitative and quantitative degradation of biomass which works out to 4446.38 kCal/kWh say 4500 kcal/kWh.

The National Productivity Council also conducted a field study for MEDA for assessment of heat rate of commissioned biomass power plants in Maharashtra. Based on the acceptable Boiler Efficiency & Turbine Heat rate, the NPC suggested that SHR should be in following range

Project with Boiler Type	Station Heat rate (kCal/kWh)
AFBC	4000-4100
Traveling Grate	4150- 4250

MNRE submitted their recommendation for tariff guidelines vide letter dated 30th September, 2011 wherein it was stated that the GHR depends upon type of fuel which in turn decides the plant configuration and technology. MNRE finally suggested following SHR for biomass power plant greater than 5 MW.

Biomass Source	IPP (>5 MW)	Tail End (<2 MW)
Rice Husk	4100	5200
Straw	4400	5500
Others	4150	5200

While providing comments on Draft CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2012; Orissa, Gujarat, Maharashtra and Madhya Pradesh Biomass Association have requested to consider the SHR as 4500 kCal/kWh as per CEA norms for the long term sustainability of biomass power sector. In view of the above, the Commission proposes to retain the norm as it is for the next control period.

1.7 O&M Expense

1.7.1 International Approach

Operation and maintenance (O&M) refers to the fixed and variable costs associated with the operation of biomass-fired power generation plants. Fixed O&M costs can be expressed as a percentage of capital costs. For biomass power plants, they typically range from 1% to 6% of the initial capital expenditure per year. Fixed O&M costs consist of labor, scheduled maintenance, routine component/equipment replacement (for boilers, feedstock handling equipment, etc.), insurance, etc. The larger the plant, the lower the specific (per kW) fixed O&M costs, because of the impact of economies of scale, particularly for the labor required. Variable O&M costs depend on the output of the system and are usually expressed as a value per unit of output (USD/kWh). They include non-biomass fuels costs, ash disposal, unplanned maintenance, equipment replacement and incremental servicing costs. The fixed and variable O&M cost has been tabulated below:

Technology	Fixed O&M (% of installed cost)	Variable O&M	
		USD/MWh	Rs./kWh (1USD= 62 Rs)
Stokers/BFB/CFC boilers	3.2-4.2 3-6	3.8-4.7	0.2-0.3

Source: US DOA2007, US EPA 2009

1.7.2 Approach adopted by CERC and other SERCs

CERC in its RE tariff Regulations, 2012, specified the norms for O&M expense for such plants at Rs.24Lakhs/MW (5% of the capital cost). Considering the same the normative O & M expenses for biomass based projects was escalated at the rate of 5.72% per annum to take care of increase in manpower and other related costs. For that reason, in the determination of generic tariff for the FY2013-14, the Commission considered O&M cost norm for biomass power as Rs.25.37 Lakh/MW.

Various SERCs have issued the Tariff Orders/Tariff Regulations for biomass based generation projects. The latest cost data with regards to O&M expense as approved by the various States Commissions are as under:

SERCs	O&M expense (Rs.lakh/MW)	Indexation Mechanism	Order/Regulation
GERC	5% of the capital cost	5.72%	Order on determination of tariff for procurement of power from biomass based power projects, 2013
MERC	21.4 (FY 10-11)	As per CERC	Regulations as on 7.6.2010
HERC	20.25 (FY 10-11)	5.72%	HERC (Terms and Conditions for determination of Tariff from Renewable Energy Sources) Regulations, 2010
PSERC	24	As per CERC	PSERC Suo Moto generic RE tariff order based on CERC RE regulations 2012

CSERC	24	5.72%	CSERC (Tariff and Other Terms for Supply of Electricity from Renewable Energy Sources and non-fossil fuel based Co-generating Stations) Regulations, 2012
JSERC	4.5% of capital cost (FY 10-11)	5.72%	Terms and Conditions for determination of tariff from biomass and cogeneration, 2010

Further, The Central Electricity Authority (CEA) came out with a report on operation norms for biomass based power plant in September 2005, wherein based on the analysis of data furnished by ten (10) biomass projects having capacity ranging from 4 MW to 8 MW following norm has been suggested:

O&M Cost elements	Suggested norm in % of the capital cost
Salaries	1.5%
Administrative expense	1%
Repairs & Maintenance	2.5%
Insurance	0.5%
Consumables	1.5%
Total	7%

CEA suggested that 7% norm may be allowed presently and same may be reviewed after 2-3 years. While suggesting above norms, CEA observed that biomass power projects are labour oriented and maintenance requirement in boiler, fuel preparation side etc. comparatively higher than coal fired plants.

Most of the biomass based power projects have moderate size in range of 4 to 6 MW. Large plants tend to have lower O&M costs due to economies of scale. Also, with the increasing innovation in the technology along-with extensive employment of IT automation to carry out O&M operation, it has been observed that O&M costs have significantly come down. Considering the same, the Commission proposes the O&M expense at Rs...Lakh/MW for the first year of the next Control Period i.e. FY2014-15 and the same is proposed to be escalated at the rate of 5.85% per annum to take care of increase in manpower and other related costs.

1.8 Calorific Value

RERC in its RERC Tariff Regulations, 2009 specified the Calorific Value (GCV) for biomass power plant employing both water cooled and air cooled condensers. The stipulations in this regard were as follows:

Particulars	kCal/kg
Calorific Value	3400

CERC in its RE Tariff Regulation, 2012 has specified the calorific value for biomass power plants for the purpose of determination of tariff shall be at 3300 kCal/kg. MNRE vide its letter to CERC dated 30th September, 2011 suggested that GCV should be decided based on the biomass type and following table should be referred for GCV of various biomass:

Type of Biomass	Moisture (%)	Dust (%)	GCV on as received basis (kCal/kg)
Mustard Residue	10.00	4.00	3300
Juliflora	13.00	1.00	2800
Rice Husk	12.00	1.50	3200

Various SERCs have issued the Tariff Orders for biomass based generation projects and the GCV approved by various State Commissions are as under:

SERCs	GCV (kCal/kg)	Order/Regulation
AERC	3300	AERC Term and Conditions for RE TARIFF Regulations, 2012
CSERC	3300	CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2012
MERC	3611	Regulations as on 7.6.2010
HERC	3458	HERC (Terms and Conditions for determination of Tariff from Renewable Energy Sources) Regulations, 2010
PSERC	3300	PSERC Suo Moto generic RE tariff order based on CERC RE regulations 2012
JSERC	3467	Tariff Order on Determination of Generation Tariff for (RPL)-Project Specific

The calorific values of individual biomass have been maintained by Indian Institute of Science, Bangalore; which through the Biomass atlas maps State wise availability of the different type of biomass fuel and also presents the power generation potential using each of the biomass fuel.

Type of Biomass	GCV (kCal/kg)	Share in Total Biomass surplus
Wheat	3800	51 %
Mustard	3400	28 %
Bajra	3950	9 %
Share in Total		**88 %**
Weighted average calorific value	**3689**	

CEA in its report on "Operation Norms For Biomass based Power Plants" September 2005 assumed GCV of 3300 kCal/kg based on the calculation of weighted average GCV for 16 biomass power plant and also taking into account of large variation in quality and variety of biomass used including variation in moisture content due to weather conditions.

The National Productivity Council (NPC) in its study mentioned that based on the fuel analysis report from the different plants, GCV & moisture variation could be as under:

Biomass	Variation in Moisture (%)	GCV (kCal/kg)
Rice husk	12-18	3000-3200
Maize Bhutia	21	3500
Cotton Stalk (Air Dried Basis)	8	3250

Based on the recommendation of MNRE, NPC and CEA, the Commission has considered the GCV of biomass at 3250 kCal/kg and after taking into account, use of 15% of coal (average coal GCV at 3600 kCal/kg and 85% uses of Biomass fuel of 3150 kCal/kg), the weighted average GCV has been considered at 3300 kCal/kg. The Commission has decided to retain the norm as proposed in the draft Regulations.

While providing comments on Draft CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2012; The Gujarat Urja Vikas Nigam Limited (GUVNL) has suggested that the GCV of cotton stalk available in Gujarat is around 3600- 3700 kcal/kg and average GCV of the biomass would be around 3500 kCal/kg.

In view of the above, the Commission proposes to retain the norm as it is for the next control period.

Prefeasibility Report

Charanka (Gujarat)

May 2012

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Chapter 1: Introduction

Central level initiative to promote solar power

National Action Plan on Climate Change

The National Action Plan for Climate Change (NAPCC), announced by the Hon. Prime Minister of India on June 30, 2008, envisions several measures to address global warming. One of the important measures identified involves increasing the share of renewable energy in total electricity consumption in the country. NAPCC has set the target of 5% as dynamic minimum renewable purchase standard (DMRPS) for FY 2009-10, with the target increasing by 1% for next 10 years.

The action plan specifically mentions issues related to power generation from biomass, small hydro and wind technologies. The NAPCC also identifies various regulatory, measures for mainstreaming power generation based on renewable energy sources like:

- A dynamic minimum renewable purchase standard at the national level with escalation a year.
- A mechanism for verification of procurement of renewable based power is also suggested along with a scheme of tradable renewable energy certificates.

Further, in order to ensure compliance with the DMRPS target, NAPCC envisages transaction of renewable energy from surplus regions to deficit regions through policy instruments.

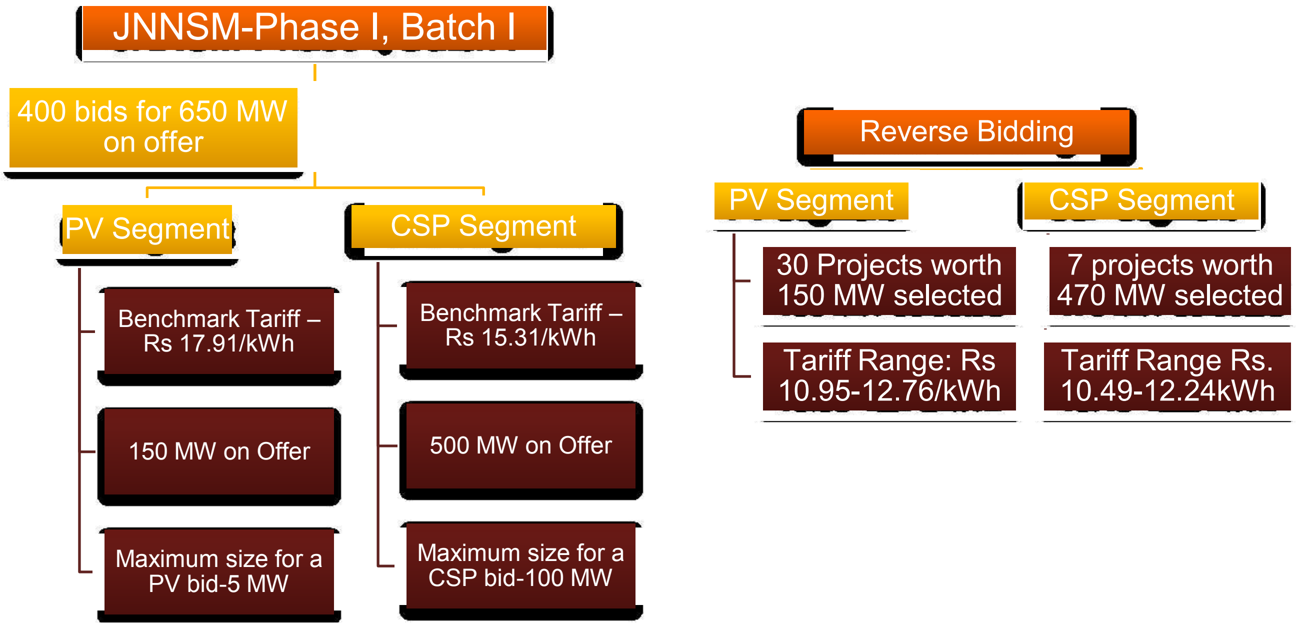
Jawaharlal Nehru National Solar Mission - Aims and Objectives

NAPCC announced by the Hon. Prime Minister of India envisages increasing the share of renewable energy in total electricity consumption in the country and has given special consideration to encourage the base of Solar Power in India. In order to promote the development and use of solar energy for power generation and other uses, the Government of India has launched the Jawaharlal Nehru National Solar Mission (JNNSM) during November 2009. JNNSM is one of the eight key National Missions envisaged under India's NAPCC. The mission has a twin objective - to contribute to India's long term energy security as well as its ecological security. The JNNSM would be implemented in 3 stages and aims to have an installed capacity of 20,000 MW by the end of the 13th Five Year Plan in 2022. It is envisaged that as a result of rapid scale up as well as technological developments, the price of solar power will attain parity with grid power at the end of the Mission, enabling accelerated and large-scale expansion thereafter. The mission includes a major initiative for promoting rooftop solar photovoltaic (PV) applications. The solar tariff announced by the regulators will be applicable for such installations.

The objectives of JNNSM are below:

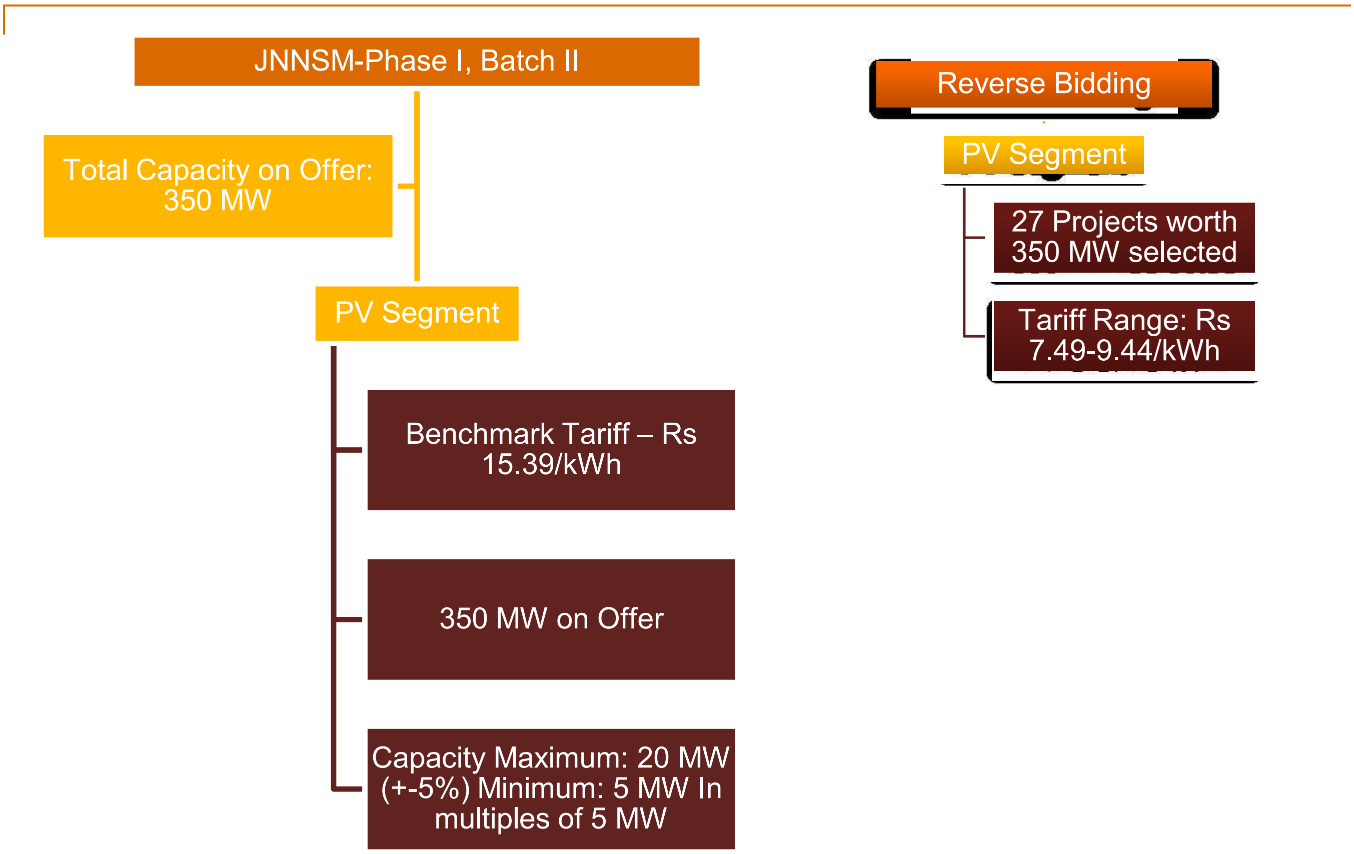
- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To increase capacity of grid-connected solar power generation to 1000 MW within three years – by 2013; an additional 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000MW installed power by 2017 or more, based on the enhanced and enabled international finance and technology transfer.
- The target of 20000MW by 2022 will primarily be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power. The transition could be appropriately up scaled, based on availability of international finance and technology.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programs for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.
- To achieve 15 million square meters solar thermal collector area by 2017 and 20 million square meters solar thermal collector area by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

Based on the objectives as laid in the National Solar Mission (NSM), over 1000MW of solar projects under the first phase, having affiliation to different solar technologies was allotted to the interested bidders. An approach of allowing 'discounted bidding' on the CERC approved 'benchmark tariff' for various solar technologies was envisaged as an instrument for selecting the prospective developers. The Bidding process under the first phase of the National Solar Mission was split into two batches with the understanding that this circumspect approach would leave enough room for rectification if some flaws or shortcomings that may emerge in the first batch of bidding. The following diagrammatic representation gives a snapshot of the bidding process that ensued in the first batch of bidding under the first phase of the Mission. Under the first batch, a total of 30 solar PV projects, each with an individual capacity of 5 MW (total capacity of 150 MW) and solar thermal projects (CSP Segment) with a total capacity of 470 MW were allocated. In addition to the 30 solar PV projects, capacity worth another 84 MW was contributed through the Migration Scheme that permits projects planned before the Mission was launched, to migrate into it and enjoy the incentives offered there under.



As the pictorial representation also suggests, there was substantial oversubscription for projects to start with, and then the government invited reverse bids asking for discounts on the initial benchmark tariff of Rs 17.91/ kWh for PV projects and Rs 15.31/ kWh on CSP projects. Thirty PV projects worth a cumulative capacity of 150 MW and seven CSP projects worth a cumulative capacity of 470MW were selected under Batch I of the scheme. Remarkably, the bidding process did result in exceedingly competitive bids. PPAs have been signed at an average levelized tariff of Rs. 12.16 / kWh for PV projects and Rs. 11.48/ for CSP (thermal) projects, i.e., the government has secured 32% and 25% discount respectively in PV and CSP projects.

Building further on the lessons learnt from the first batch of bidding, bids were invited for a cumulative capacity of 350MW in the second batch of Phase I. The entire quota of 350MW was for capacity in solar PV only. CERC revised the benchmark tariff for solar PV in light of the dropping trends in solar equipment prices. The following diagrammatic representation further illustrates the Batch II bidding process and its outcome.



The lowest bid submitted in Batch II, offered more than 50% discount on the CERC benchmark tariff. This lowest bid submitted was for a 5 MW capacity project and the quoted tariff was Rs. 7.49 per KWh. [1]The tariffs quoted by winning bidders in Batch II bidding ranged from Rs. 7.49 to Rs. 9.44 per kWh. This tariff range is remarkably lower than the one discovered in Batch I. In fact, the highest winning tariff in Batch II is almost Rs 1.5 lower than the lowest winning tariff in Batch I. Such a steep drop in tariffs, that too within a short of one year, augurs well for the Indian solar industry and may to some extent be attributed to the adaptive policy framework.

JNNSM thrust towards R&D Initiatives-Development of CSP demonstration projects

Further, JNNSM envisages development of pilot projects of those solar technologies which are not commercially proven. Also, these Pilot demonstration projects are closely aligned with the Mission's R & D priorities and designed to promote technology development and cost reduction. The Mission, therefore, envisages the setting up of the following demonstration projects in Phase I, in addition to those already initiated by MNRE and those, which may be set up by corporate investors:

- 50-100 MW Solar thermal plant with 4-6 hours' storage (which can meet both morning and evening peak loads and double plant load factor up to 40%).
- A 100-MW capacity parabolic trough technology based solar thermal plant.
- A 100-150 MW Solar hybrid plant with coal, gas or bio-mass to address variability and space-constraints.
- 20-50 MW solar plants with/without storage, based on central receiver technology with molten salt/steam as the working fluid and other emerging technologies.

It is further contemplated that such pilot demonstration projects would be allocated to the interested developers who would be showcasing the adequate 'financial and technical' criteria. Further, it is envisaged that 'Generation based Incentive' would be provided to such projects. This initiative would be in the line of Government of India's previous initiative of providing GBI benefits to develop 50MW of solar projects during 2009-10.

[1] EQ International Magazine : www.eqmqglive.com

CERC RE Tariff Regulations -Salient Features

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 61and section 178(2) of the Electricity Act, 2003 had notified the CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources), Regulations, 2012. Applicability of these regulations shall be confined to Central Sector and Inter State Generation projects, however, under Section 61 of EA 2003; these regulations would be guiding principles for State Electricity Regulatory Commissions while dealing with the matters related to energy generation from RE sources. The salient features of the Tariff Regulations applicable for the Solar Projects are as follows:

Salient Features of Tariff Regulations for Solar Energy Projects

Solar PV and Solar Thermal Projects – Based on technologies approved by MNRE	
General Principles	
Resolution	**Provisions in Regulation**
Control Period	Five (5) years
Tariff Period	Solar PV and Solar Thermal Projects – 25 years
Tariff Structure	Single Part Tariff- Fixed components shall be: • Return on Equity • Interest on loan capital • Depreciation • Interest on working capital • Operation and maintenance expense
Tariff Design	The generic tariff shall be on levelised basis for the Tariff Period
Dispatch Principles	a. All plant with installed capacity of 10MW and above shall be treated as 'MUST RUN' power plants and shall not be subjected to 'MOD'
Financial Principles	
Capital Cost	Benchmark Capital Cost for Solar PV and Solar Thermal Projects shall be reviewed annually
Discounting Factor	Weighted Average of Cost of Capital
Debt Equity Ratio	70:30
Loan and Finance Charges	Loan Tenure – 12 years
Interest Rate	a. Average long term prime lending rate (LTPLR) of SBI prevalent during the first six months plus 300 basis points. b. Repayment of loan shall be considered from the first year of COD
Return on Equity	Pre - Tax 20% for first ten years and Pre - Tax24% from eleventh year onward till useful life
Depreciation	a. Value base shall be Capital cost of the asset b. 5.83% for the first twelve years and the rate of depreciation from the 13th year onwards has been spread over useful life
Interest on Working Capital	a. O&M for 1 month b. Receivables for 2 months of energy charge on normative CUF

	c. Maintenance spare @ 15% of O&M expense
Operation and Maintenance Expense	R&M expense + A&G expense + Employee expense Escalated at 5.72% per annum over first year of control period
Rebate	For payment of bills through letter of credit, a rebate of 2% shall be allowed Payments made other than through letter of credit within 1 month of presentation of bills by the generating company, a rebate of 1% will be allowed
Late payment surcharge	Delay beyond the period of 60 days from the date of billing attracts late payment surcharge of 1.25% per month
Sharing of CDM benefits	100% of the gross proceeds to be retained by the developer in the first year In second year, the share of beneficiaries shall be 10% which shall be progressively increased by 10% every year until it reaches 50%, where after the proceeds shall be shared in equal proportion, by generating company and the beneficiaries
Subsidy or incentive	Accelerated depreciation or generation based incentive shall be factored in while determining the tariff
Taxes and duties	Taxes and duties shall be passing through on actual incurred basis.

The RE Tariff Regulations specifies that the benchmark capital cost norm for Solar Power projects shall be reviewed annually. Accordingly, the Commission has specified the benchmark capital cost norm for Solar PV and Solar Thermal projects as Rs. 1000lakh/MW and Rs.1300lakh/MW respectively for 2012-13.

Keeping into consideration the benchmark capital cost norm and other norms specified by CERC, the tariff applicable for Solar PV and Thermal Projects commissioned during 2012-13 stands as Rs. 10.39/kWh and Rs. 12.46/kWh respectively.

CERC IEGC Regulations, 2010 - Analysis of the specific provision

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 79(1) (h) and section 178(2) (g) of the Electricity Act, 2003 had notified the CERC (Indian Electricity Grid Code), Regulations, 2010. This code will be applicable to NLDC, RLDC/SLDCs, ISGS, and Distribution Licensees/SEBs/STUs/regional entities, Power Exchanges and Wind and Solar Generating Stations.

In order to encourage the solar based generation into the electricity grid, the IEGC has given due consideration for such segment. The Grid Code provides that in case the generation from solar power project deviates from the schedule the financial burden shall be borne by all the users of the Inter-State Grid, instead of the concerned solar project developer. The IEGC provides the methodology for rescheduling of solar energy on three (3) hours and the methodology of compensating the solar energy rich state for dealing with variable generation through Renewable Regulatory Charge. In pursuance of this, appropriate meters and data acquisition systems facility shall be provided for accounting of UI charges and transfer of information to SLDC and RLDC. The provisions of the IEGC shall be applicable from January 1, 2011, for new solar generating plants with capacity of 5MW and above connected to 33kV and above who have not signed any PPA with States or others. Some of the key and enabling provisions for solar energy in IEGC are as below,

Provision for Solar Energy under IEGC

Provisions in IEGC,2010	Description
Special conditions for solar (Reg 5.2(u):System security Aspects	• System Operator (SLDC/RLDC) shall make all efforts to evaluate the solar and wind power and treat as a '**Must Run'** Plant. • System Operator may instruct the solar generator to back down generation on consideration of grid security or safety of any equipment or personnel is endangered and solar generator shall comply with same. • For this, data acquisition system facility shall be provided for transfer of information to concerned SLDC and RLDC.
Scheduling of Solar Power (Reg. 6.5(23)(i))	• Schedule of the Solar generation shall be given by generator based on the availability of the generator, weather forecasting, solar insolation, season and normal generation curve and shall be vetted by RLDC and incorporated in inter-state schedule. • If the RLDC is of opinion that the schedule is not realistic, it may ask the solar generator to modify the schedule
Implications of Scheduling	• In case of solar generation no UI shall be payable/receivable by the generator for any deviation in actual generation fro schedule. • The host state shall bear the UI charges for deviation in the actual generation from schedule. • The net UI charges borne by the host state due to solar generation, shall be shared among all the states of the country in ration of their peak demands in previous month based on the data published by CEA, in form of regulatory charge known as Renewable Regulatory Charge operated through the Renewable Regulatory Fund. • The provision shall be applicable, with effect from 1.1.2011 for new solar generating plants with capacity of 5MW and above and connected at 33Kv level and above and who have not signed PPA with states or others as on date of coming into force of this IEGC.

CERC Initiative for Transmission/Evacuation of Solar Power

Under the mandate of statutory provisions of Section 61 of the Electricity Act, 2003 inter-alia para 5.3.4 and para 7.2(1) of the National Electricity Policy and Tariff Policy respectively, Central Electricity Regulatory Commission (CERC) has undertaken the exercise to frame regulations on sharing of transmission charges and losses among the users.

The regulations facilitate the solar based generation by allowing zero transmission access charges for the use of the Inter State Transmission System and allocating no transmission loss to the solar based generation. Solar power generators shall be benefited in event of use of the ISTS. Since such generation would normally be connected at 33 kV, the power generated by such generators would most likely be absorbed locally. This would cause no / minimal use of 400 kV ISTS network and might also lead to reduction of losses in the 400 kV network by doing away the need for power from distant generators. The cost of energy from solar based generation is perceived to be costly as compared to other sources, including renewable energy sources, and further application of ISTS charges and losses would further reduce the acceptability of power generated from solar sources. This regulation thus encourages solar based generation and inter-state transactions based on solar energy.

State Level Initiatives and Development Targets

Spurred by national level initiatives and policy push, several states like Gujarat, Rajasthan, Madhya Pradesh, Karnataka and Jammu & Kashmir have also formulated and adopted solar policies for development of solar energy projects in their respective states. Salient Features of these policies have been discussed herewith.

Gujarat

- Gujarat, among all the other states, has taken the lead and already allotted projects worth a cumulative capacity of 716 MW to 34 national and international project developers against the declared 500 MW in their policy. Of the 716 MW, 365 MW has been allocated to Solar PV and the remaining 351 MW to Solar Thermal Power plants.

- Major players in the state include AES Solar, Astonfield Solar, Azure Power Ltd. with allotments ranging from 5 to 50 MW.

Rajasthan (Draft)

- Rajasthan has set a target of developing 10,000-12,000MW solar power capacity in the next 10-12 years.

- It has been mandated that 200MW of solar power shall be developed till 2012-13 and an additional 400MW power shall be developed between 2014 and 2017. The State also plans to develop 1000MW of solar parks

Madhya Pradesh (Draft)

- Madhya Pradesh targets a total solar power capacity development of 500MW.

- The facility of wheeling solar power, exemption of open access charges and electricity duty shall be extended to developers and distributors

- Power evacuation facility shall also be extended to concerned licensees.

Jammu & Kashmir

- Under this policy, prior weightages to be given to financial capacity, technical capability, past experience and other relevant attributes of the applicants, the sub-categories of these attributes to be evaluated and their inter-se weightage, the guidelines for evaluation and the passing score on attributes /in aggregate required for pre-qualification shall be specified in the bid documents inviting bids for pre-qualification.

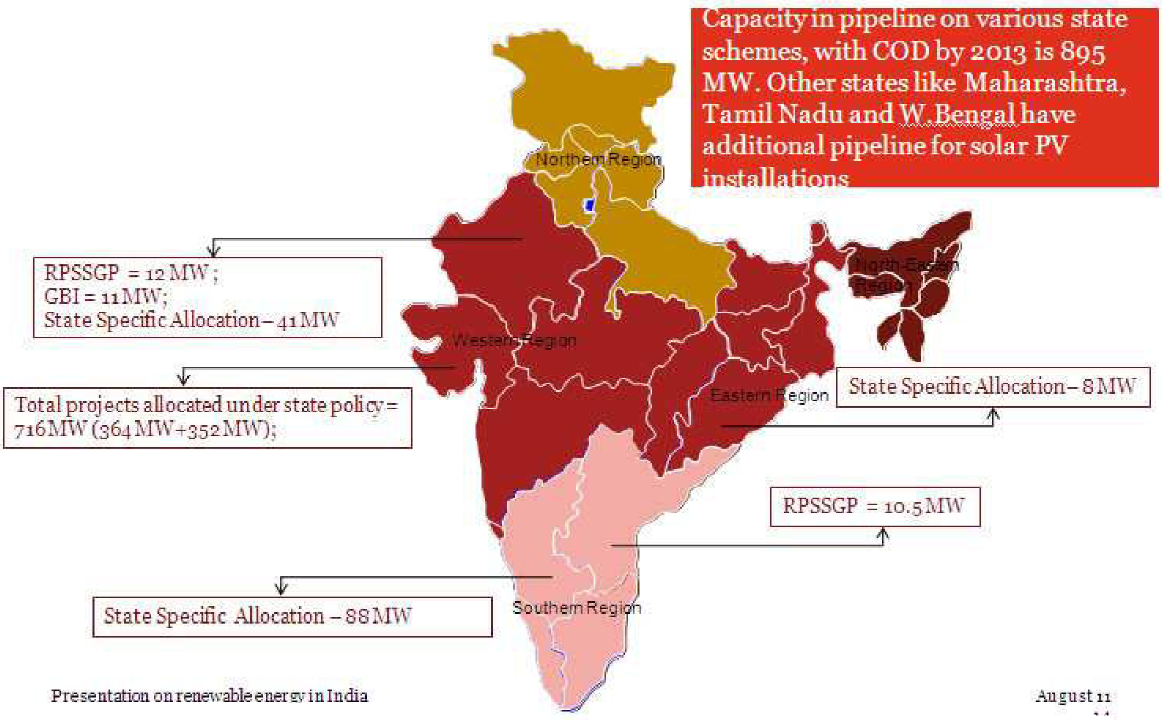
- The minimum project capacity shall be 1 MW. However, if MNRE launches any scheme for lower capacity power plant then that shall also be considered.

Karnataka

- Karnataka targets a total solar power capacity development of targeting capacity addition in solar power projects by 350 megawatts by 2016.

- The solar PV projects that plan to sell their electricity to state utilities at preferential tariff have to have a capacity of between three and 10 MW.

- To keep the costs lower, policy allows developers to inject power at 11kV and above.



Solar Thermal Technology- An Introduction

Concentrating solar power (CSP) plants produce electricity by converting the infrared part of solar radiation into high temperature heat using various mirror/reflector and receiver configurations. The heat is then channelled through a conventional generator. The plants consist of two parts: one that collects solar energy and converts it to heat, commonly known as 'solar field' and another that converts heat energy to electricity, known as 'power block'.

CSP plants use the high-temperature heat from concentrating solar collectors to drive conventional types of engines turbines. For power generation, temperatures more than 200 °C are preferred. All CSP are based on four basic essential sub systems namely collector, receiver (absorber), transport/ storage and power conversion.In solar collectors of such systems, the incoming radiation is tracked by mirror fields/lenses which concentrate the energy towards absorbers. The absorbers receive the concentrated radiation and transfer it thermally to the working medium, hereby transferring the heat energy to it. The heated fluid may reach high temperatures and may be used for driving the turbine to generate power. The heat carrier in these systems can be oil, molten salts, pressurized water or steam.

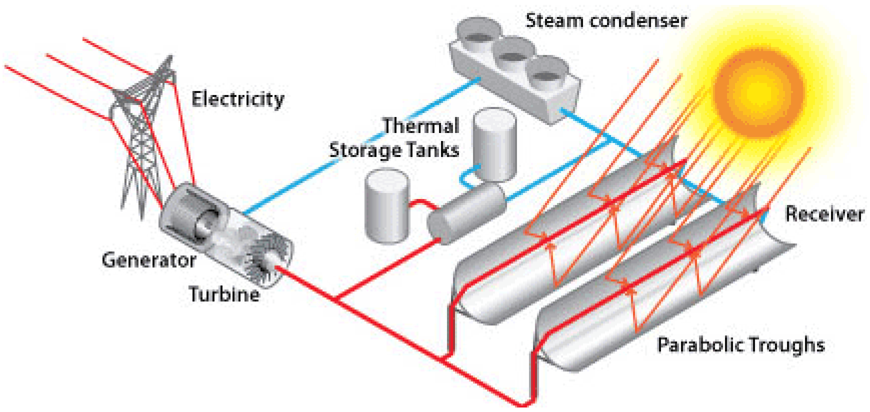
Different concentrating technologies have been developed or are currently under development for various commercial and Industrial applications as well as power generation. Such solar thermal concentrating systems can significantly contribute to efficient and economical, renewable and clean energy supply.

Following four CSP technologies have either reached commercialisation stage or are near it:

- Parabolic Trough
- Power towers
- Parabolic Dishes (Dish-Stirling)
- Compound Linear Fresnel Reflectors (CLFR)

Parabolic Trough

The parabolic-trough solar concentrators are one of the basic elements of a concentrating solar power plant. The main elements of the plant based on the parabolic trough technology are: the solar field, the storage system, the steam generator and the auxiliary systems for starting and controlling the plant.



(Source: NREL)

Several collector elements of the solar field are composed in series to create the single collector line. The collected thermal energy is determined by the total number of collector elements which are characterized by a reflecting parabolic section (the concentrator), collecting and continuously concentrating the direct solar radiation by means of a sun-tracking control system to a linear receiver located on the focus of the parabolas. Parabola has the property of focussing the incoming radiation as its focus. Working on this principle, linear concentrators of parabolic shape are usually mirrors or highly reflective surfaces and can be turned in angular movements towards the sun position and concentrate the incoming solar radiation onto a long-line receiving absorber tube. The mirror is anchored at four points to the steel structure. The mirrors, mountings and adhesives all have the same expansion coefficient, guaranteeing durability even under extreme temperature fluctuations. The mounting elements are made from special ceramics giving them a high level of mechanical strength and are non-corrosive. The absorber pipe is composed of a multi-layered stainless-steel pipe, with an absorption level of around 95% and radiation level of approximately 14% of its heat at temperatures of around 400 degrees Celsius. The steel pipe is surrounded by a vacuum-isolated concentric borosilicate glass cladding tube with anti-reflective coating, which allows for over 96% penetration of solar radiation.

A heat transfer fluid, circulating in the pipe, is used to transfer the absorbed solar energy, which is then piped to an exchanger or a conventional conversion system. 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. Parabolic trough systems cannot make use of diffuse irradiation as they use only direct-beam sunlight and require tracking systems to keep them focused toward the sun and are best suited to areas with high direct solar radiation. Most systems are oriented north-south with single-axis tracking during the day. The integration of heat storage allows the power plant to function at full capacity both on overcast days and at night

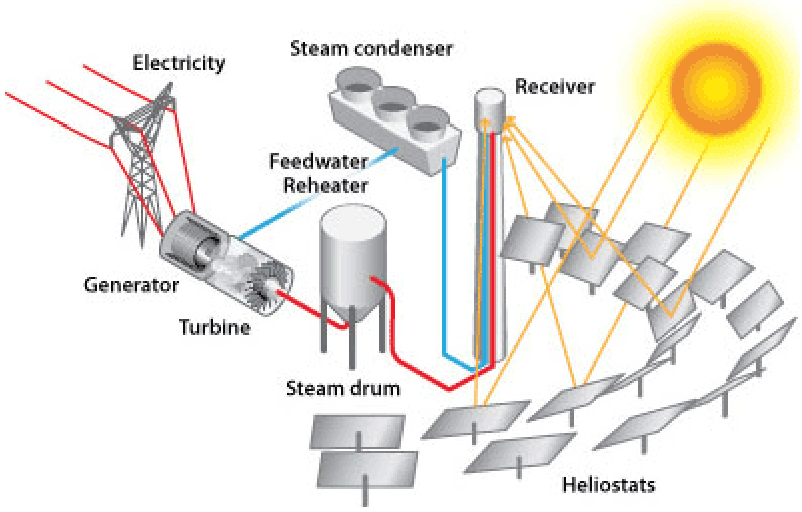
Storage system is the integral and an important part of the parabolic trough based power plants. Thermal Energy Storage (TES) option can collect energy in order to shift its use to later times. Hence, the functional operativeness of a solar thermal power plant can be extended beyond periods of no solar radiation without the need of burning fossil fuel. The most advanced technology for heat storage in trough collector plants considers the use of a two-tank molten salt system which functions like a thermos flask and are able to assure that the salt maintains its temperature and decrease the thermal losses. The used power conversion systems are based on the conventional Rankine-cycle steam turbine generator.

Several Parabolic trough based power generation plants are in operation. SEGS, California is a collection of 9 plants with a combined capacity of 350 MW. Nevada Solar, completed in 2007 has a capacity of 64MW. Andasol, Spain has 4 power plants with a combined capacity of 50MW.

Solar Tower (Central Receiver Systems)

Central receiver systems use heliostats to track the sun by two axes mechanisms following the azimuth and elevation angles with the purpose to reflect the sunlight from many heliostats oriented around a tower and concentrate it towards a central receiver situated atop the tower. A heat-transfer medium is employed in the central receivers to absorb the highly concentrated radiation reflected by the heliostats and converts it into thermal energy, which is used to generate superheated steam for the turbine.

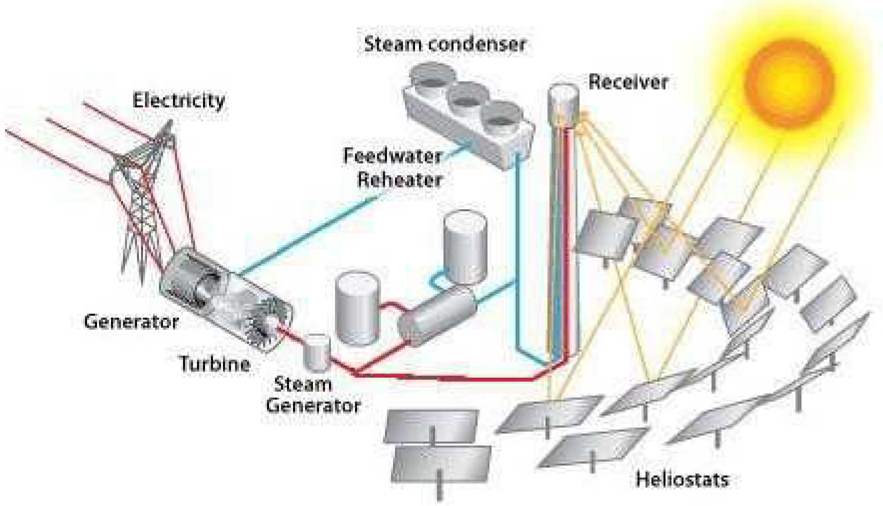
This technology has the advantage of transferring solar energy very efficiently by optical means and of delivering highly concentrated sunlight to one central receiver unit, serving as energy input to the power conversion system. In spite of the elegant design concept and in spite of the future prospects of high concentration and high efficiencies, the central receiver technology needs still more research and development efforts and demonstration of up-scaled plant operation to come up to commercial use in Indian conditions. Its main attraction is the prospect of achieving higher process temperatures than other CSP technologies, by concentrating solar irradiation to supply energy to the topping cycle of any power conversion system. This technology can also increase the efficiency of energy storage systems.



(Source: NREL)

Different receiver heat transfer media that have been successfully used are water/steam, liquid sodium, molten salt, ambient air, oil. To date, the heat transfer media demonstrated include water/steam, molten salts and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to have an early energy conversion cycle as in a combined cycle power plant, increasing the global efficiency.

The diagram above illustrates the layout of a central receiver based CSP plant with direct steam production and steam drum storage. A more efficient approach is using molten salt as the heat transfer fluid and for storage. Liquid salt, after absorbing heat through the receiver can withstand and effectively transfer heat at temperature range 200ºC - 700ºC and can be stored for use during night. Hot salt can be pumped to a steam generating system that produces superheated steam through conventional Rankine cycle. Storage tanks can be designed with sufficient capacity to power a turbine at full output for up to 13 hours. The process layout for solar tower with storage is shown below:



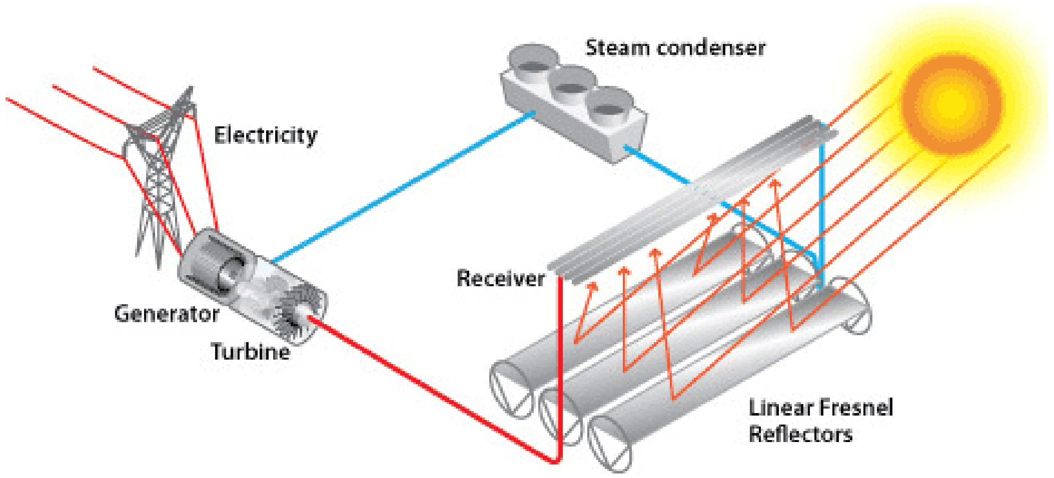
Heliostats that track the sun and reflect the rays to the absorber are to be designed and laid out carefully to optimize the annual performance of the plant. The energy collection in the tower is directly proportional to the heliostat field which is in turn determined by the number of heliostats and their area. The project has to be designed such that steam requirement of the turbine is fulfilled and there is enough energy left to consequently charge the thermal storage system for power production during non sunny weather. Future solar tower plants have the good long-term perspective for high conversion efficiencies and for use of very efficient energy storage systems by utilization of high temperatures in order to enlarge the solar capacity or solar share.

In 2008, a 4-6 MW a solar power plant came up in Israel's Negev Desert. The site features more than 1,600 heliostats that track the sun and reflect light onto a 60 meter-high tower. The concentrated energy is then used to heat a boiler atop the tower to 550 °C, generating superheated steam. A working tower power plant is PS10 in Spain with a capacity of 11 MW; composed of 624 heliostats and a field area of 75,000 m², concentrating the radiation onto a receiver located on tower that is 115 m tall. Subsequently, PS20 was also build with thermal storage to boost power production under non-sunny conditions. The PS20 solar field has 1,255 heliostats and tower of 160 m.

The 15MW Solar Tres plant with heat storage is under construction in Spain. A 10MW power plant in Cloncurry, Australia uses Graphite for heat storage. Morocco is building five solar thermal power plants. The sites will produce about 2000 MW by 2012.

Linear Fresnel

The Linear Fresnel technology uses long, flat or slightly curved mirrors to focus sunlight onto a linear receiver located at a common focal point of the reflectors. The receiver runs parallel to and above the reflectors and collects the heat to boil water in the tubes, generating high-pressure steam to power the steam turbine (water/direct steam generation, no need for heat exchangers). The heat thus generated is then channelled through a conventional steam generator to generate electricity.



(Source: NREL)

The reflectors make use of the Fresnel lens effect, which allows for a concentrating mirror with a large aperture and short focal length. This reduces the plant costs since sagged-glass parabolic reflectors are typically much more expensive. The collector field comprises mirrors in parallel rows aligned on a north-south axis which enables the single-axis mirrors to track the sun from east-west direction to ensure that the sun is continuously focused on the receiver pipes/absorber tubes. The amount of power generated by the Linear Fresnel plant depends on the amount of direct sunlight and these technologies use only direct-beam sunlight, rather than global horizontal irradiation. The plant configuration and the layout depends on the project developer but initial installations had mirrors having a width of 0.5 m, arranged in rows and focusing the rays on a fixed receiver tube, along the length of the mirrors.

Since the optical efficiency as well as the working temperatures are considerably lower than with other CSP concepts, saturated steam conditions are mostly considered for this technology. Alternatively, heat could be stored in high-temperature storage mediums and superheated to ultimately drive steam turbines, thus providing greater efficiencies. The receiver is stationary and so fluid couplings are not required (as in troughs and dishes). The mirrors also do not need to support the receiver, so they are structurally simpler. When suitable aiming strategies are used (mirrors aimed at different receivers at different times of day), this can allow a denser packing of mirrors on available land area.

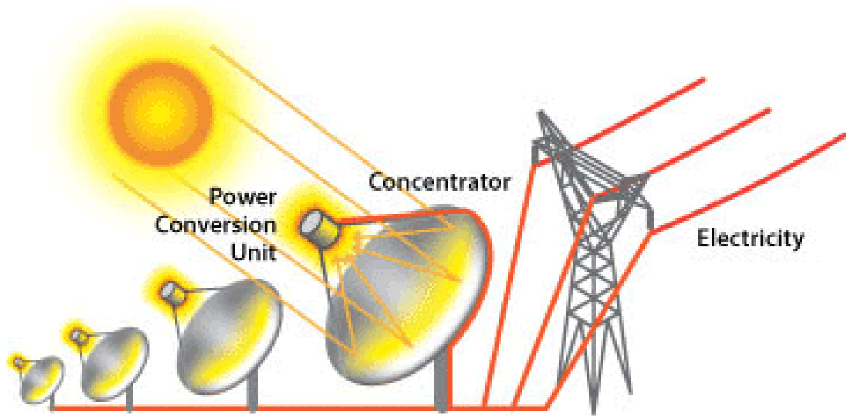
Linear Fresnel plants can also be "hybrids," and can supplement the solar output during periods of low solar radiation and in night through fossil fuels, normally with a natural gas-fired heat or a gas steam boiler. CLFR can also be integrated with existing coal-fired plants.

Unlike other CSP technologies, the material requirements for CLFR are very simple and the structure is lighter, leading to reduced setup costs and operational costs. Also, the mirrors are packed closer, have simpler tracking system, and are less affected by higher wind speeds and rain. Fresnel mirrors are simple, cheaper and lighter than parabolic trough mirrors, leading to a simplified plant design compared to other CSP technologies. Major CLFR Project developers include AREVA Solar (Ausra), Novatec Solar, SPG etc. In 2008, the German Solar Power Group GmbH started execution of a solar thermal power plant in central Spain, the first commercial solar thermal power plant in Spain based on the Fresnel collector technology. The planned size of the power plant will be 10 MW.

Since 2009, the Fresnel solar power plant of Novatec Biosol is in commercial operation in southern Spain. The solar thermal power plant is based on linear Fresnel collector technology where the absorber tube is positioned in the focal line of the mirror field in which water is evaporated directly into saturated steam at 270 °C and at a pressure of 55 bar by the concentrated solar energy. Ausra has finished construction of the 5 MW Kimberlina Solar Thermal Energy plant in Bakersfield, California and also built a linear fresnel reflector plant in New South Wales, Australia to supplement a coal fired plant.

Parabolic Dish Systems

Dish/engine systems convert the thermal energy in solar radiation to mechanical energy and then to electrical energy in much the same way that conventional power plants convert thermal energy from combustion of a fossil fuel to electricity. A paraboloid dish-shaped reflector (commonly called as parabolic dish) concentrates sunlight on to a receiver located at the focal point of the dish. Dish systems use these parabolic reflectors to focus the sun's rays onto a dish-mounted receiver at its focal point. This requires that the dish track the sun in two axes. In the receiver, a heat-transfer medium takes over the solar energy and transfers it to the power conversion system, which may be mounted in one unit together with the receiver (e. g. receiver/Stirling engine generator unit) or at the ground. Due to its ideal optical parabolic configuration and its two axes control for tracking the sun, dish collectors achieve the highest solar flux concentration, and therefore the highest performance of all concentrator types in terms of peak solar concentration and of system efficiency.



(Source: NREL)

Dish systems may optionally be arranged in large dish arrays in order to accumulate the power output from the kWe capacity up to the MWe range. The power conversion subsystem of dish systems is mainly based on the Stirling engine generator system, but also on the water/steam powered turbine or piston engine generator system or on the gas turbine generator system.

Dish/engine systems utilize concentrating solar collectors that track the sun in two axes. A mirror or a reflective surface reflects incident solar radiation to a small region called the focus. The size of the solar concentrator for dish/engine systems is determined by the engine. At a nominal maximum direct normal solar insolation of 1000 W/m^2, a 25-kW dish/Stirling system's concentrator has a diameter of approximately 10 meters. The most durable reflective surfaces have been silver/glass mirrors, similar to decorative mirrors used in the home. Attempts to develop low-cost reflective polymer films have had limited success. Because dish concentrators have short focal lengths, relatively thin glass mirrors (thickness of approximately 1 mm) are required to accommodate the required curvatures. In addition, glass with a low-iron content is desirable to improve reflectance. Depending on the thickness and iron content, silvered solar mirrors have solar reflectance values in the range of 90 to 94%.

The ideal concentrator shape is a paraboloid of revolution. Some solar concentrators approximate this shape with multiple, spherically-shaped mirrors supported with a truss structure. An innovation in solar concentrator design is the use of stretched-membranes in which a thin reflective membrane is stretched across a rim or hoop.

Dish system also utilise receivers which absorbs energy reflected by the concentrator and transfers it to the engine's working fluid. The absorbing surface is usually placed behind the focus of the concentrator to reduce the flux intensity incident on it. Stirling engine receivers are the most commonly used engine receivers where the concentrated solar energy is transferred to a high-pressure oscillating gas, usually helium or hydrogen. Generally there are two types of Stirling receivers, direct-illumination receivers (DIR) and indirect receivers where intermediate heat-transfer fluid is being used. Directly-illuminated Stirling receivers adapt the heater tubes of the Stirling engine to absorb the concentrated solar flux. Because of the high heat transfer capability of high-velocity, high-pressure helium or hydrogen; direct-illumination receivers are capable of absorbing high levels of solar flux.

The engine employed in the dish system converts heat to mechanical power in a manner similar to conventional engines, that is by compressing a working fluid when it is cold, heating the compressed working fluid, and then expanding it through a turbine or with a piston to produce work. The mechanical power is converted to electrical power by an electric generator or alternator. A number of thermodynamic cycles and working fluids have been considered for dish/engine systems. These include Rankine cycles, using water or an organic working fluid; Brayton, both open and closed cycles; and Stirling cycles.

Dish systems with supplementary combustion of fossil fuels integrated into the receiver component are a better solution for Industries as solar energy is not available 24 hours a day, even with thermal storage. Such systems are currently under development and are expected to be available for first demonstration projects in the near-term run.

Dish/engine systems are characterized by high efficiency, modularity, autonomous operation, and an inherent hybrid capability (the ability to operate on either solar energy or a fossil fuel, or both). Of all solar technologies, dish/engine systems have demonstrated the highest solar-to-electric conversion efficiency. The modularity of dish/engine systems allows them to be deployed individually for remote applications, or grouped together for small-grid (village power) or end-of-line utility applications.

In January 2010, Stirling Energy Systems commissioned a 1.5-megawatt power plant using Stirling technology in Peoria, Arizona.

Comparison of various CSP technologies

	Parabolic trough	Solar Dish	Solar Tower	Linear Fresnel
Working Temp.	150- 600 °C	Upto 1000 °C	Upto 1000 °C	Upto 400 °C
Conversion Efficiency	Around 20 %	Around 30 %	Around 20-25 %	Around 15-20 %
Concentration ratio	10-100	1000-4000	600-1000	10-100
Storage	Possible	Not possible	Possible	Possible
Area required (Acre/MW)	7-8	7-10	8-12	4-5
Commercial status	Commercial	Some pilot projects in the country	Only prototypes under Demo	Pre-commercial
Thermodynamic power cycle	Rankine	Stirling, Brayton	Brayton, Rankine	Rankine
Tracking	Single axis	Double axis	Double axis	Single axis
Advantages	Long-term proven reliability and durability	High temperature allows high efficiency of power cycle	High temperature allows high efficiency of power cycle	Simplified plant design, lower investment and operational costs
	Storage options available	High tolerance of variation in land slope	Tolerates non-flat sites	Tolerance for slight slopes, modularity in system
	Direct steam generation proven	High Modularity	Possibility of combined power cycles	Direct steam generation proven
	Highest number of commercial installations	High efficiency	Ability to provide high-temperature steam, higher generation efficiencies	minimized structural costs, low wind loads, and lower maintenance costs
	Better R&D experience; hybridization and storage optional	Great modular system; hybridization is optional	High conversion efficiency; storage and hybridization option	Small operation experience; storage and hybridization option
Disadvantages	Limited temperature of heat transfer fluid hampering efficiency and effectiveness	Not commercially proven in India	High maintenance and equipment costs	Storage for direct steam generating systems (phase change material) in very early stage
	Complex structure, high precision required during construction	High complexity compared to stand-alone PV	High land requirements	Larger area requirement cannot be placed close to process setup.
	Requires flat land area			Low efficiency

The above sections provide insight about the salient features of the CSP technology required for generating power. It needs pertinent mentioning some of the components, sub-systems used in all the aforementioned technologies are common in nature and play an important role in the functioning of the systems. Some of the typical components of the CSP plant which have a common bearing with all the technologies are as follows:

<table>
<tr><th colspan="4">CSP Plant</th></tr>
<tr><th colspan="2">Solar Block</th><th rowspan="2">Power Block</th><th rowspan="2">Balance of Plant (BOP)</th></tr>
<tr><th>Solar Field</th><th>Thermal Storage</th></tr>
<tr><td>• Receiver
• Reflecting Panels
(Heliostats, mirrors)
• Tracking System
• Heat transfer fluid
(Water, oil, salt, air)
• Hydraulic drive
• Supporting structures
• Civil Works</td><td>• Storage medium
✓ Molten salts
✓ Metals
✓ Ceramic/porcelain
• Circulation pump
• Storage tanks
• Insulation</td><td>• Steam Generator
• Turbine
• Power Generator
• Condensers
• Transformer
• Cooling Tower</td><td>• Pipes
• Electric cables
• Pressure Vessels
• Water tanks</td></tr>
</table>

Solar field is not particular to any project. Typically in all technologies solar field is made of:

- Receiver: Receivers are either made of evacuated tubes, normal steel pipes or special cavities. The receiver tube has the co-axial structure made of external glass tube and concentric steel tube where heat transfer fluid flows. Coating on the steel tube ensures maximum absorption of the solar light spectrum with maximum re-emission by the hot tube surface. Vacuum stability in the room between glass and the steel tube is guaranteed by getter material stratified on the glass surface.
- Heliostats, mirrors and reflecting surfaces: Parabolic troughs, Fresnel mirrors, heliostats or parabolic dishes all are mirror based. The mirrors are either curved or flat and either glass-silver or high-reflectivity aluminium surfaces. A heliostat usually uses a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky. In the heliostat reflective surface of the heliostat is kept perpendicular to the bisector of the angle between the directions of the sun and the target as seen from the mirror. In almost every case, the target is stationary relative to the heliostat, so the light is reflected in a fixed direction. Heliostats are essentially distinguished from solar trackers or sun-trackers that point directly at the sun in the sky. However, some older types of heliostat incorporate solar trackers, together with additional components to bisect the sun-mirror-target angle. A conventional design for the heliostat's reflective components utilizes a second surface mirror. The sandwich-like mirror structure generally consists of a steel structural support, an adhesive layer, a protective copper layer, a layer of reflective silver, and a top layer of tempered float glass. Conventional heliostat is often referred to as a glass/metal heliostat. Alternative designs incorporate recent adhesive, composite, and thin film research to bring about materials costs and weight reduction.
- Tracking System: A solar tracker is a kind of device that exhibits the property of orienting various payloads toward the sun. Payloads can be any type of optical devices. The primary benefit of a tracking system is to collect solar energy for the longest period of the day, and with the most accurate alignment as the Sun's position shifts with the seasons. In addition, the greater the level of concentration employed the more important accurate tracking becomes, because the proportion of energy derived from direct radiation is higher, and the region where that concentrated energy is focused becomes smaller. Generally the tracking system can be classified as the single axis tracking system and the double axis tracking system. Single axis trackers have one degree of freedom that acts as an axis of rotation. Single axis system can be aligned in any direction with advanced tracking algorithms. There are several common implementations of single axis trackers. These include horizontal single axis trackers (HSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT). Dual axis trackers have the flexibility for two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis. Dual axis systems are classified by the orientation of their primary

axes with respect to the ground. Two common implementations are tip-tilt dual axis trackers (TTDAT) and azimuth-altitude dual axis trackers (AADAT).

- Heat Transfer fluid: HTF are usually artificial oils with altered boiling and/or freezing points, water - deaerated – air, gases and molten salts – phase changing materials that become liquid when heated. Traditionally mineral oil is being used as the heat transfer fuel which is also inflammable and toxic in nature. This type of heat transfer fluid has low specific heat and temperature restrictions to operate which further limits the operating temperature of the plant. Molten salt as the heat transfer fluid is specially formulated for solar applications that demand the optimum purity and performance. It has superior heat transfer compared to other fluids in its class. It also exhibits high thermal stability but however it has high freezing point rendering it difficult to operate it at regions with high ambient temperature. Improved heat transfer efficiency reduces a system's total energy requirements, and increases system longevity. The more efficient the heat transfer system is, the less energy that is required to maintain the bulk operating temperature of the fluid.
- Hydraulic Drives: Collector units of the solar field has its own solar sensors and the hydraulic drives which enables the mirrors to track the position of the sun and also allows the collector unit to track the sun along with its changing path. The hydraulic drives can adjust the 150 meter long collector chains with a precision of up to a tenth of millimeter allowing them to follow the sun on its daily course from east to west along a single axis.

Thermal storage section constitutes the important section of the CSP based power projects. Storage system can allow the operation of the plants to take place on the continuous and regular basis. Moreover, it also helps in increasing the operational temperature of the plant and thereby contributing towards enhancement of operational efficiency of the power plant. Important constituents of the storage section are as follows:

- Heat storage systems/tanks: Thermal Energy Storage (TES) option can collect energy in order to shift its use to later times, or to smooth out the plant output during irregularly cloudy weather conditions. Hence, the functional cooperativeness of a solar thermal power plant can be extended beyond periods of no solar radiation without the need of burning fossil fuel. Periods of mismatch among energy supplied by the sun and energy demand can be reduced. Concrete based heat storage systems are the most effective heat storage systems in the operation.

  Generally the Thermal Storage System is largely composed of two tanks, the cold tank that contains the storage medium at lower temperature and the hot tank that contains the storage medium at a higher temperature. Other components of the heat storage system are:
  - ✓ Storage medium inventory;
  - ✓ circulation pumps;
  - ✓ Piping.

  In presence of direct solar radiation the medium is pumped out from the cold tank to circulate in the solar field and is finally heated up to a higher temperature to be accumulated in the hot tank. When steam production is requested a medium flow is taken from the hot tank, circulated through the steam generator and finally re-collected in the cold tank.

- Storage medium: Storage of the heat on the short term basis can be provided by the fire-bricks, ceramic oxides, fused salts which melts at higher temperature Hitech, a fused salt mixture which is stable upto 540 °C is also identified as the promising energy storage medium. Current work is also carried by rocks, eutectic salts, and some synthetic organic materials of low pressure such as Gilotherm. For choosing a conventional storage material, its energy density, thermal conductivity, corrosion characteristics, cost and convenience to use as well as operating temperature of the fluid is diagnosed. The storage space must be also well insulated against heat losses.

Rationale for site selection for CSP projects

In order to select the optimal sites for the CSP demo projects, the Ministry of New and Renewable Energy (MNRE) sent invitations to states and asked for recommendations for the projects. The recommendations were based on meeting site requirements for two categories of CSP projects. The first category contained 3 of the 7 projects which had specific requirements which could be met only at specific sites, and the second category contained the remaining 4 of 7 projects which had no site specific requirements and could be located anywhere. The following table lists these two types of projects.

Site Specific Projects	Non-site Specific Projects
CSP project with storage (>= 10 hours)	CSP project with biomass support (Solar >= 60%)
CSP project with high operating temperature (>=500°C)	CSP project with gas support (Gas usage <= 30%)
CSP project with hybrid cooling (water <= 30%)	CSP project augmenting a coal fired power plant
	CSP project using Stirling Engines

MNRE laid out a detailed information template that had to be filled out for each recommended site. These requirements included parameters like status of land ownership, power evacuation facilities, water and road availability and geographical parameters like average ambient temperature, humidity, rainfall, endemic flora and fauna etc.

In response to MNRE's invitation of recommendations, 5 states – Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh and Karnataka - responded with potential locations along with the information described above. Based on this data, MNRE conducted a short-listing exercise to select the final candidate sites for the projects. This short listing was based on a quantitative scoring scale with specific points being assigned to specific site-attributes, as described below.

#	Site Attribute	Evaluation Criteria
1	Power evacuation	Not constructed = excluded; constructed/under construction = 5 points
2	GSS Type	no 110 KV or 132 KV GSS = excluded; otherwise: 5 points
3	Distance to the site	less than 1 km = 5 points <10 km = 4 points <20 km = 3 points and so forth with >50 km = 0 points

4	Water availability	Not available = excluded;
		with limitations = 2 points;
		no limitations = 5 points;

5	Acquired land	acquired = 5 points;
		under acquisition = 3 points;
		not acquired/to be acquired = 0 points

6	Area	less than 50 hectares = excluded; largest area: 5 points (all the rest proportionally scored)
7	Access to the site	no access = excluded; otherwise = 5 points
8	Populations nearby	< 1000 = 5 points; < 2000 = 4 points and so forth with < 50000 = 1 point
9	DNI	less than 5 KWh/m2 = excluded; highest DNI = 5 points (all the rest proportionally scored)
10	Solar Park	in existing/construction Solar Park = 5 points; in solar park being planned = 3 points

Based on this scoring metric, the following table shows the final candidate sites.

State	Proposed Location	Included	Reasons for exclusion
Rajasthan	Bhadla	Yes	Ok*
Rajasthan	Mathnia		no water
Rajasthan	Ramgarh		small size
Gujarat	Harshad		not ready
Gujarat	Charanka	Yes	Ok
Tamil Nadu	Kulathur		land issues
Tamil Nadu	Terkuveerapandiyapuram	Yes	Ok
AP	Gadwal		big boulders
AP	Ramagundam		not ready
AP	Nennal	Yes	Ok
AP	Gurajala		limestone slabs and river embankment
AP	Rajamundry		low DNI
Karnataka	Tulasigere		stone and rocky soil

* site has a GSS under construction, but will use a nearby existing GSS in the meantime

For each of the 4 selected sites, the respective state government is asked to provide a letter of comfort stating that:

- Land will be allotted
- Power evacuation will be available
- Water will be available
- Accesses will be made available, if required

These aspects along with the technical short-listing process described above will ensure that the sites selected for the demo projects are optimal choices.

Chapter 2: Technical Feasibility assessment

Project specific site details

Based on a quantitative scoring scale with specific points being assigned to specific site-attributes, and through field visits of the probable sites, the optimal sites selected for the demonstration projects were Bhadla (Rajasthan), Charanka (Gujarat), Terkuveerapandiyapuram (Tamil Nadu) and Nennala(Andhra Pradesh). Based on a careful consideration of physical and technical attributes like solar radiation level, availability of water, evacuation infrastructure, land area requirement etc., each of these four sites had to be selected for any of the following three proposed configurations:

Project configurations	Size of project (MW)	Maximum No. of Projects
CSP project with storage (>= 10 hours)	10-100	2
CSP project with high operating temperature (>=500°C)	20-100	1
CSP project with hybrid cooling (water <= 30%)	20-100	1

CSP is viable only in regions with high level of solar irradiance. CSP technologies, other than Stirling dish use Rankine cycle to convert heat energy to electricity through use of conventional steam generators. Water is consumed for steam production as well as for cooling/condensation. Thus water requirement is an important issue with CSP plants because areas with high DNI i.e. with higher sun intensity mostly correspond to places where there is scarcity of water. Considering the fact that water is the primary issue in Bhadla, hybrid cooling has been selected for this location. Hybrid cooling thus employed will reduce water consumption in the plant and the higher DNI will compensate for the reduced efficiency that hybrid cooling plants have compared to conventional wet cooling.

The size of the collector field for CSP plant, particularly one designed to provide heat-storage is high. The land requirement for a plant with thermal storage is almost 3 times and may go even higher than a plant without storage. Additionally there is some area requirement for storage equipments/mediums which may be as high as 15 % of the entire area. All the four sites have almost the same available land area with Nennala and Terkuveerapandiyapuram, having 160 hect. available area which is slightly more than 140 hect. available in Charanka. Also, the CUF is higher with plants with storage provisions as the hours of operation increase by the storage time and hence the water requirement increases drastically. Availability of water is thus a critical issue that needs to be addressed while considering storage for CSP plants. CSP plants require continual water supply for steam generation, cooling and cleaning solar mirrors. Considering these two factors, Nennala (Andhra Pradesh) and Terkuveerapandiyapuram (Tamil Nadu) were chosen for large storage configurations. Nennala benefits from a natural availability of water and is a green land bordered by agricultural lands.

Terkuveerapandiyapuram benefits from a natural availability of water and is a green land bordered by some patches of agricultural lands and several thermal power plants. The DNI is quite good and may provide a good source for power generation, on the other hand the ambient temperatures are high and a successful project under these conditions would show the possibility to deploy CSP with large storage in areas that are likely to be rich in DNI.

CSP technologies use direct sunlight, measured as Direct Normal Irradiation (DNI); which is the sunlight that is not diffused or deviated by clouds, fumes or dust in the atmosphere and which reaches the Earth's surface in parallel beams for concentration. All these four locations have DNI greater than 5 KWh/m^2 and hence high operating temperature configuration (>=500°C) can be assigned to any of the remaining sites. Charanka, the first solar park in India is already harbouring several PV projects; totalling nearly 300 MW out of the total park capacity is 590 MW. The masterplan of the solar park outlined a water body (man made lake) to be constructed at the site to prevent lack of water during canal unavailability. That lake is already constructed and so water is not a major issue at Charanka. Considering the fact that Gujarat is endowed with abundant solar intensity and

that high operating temperature requires high hourly DNI values it seems a natural choice that Charanka be the location for a high operating temperature project.

The following information was collected on the Charanka site:

State	**Gujarat**
Location	Charanka, Santalpur taluka, Patan district, Gujarat
Qualification	Solar Park
Nearest city (name and distance in km)	
- At least state two GPS coordinates at the borders	23 54'36.19" N, 71 12'13.87" E
Area (hectares)	140 hect
Ownership of the land	Private land
- Options: acquired by the state or private or to be acquired	in acquistion by GPCL
- If to be acquired, please state the necessary time	6, 7 months
Power evacuation facilities	to be constructed
Type of sub-station (voltages)	66/132/220/400 kV
Distance of the sub-station to site	in the solar park
Soil analysis	Completed
- If completed, name of company that did the soil analysis	
Water availability	available from canal
- Quantity (cusec -cubic meter per second)	
- If Ground water at what depth?	
- If canal, what is the distance to the land?	8 km from site
- Any other source	ground water
- Any restrictions in the use of the water	not available: 40 days
Access roads	Exist
- Name of the road, if exists	20 km from NH-15, 10 km from State highway
- Type of road - width	
- Type of road - pavement type	Asphalt
- Connection from and to (in km)	Pucca road
Solar radiation - DNI - Direct Normal irradiation	5600.3
Solar radiation - GHI - Global Horizontal irradiation	5763.6
Solar radiation - Diffuse irradiation	1987.9
Ambient temperature	
- Options: ground measured data, no ground measured data	
Humidity	
- Options: ground measured data, no ground measured data	IMD
Wind speed	

- Options: ground measured data, no ground measured data	
Wind direction	
- Options: ground measured data, no ground measured data	
Rainfall	
- Options: ground measured data, no ground measured data	IMD
Populations nearby?	
- State the number of people and the distance to the land up to a 5 km radius of the land	5000
- Main ocupation	Farming, husbandry
Endemic fauna in the site	Environmental assessment undertaken, Chapter-5
Endemic flora in the site	Environmental assessment undertaken, Chapter-5

The summary of the evaluation data is given below:

Power evacuation	on construction
Type	66/132/220/400 kV
Distance to the site	in the solar park
Water availability	available from canal
water limitations	not available: 40 days
Acquired land	in acquistion by GPCL
Area	140 hect
Access to the site	Exist
Populations nearby	5000
DNI (per day)	5.60
Solar Park	Existing

Technology Configuration

Concentrated solar power plants generally operate at temperature range between 200-800 °C. In order to scale up the operational temperature of such projects for improved requirements, certain modifications needs to be introduced in the plants. Operating CSP based power plants at higher temperatures offers sizeable benefits from the projects. Operation at a higher temperature brings higher efficiency to the plant which thereby reduces the generation cost and inhibits the effect of ambient temperature on the working of the power project.

As discussed above, attaining high operational temperature requires modification in the certain sections of the CSP based power plant. CSP plants which use storage system for a long duration operation shall employ better working or heat transfer fluids (HTF). Commonly used heat transfer fluids like thermal oil cannot provide operations at temperature above 400°C. Therefore, for achieving high temperature requirement, new heat transfer fluids such as molten salts needs to be used. Heat transfer fluids like salts have salient characteristic of high thermal capacity, low conductivity and high temperature stability.

Another approach to increase the operating temperature of the CSP projects is to provide high concentration ratio, particularly in the case of tower and Fresnel technology, wherein the aperture area of the heliostats and the mirrors could be increased. Increasing the aperture area would concentrate relatively high incoming solar radiation beams to the focus and hence would generate higher operating temperature.

Also, for further improving the operational temperature of the CSP plants based on storage facility and wherein, the molten salt or thermal oil is being used, auxiliary heaters can be deployed for heating the oil to further

higher temperature. If steam is used as the working fluid, auxiliary heaters may be used to superheat the steam to increase the efficiency of the plant.

Improving the properties of the selective coating on the receiver represents another opportunity for improving the efficiency of CSP projects (particularly parabolic trough and Fresnel) and reducing the cost of solar electricity. Additionally, increasing the operating temperature above the current operating limits of 400ºC can improve power cycle efficiency and reduce the cost of thermal energy storage resulting in reductions in the cost of solar electricity. Improving the stability and performance of the absorber tubes to move to higher operating temperatures is the biggest challenge faced right now by project developers. More-efficient selective coatings with high solar absorptance and low thermal emittance provide thermal stability above 500ºC, with improved durability and reduced cost.

Simulation with potential technology

The configuration specifics for this site have described in the previous section. Operating temperatures higher than 500ºC are to be ensured for the CSP plant to be set up in Charanka. The minimum CUF is 20% and the maximum is 30%. Implementing storage is encouraged, since storage will help in balancing the higher concentration required for achieving higher temperature which may lead to more hours at nominal rating. In terms of technology, the design of solar field is expected to be the major difference in the project, and commercial or off-the-shelf solutions are expected for the components with the exception of the turbine which may be new in CSP power plants, thus special considerations have been incorporated in the specific technical evaluation criteria.

In terms of the main areas in the project we have:

Solar field	Balance of Plant
- Heliostats, Mirrors or reflective surfaces - Receivers (evacuated tubes, steel pipes, cavities) - Collector Frames - Corrosion (applicable to any metallic structure) - Foundations - Tracking motors and algorithm - Electrical cables - HTF (water, oils, molten salts, air)	- Pressure vessels (Steam drum, expansion vessel, blow-down, deaerator) - Piping and pumps (pipes, pumps and feed heaters) - Electrical cables - Heat exchanger - Water Tanks or reservoirs (demineralization plant) - Heat storage tanks - Turbine (with alternator and step transformer) - Cooling tower

In terms of design and engineering no evaluation will be performed, since the whole nature of these projects is to allow innovative designs and engineering to be used, so all solar thermal technologies are allowed with an exception of Stirling engines which currently do not offer any storage solution. The area available for the project is 140 hectares which encompasses solar field plus Balance of Plant to fit in, which obviously limits the power plant rating and the consequent power generation. An exercise was done to design the maximum power plant that would fit in such area obeying the CUF limitations and based on the radiation data supplied by the NREL/MNRE database that is available online. A privately developed model was used that uses an energy balance on an hourly basis, takes into consideration the solar field and the concentration factor, the optical and thermal losses of the solar field, the amount of energy necessary to vaporize water at the defined temperature, the amount of energy necessary to generate steam and based on the energy available from the solar field a certain amount of steam is generated and based on the efficiency of the turbine considered thus a power yield is obtained. Storage is considered and accounted for so that maximum and minimum number of hours of storage and thus average and peak CUF can be obtained. Additionally the heat exchanger efficiency as well as the IAM (Incident Angle Modifier) is also an input as well as the latitude of the place that adds some end losses on the collector (basically decreases the area available). Some differences apply to parabolic trough and Solar tower in terms of the way the solar field is emulated. The main outputs are the following and they were compared with the SAM model (in what can be compared):

Variables	Troughs (500ºC)	Towers (500ºC)
Total power rating	33 MW	40.5 MW
Total yearly generation	85 GWH	102 GWH
Average CUF	29%	29%

Peak CUF achieved (at least in one day)	47%	46%
Hours of storage	4.03	3.93
Total area of the power plant considering a 3x factor, that is the total size of the plant = 3 x solar field	147.7 hect	146.5 hect
Total area of the solar field (no spaces)	49.2 hect	48.8 hect
Average total efficiency	**16.7%**	**19.4%**

A high operating temperature of 600ºC was considered in the solar field and 500ºC for the steam operation.

These results are not to be treated as benchmark for the project site as the purpose of the study was to get a better understanding of the system efficiency under available conditions. Hence, these results indicative, since the DNI was not locally measured and all the considerations used on the model were not specific to any technology but from benchmarks and known parameters of solar fields and Balance of Plant. A conservative view should be used and 10 to 15% less output is expected even if the DNI was exactly the same as the one used for the simulation.

Based on the site specific details and simulations with various technology configurations, Charanka has been selected for pilot CSP plant with high operating temperature.

Chapter 3: Financial feasibility assessment

Project financing structure

The proposed CSP demo plants are designed to be one-of-kind, innovative pilot projects that will highlight the technical, commercial and economic viability of these technologies. Due to the highly experimental natural of these pilot plants, the Government of India is planning to make available specialized sources of funding for these projects. These funding sources are designed to facilitate CSP projects by offering longer term financing at extremely competitive rates, while only requiring the developer to contribute 20% of the total project cost as own equity.

While the exact quantum and terms of availability of these funds cannot be ascertained accurately at this stage, the following table highlights the potential project financing options that these CSP demo plants can be expected to employ for debt funding.

#	Funding Source	Cost of borrowing	Tenure	Clauses/Covenants
1	Asian Development Bank (ADB)	LIBOR plus 0.5% mark-up = ~1.45% + commitment charges. Assumed at 4% to include other spreads	5 years moratorium and 20 years repayment	ADB can only provide this loan to a sovereign Govt. Of India entity. Mechanisms to pass this on from GoI to private developers will have to be considered.
2	Clean Technology Fund	0.25% non-escalating	10 years moratorium and 30 years repayment	Only accessible through ADB. Needs to have a 1 is to 5 leverage ratio and must be for a demonstrable innovative use – CSP pilot projects fulfil this second criteria
3	Commercial loans	Risk weighted market rate = ~ 9-12%	1 year moratorium and 8 to 10 year repayment	Commercial lenders will perceive CSP demo projects to be highly risk, and will require some kind of collateral/assurance which is likely to raise cost of borrowing and/or limit availability

Based on these sources and characteristics of financing, the following funding mix has been assumed for the projects:

Mode of funding and its features	Interest rate	Repayment tenure (years)	Moratorium period (years)	Proportion of total capital cost
ADB and CTF blended loan	6.0%	20	5	40%
Developer's equity	Return on equity at 22.4% as per prevailing CERC norms			20%

In addition to the debt financing option listed above, the Government of India will also support the demo projects by offering a viability gap funding in the form of a grant. The amount of grant required by a project is fixed at 40% of the total project cost. The grant will be made available as three staggered payments each year since the start of the project construction (assumed to be 3 year). The grant will be paid out in unequal proportions:- 10% in the 1st year, and 45% each in the following two years.

The following presents the expected project (financial and economic) and equity returns for the project assuming a flat tariff of Rs. 5.82/kWh.

Project specific details

The following are the project specific financial and technical details that form the basis of our estimations. All other assumptions not mentioned below are assumed to be as per the prevailing CERC norms for solar thermal projects (please see appendix 1 for details). It is important to note that these details are merely representative and in no way suggest the likely configuration that might come up.

#	Parameter	Value
1	Capital Cost	Rs. 180 million per MW
2	CUF	30%
3	Capacity	35 MW

VGF estimation

Allowed Tariff (INR/kWh)	**5.82**
Project IRR	4.93%
Equity IRR	7.13%
Economic IRR	7.96%
LCOE	5.89

Chapter 4: Social feasibility assessment

Social & Poverty Impact

The proposed CSP will be located in the village Charanka in Santalpur taluka of Patan district, of Gujarat. This will be within the proposed solar park area. Gujarat Power Corporation Limited will be the nodal agency for acquisition of land. The Project will contribute both directly and indirectly to poverty reduction through economic development. A social impact assessment report was already prepared for the Charanka solar park and its associated transmission lines under ADB's technical assistance for the ongoing ADB's funding for the Gujarat Solar Power Transmission project. Most of the social parameters are same for the CSP site as well. However, separate social assessment will be carried out for the proposed CSP site. A brief summary of the social issues are described here.

The total population of Patan district is 11,82,709. The overall sex ratio is 932 female for every 1000 males (rural 938 and urban 932). About 80 % of the population lives in rural areas. The total literacy rate is 60.4 %, 73.6 % among males and 46.3 % among females. About 90 % of households are Hindu and 10 % are Muslim. The average family size of sampled households is 5.37. The sex ratio of households is 849 females for every 1000 males. The overall literacy rate of surveyed households is 71 %. Literacy among males is about 79 %, while for females it is 62%. Women traditionally have lower levels of secondary and higher education. Overall, only 2 % of households have members who are graduates.

Availability of water is a problem for households. Although 86 % have piped water supply, 95 % of households still depend on outside sources of water. On average, it takes peoples 26 minutes to get water from outside sources. In terms of sanitation facilities, more than one-third of households have no toilet facility in their homes. Similarly, about one third of households do not have a bathroom for females. About 94 % of households use wood as cooking fuel. Other fuels used include dung cakes and kerosene though 94 % of households report to have electricity in the home.

Occupationally, 45 % of peoples in the age group of 18 years and above work as agricultural labourers, farmers and/or cultivators. About 57 % of women report to be home makers. Jobs in the private sector are restricted to males with more than 5 % engaged in the sector. Skilled workers and entrepreneurship/self employment in the project area is limited. Most males work in agriculture as labourers on a seasonal basis. Nearly one fourth of households report having a single earning member. In one third of households, there are two earning members. In 53 % of households, no female members reported contributing to the household income. Though the study tried to explore types of skills training possessed by household members, it was noted that few inherited skills of tailoring or carpentry informally, therefore, it appears people receive very little skill based training from either the government or private institutions. This is apparent for both genders.

In surveyed households, a little more than one fifth (22 %) reported of possessing agricultural land. In the project area, wheat and bajra are the main crops followed by cotton and Jira (Cumin seeds). Among households, of those that have agricultural land, 65 % cultivate Bajra and 33 % cultivate wheat. Cotton and Jira are cultivated by 13 % of households and Jawar by 11 %. About two-thirds of households report having live stock at their respective homes. The most frequently owned durable goods are television sets, electric fans and telephones/mobiles (70 % or more households). Similar is the case for ownership of radio - 46 % of the total sampled household reported of having a radio. Luxury items like air conditioners are not owned by households covered under the study. Similarly, four wheelers like cars/jeeps, washing machines, refrigerators and sewing machines are owned by few households. In the surveyed project area it was found that the major earning was from labour (daily wages and seasonal) followed by agriculture as farmers. Only 8 % of the households reported earnings from job and services and dairy products each.

The total average annual income from all sources is Rupees 50,709/-. Income from daily wage labour contributes to the maximum earnings. However, the average income from agriculture is Rupees 56,696/- highest among all sources in the project area followed by income from other sectors. The average annual expenditure of households is slightly higher than their average annual income. This suggests that many households either take loans or have concealed the exact income. Among the households, nearly 39 % of expenditure is spent on food and 20 % on social functions like rituals, festivals and marriages. Expenditure on education is only 2 % as most households access government educational services. Findings suggest that the majority of households are from lower economic backgrounds and have limited access to skilled based jobs. The majority are employed as daily wage agricultural labourers which is generally seasonal.

Medical coverage is equally divided between government and private sector services. The nearest health facility for two thirds of households is a primary health centre. However, 73 %, of households have a health facility available outside their respective villages. The average distance to a health centre is 11.3 kilometres. About 84 % of households travel a minimum of 8 kilometres to access health services. Most households reported having visited a health worker during the last six months preceding the survey. The majority, about 87 %, receive messages and services on polio immunization which is a universal health programme run by the state government and the UN WHO[2]. Family planning services are also available though coverage is not widespread. Many households receive health information on malaria, dengue, maternity and child health and HIV/AIDS.

The Project will contribute both directly and indirectly to poverty reduction through economic development. A Poverty and Social Analysis will be conducted to assess and identify ways in which the project might best address poverty reduction and social development issues. A social impact assessment report will be prepared. The poverty and social analysis will be undertaken addressing the key social issues in accordance with ADB's Guidelines for Incorporation of Social Dimensions in Bank Operations and ADB's Handbook on Poverty and Social Analysis The analysis will broadly cover various components such as (i) identifying the affected population and potential beneficiaries including minorities (indigenous people), (ii) assess the stage of development of different groups of the population, (iii) assess the gender impact of the Project, (iv) assess the needs of the affected population and their expectations from the Project, (v) assess the affected population's absorptive capacity to receive benefits from the Project, and potential to participate in implementing the Project. The methodology to be adopted in conducting poverty and social analysis will include both primary and secondary data. All available secondary socioeconomic data will be collected for the project areas through proper sources which will be reviewed and compiled. In addition to the secondary data, primary data will be collected through survey which will have both quantitative and qualitative methods. A sample socioeconomic survey will be conducted in the project area (CSP site) to collect the baseline information using a structured soco-economic questionnaire. The qualitative methodology will include but not limited to focused group discussions, key informant interviews and informal discussions with stakeholders. The survey will aim at collecting information pertaining to issues related to social, poverty, gender, indigenous people, and health issues especially HIV/AIDS, trafficking and labour etc. The findings of the social and poverty analysis will be presented as Summary Poverty Reduction and Social Strategy (SPRSS), in accordance with the ADB format.

Impact on Land Acquisition and Involuntary Resettlement

Private land is to be acquired by Gujarat Power Corporation Limited. 140 hectares of private land will be acquired by Gujarat Power Corporation limited. The land is mostly agricultural land. No physical displacement is foreseen. However, loss of agricultural land is foreseen. Detailed land survey and the ownerships will be collected. The sub project will be categorized as A as far as the resettlement issues are concerned. A Resettlement Plan will be prepared as per ADB's Safeguard Policy Statement (SPS), 2009 and Government of India's Policy on Rehabilitation and Resettlement (national Rehabilitation and Resettlement Policy- NRRP-2007)

[22] United Nations World Health Organization.

Impact on Indigenous People

There are no such tribal populations found in the area which. There are no demarcated tribal areas found in the sub project area. No household or group belonging to scheduled tribes will lose housing, strip of land, or other fixed assets. Therefore, the IP issues are insignificant in the sub project area. Based on the assessment, the sub project can be categorized as C as far as the IP issues are concerned. However, necessary steps and mitigations will be taken during the detailed survey. If any IP is found during the detailed survey based on the final design, it will be addressed suitably as per ADB's Safeguard Policy Statement (SPS), 2009.

Impact on Gender

Though most women classified themselves as home workers, nearly half of all women surveyed work as agricultural labourers and 39 % are engaged in cultivation. About 14 % of women also work as daily wage labourers. In the project area, women's participation in household decision making is high. More than 90 % of households report that women participate in decisions like finance, education and child health care, purchase of assets and day to day activities. The perception of women and children's safety and mobility is positive in the project area. However the provision of adequate street lights is inadequate in the project area. About 95 % of households admitted that that the provision of street lighting will result in an increase of women's mobility during the evening.

Women are largely responsible for household energy management, such as collecting, chopping and storing firewood. Therefore access to energy has a specific gender dimension. Renewable energy projects in India have demonstrated that renewable energy can directly contribute to poverty alleviation and gender benefits. Installing solar lights in homes enables children to study in the evenings and improve school performance. Solar lanterns have made the business of many women entrepreneurs profitable. Solar driers are a boon in remote areas for drying of fruit and vegetables. Even garment workers have been using solar energy to save electricity costs while running their sewing machines. Vocational trades involving the NGOs may be initiated for women to empower them by providing skills on tailoring, embroidery, food products etc. as cattle rearing is one of the major occupation of the people therefore some milk processing units and small scale industries to produce ghee, and other milk products can also be initiated with the provision of market linkages. However, all these activities do have a direct link with the availability of energy.

The EA will ensure that women are consulted and invited to participate in group based activities and where possible, women will be given the opportunity to learn new skills that may provide alternative forms of income generation and livelihood. Efforts will be made during the detailed assessment to assess the possible gender benefits of the project. If required, a gender action plan will be formulated to maximise project benefits for women through gender mainstreaming in the project and a gender responsive participation framework. Gender mainstreaming will include activities associated with empowerment, skills training, capacity building and gender sensitisation.

Other Social Issues (Labour and Health etc)

Temporary employment opportunities will be available for skilled and unskilled labor during project implementation and operation. Standard assurance on labor will be included in civil work contracts. Necessary health safety measures will be taken by the construction contractor to combat any disease like, HIV, STD due to the influx of migratory labour from outside.

Public Consultation and Stakeholders' Participation

Initial consultations have been carried out with the project authorities. Preliminary consultations were also carried out in the sub project sites. The Consultations will be continued involving all the stakeholders all through the project planning and implementation.

An initial Poverty and Social Analysis has been prepared as per ADB's format and presented below.

INITIAL POVERTY AND SOCIAL ANALYSIS (IPSA)

Country:	**India**	**Project Title:**	**Concentrating Solar Power Project (Charanka)**

Lending/Financing Modality:	**XXX**	**Department /Division:**	**SARD/SAEN**

I. POVERTY ISSUES

A. Links to the National Poverty Reduction Strategy and Country Partnership Strategy

Achieving "poverty reduction and social development through faster and more inclusive growth" is a priority in India's 11th Five Year Plan (FYP) (2007-2012). The Planning Commission's approach paper to the 11th FYP identifies infrastructure bottlenecks and lack of adequate long-term funds for infrastructure as key binding constraints to realizing more equitable and sustainable growth and bridging the gender divide in the country. In addition, the Paper states that "good quality infrastructure is the most critical physical requirement for attaining faster growth in a competitive world and also for ensuring investment in backward regions". ADB's Country Partnership Strategy (CPS) for 2009 – 2012 aims to tackle poverty by supporting faster, more inclusive and gender equitable economic growth through job creation; improvement in the education, health and other social sectors; the provision of basic essential services to the poor; and bridging the divide between regions, sectors, and gender in the state.

India is bestowed with good solar irradiation across the country. In January 2010, the Government of India (GOI) launched Jawaharlal Nehru National Solar Mission (JNNSM). The targets of the JNNSM are, among others, to (i) create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022; (ii) ramp up capacity of grid-connected solar power generation to 1,000 MW within three years; and an additional 3,000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff; (iii) deploy 20 million solar lighting systems to rural areas by 2022; and (iv) create favorable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership. Availability of clean and reliable sources of energy is expected to catalyze economic growth in the service areas of future renewable energy projects and thereby create more economic opportunity for the population including the poor. The Project's impact would be the development of long-term sustainable energy sources in a cost-effective manner in India.

The Project is aligned with the India Country Partnership Strategy (CPS) 2009-2012. One of the four strategy pillars of the CPS is the support for inclusive and environmentally sustainable growth, through the continued focus on infrastructure development and the enhanced focus on renewable energy. The Project will contribute to achieving the targeted capacity for solar power generation through 2012. The Project will contribute to the economic development of Gujarat through increased employment opportunities and increased tax revenues. Direct impact to local employment is expected during the construction and operation stage, while the tax revenues from the Project during operation stage can be used to fund social development projects that will benefit the poor and vulnerable and will have indirect impact

B. Targeting Classification

☒General Intervention ☐Individual or Household (TI-H) ☐Geographic (TI-G) ☐Non-Income MDGs (TI-M1, M2, etc.)

Explain the basis for the target classification: The Project is classified as General Intervention as power produced will be evacuated in the main grid where it will be available to the broad power users. The availability of electric power has an indirect but strong link with reducing poverty and encouraging economic growth.Though the Project will have a number of indirect benefits to end users in terms of investment and improvements to local public infrastructure, creation of economic potential and activity, greater wealth and opportunity in communities – all of which have a catalyst effect in directly improving peoples general well being and quality of life; despite this, power sector interventions are not considered as the single contributing factor to achieving more generalized and sustainable poverty reduction and alleviation. The classification therefore recognizes that while power itself will

not implicitly decrease poverty, it is a critical stepping stone to attracting other means of economic investment and development that will provide the foundation for concrete poverty reduction strategies in the future.

C. Poverty Analysis

1. If the project is classified as TI-H, or if it is policy-based, what type of poverty impact analysis is needed? Not applicable.

2. What resources are allocated in the PPTA/due diligence? Social and gender analysis will be carried out by social development / safeguard specialist. Analysis will include the collection of baseline data (e.g., household surveys, including gender disaggregated data), assessment of primary and secondary data, and focus group discussions and public consultation with project affected peoples. Funds for social and gender analysis will be made available through the project PPTA.

3. If GI, is there any opportunity for pro-poor design (e.g., social inclusion subcomponents, cross subsidy, pro-poor governance, and pro-poor growth)? Not at present.

II. SOCIAL DEVELOPMENT ISSUES

A. Initial Social Analysis

Based on existing Information:

1. Who are the potential primary beneficiaries of the project? How do the poor and the socially excluded benefit from the project? The primary beneficiaries of the Project are - those who will receive clean renewable electricity from the project (these could be local, regional or even national and are therefore deemed as indirect beneficiaries); - those who will be temporarily be employed during construction and permanently employed for operations of the project; - and –women, who will benefit from: a) household electricity and street lighting, reduced time burdens from domestic chores and increased safety and security during night hours ;b) improved living standards and health condition.

2. What are the potential needs of beneficiaries in relation to the proposed project? The primary needs of poor and vulnerable stakeholders are jobs during construction and operation, access to markets in remote areas, and improved infrastructure and basic services like health, education and sanitation in the project area.

3. What are the potential constraints in accessing the proposed benefits and services, and how will the project address them? Remoteness of the project location.

B. Consultation and Participation

Indicate the potential initial stakeholders.

1. Primary stakeholders are peoples living in the direct area of influence of the project and its associated facilities. Other stakeholders include public & private sector shareholders and Government of Gujarat and Government of India.

2. What type of consultation and participation (C&P) is required during the PPTA or project processing (e.g., workshops, community mobilization, involvement of nongovernment organizations and community-based organizations, etc.)? Public consultations and focus group discussions will be carried out with project stakeholders during the project planning and implementation stages of development.

3. What level of participation is envisaged for project design?

☒ Information sharing ☒ Consultation ☐ Collaborative decision making ☒ Empowerment

4. Will a C&P plan be prepared during the project design for project implementation? ☐ Yes ☒ No

Consultations will be managed through a mix of formal and informal consultations with the affected communities – on an as needed basis. The nature and scale of impacts and the number of affected peoples is expected to be limited, thereby exempting the need for a structured and systematic process of engagement. Social assessment will nonetheless include gender sensitive and targeted consultation to ensure that women's needs are analyzed and opportunities considered.

C. Gender and Development: Proposed Gender Mainstreaming Category: Some Gender Benefits

1. What are the key gender issues in the sector/subsector that are likely to be relevant to this project/program? Opportunities to benefit and improve the quality of life and well being of women will be assessed during project

appraisal. Where opportunity exists, these will be funded under a specific gender and community based technical assistance fund. The main (indirect) benefits expected to women will be in the form of access to new, improved or more reliable lighting in homes and villages. This will reduce women's time and burden on household and domestic activities; - improve their health and well being, as this will replace the need for more costly, less clean and efficient sources of energy(e.g., firewood, kerosene) for household heating and lighting. Opportunities may also focus on creating new or alternative forms of livelihoods, provision of skilled training and/or education.

2. Does the proposed project/program have the potential to promote gender equality and/or women's empowerment by improving women's access to and use of opportunities, services, resources, assets, and participation in decision making? ☒ Yes ☐ No

Please explain. The benefits to women will be felt and seen locally, within their family and community structures.

3. Could the proposed project have an adverse impact on women and/or girls or to widen gender inequality?

☐ Yes ☒ No Please explain Women are expected to benefit from the intended outcomes of the project.

III. SOCIAL SAFEGUARD ISSUES AND OTHER SOCIAL RISKS

Issue	Nature of Social Issue	Significant/Limited/ No Impact/Not Known	Plan or Other Action Required
Involuntary Resettlement	Construction of CSP will require approximately 140 hectares of land which is primarily private land.	**Significant**	☒ Resettlement Plan ☐ Resettlement Framework ☒ Environmental and Social Management System Arrangement ☐ None ☐ Uncertain
Indigenous Peoples	The area where the project will be constructed is not owned/used/claimed by any IP or scheduled tribe.	**No Impact**	☐ Indigenous Peoples Plan ☐ Indigenous Peoples Planning Framework ☒ Environmental and Social Management System Arrangement ☐ None ☐ Uncertain
Labor ☒ Employment Opportunities ☐ Labor Retrenchment ☒ Core Labor Standards	Temporary employment opportunities will be available for skilled and unskilled labor during project implementation and operation. Standard assurance on labor will be included in civil work contracts.	**Limited Impacts**	☐ Plan ☐ Other Action ☒ No Action ☐ Uncertain
Affordability	Power will be sold directly to the grid. No affordability issue is expected. Power tariff will be determined by Competent authority.	**No Impact**	☐ Action ☒ No Action ☐ Uncertain
Other Risks and/or	The project will minimize the risk of HIV/AIDS	**Limited**	☐ Plan

Vulnerabilities ☒ HIV/AIDS ☐ Human Trafficking ☐Others (conflict, political instability, etc.), please specify	among the migratory and local workforce through awareness raising initiatives.	This will be further assessed during the social due diligence under PPTA	☐ Other Action ☐ No Action ☒ Uncertain

IV. PPTA/DUE DILIGENCE RESOURCE REQUIREMENT

1. Does the TOR for the PPTA (or other due diligence) include poverty, social and gender analysis and the relevant specialist/s?

☒ Yes ☐ No

2. Are resources (consultants, survey budget, and workshop) allocated for conducting poverty, social and/or gender analysis, and C&P during the PPTA/due diligence? ☒ Yes ☐ No

Consulting requirements include the use of individual consultants which include international social development /safeguards specialist for more immediate due diligence tasks including necessary costs for carrying out the social surveys etc.

Chapter 5: Environmental feasibility assessment

Legal Regulatory Framework

It is important that the CSP projects that will emerge from the MNRE project are in tune with the legal framework in the country and state. The existing laws and regulations concerning environmental conservation may restrict certain developmental activities. It is important that the Environmental Management Framework prepared for the CSP project remains responsive to the changing legal framework. The following laws, regulations and policies have been reviewed in this chapter for their relevance to the CSP project context.

National Environmental Laws

The Environmental regulations, legislation, policy guidelines that may impact this project, are the responsibility of a variety of government agencies. The principal Environment Regulatory Agency in India is the Ministry of Environment and Forests (MoEF). MoEF formulates environmental policies and accords environmental clearances for different projects. The relevant environmental legislations in India are mentioned below

(i) The Water (Prevention and Control of Pollution) Act, 1974, amended 1988.
(ii) The Water (Prevention and Control of Pollution) Rules, 1975.
(iii) The Air (Prevention and Control of Pollution) Act 1981, amended 1987.
(iv) The Air (Prevention and Control of Pollution) Rules, 1982.
(v) The Environment (Protection) Act, 1986, amended 1991 and including the following Rules/Notification issued under this Act.
- The Environment (Protection) Rules, 1986, including amendments.
- The Municipal Solid Wastes (Management and Handling) Rules, 2000.
- The Hazardous Wastes (Management and Handling) Rules, 2003.
- The Hazardous Wastes (management, handling and transboundary movement) Rules 2009.
- The Bio-Medical Waste (Management and Handling) Rules, 1998.
- Noise Pollution (Regulation and Control) Rules, 2000.
- Wild Life (Protection) Amendment Act, 2002.
- Ozone Depleting Substances (Regulation & Control) Rules, 2000.
- The Biological Diversity Act, 2002.
- The Environment Impact Assessment Notification, 1994; amended up to 2009;
- Batteries (Management & Handling) Rules, 2001.
- The Environmental Clearance Notification, 1994.

(vi) Noise Pollution (Regulation and Control) Rules, 2000.
(vii) The Indian Wildlife (Protection) Act, 1972, amended 1993.
(viii) The Wildlife (Protection) Rules, 1995.
(ix) The Indian Forest Act, 1927.
(x) Forest (Conservation) Act, 1980, amended 1988 (National Forest Policy, 1988).
- Forest (Conservation) Rules, 1981 amended 1992 and 2003.
- Guidelines for diversion of forest lands for non-forest purpose under the Forest (Conservation) Act, 1980.

(xi) The National Environmental Appellate Authority Act, 1997.
(xii) The National Green Tribunal Act, 2010.

Other National Policy Acts

The Indian policy framework consists of following main regulations:

1. The Electricity Act, 2003.
2. National Resettlement & Rehabilitation Policy, 2007 (NRRP) (MoRD, DoLR).
3. Right of Way and Compensation under Electricity Laws.
4. Land Acquisition Act, 1894.
5. The Indian Telegraph Act (ITA), 1885.
6. Indian Treasure Trove Act, 1878 as amended in 1949.
7. Provisions of the Panchayats (Extension to the Scheduled Area) Act, 1996.

8. The Right to Information Act, 2005.
9. National Policy on HIV/AIDS and the World of Work, Ministry of Labour and Employment, GoI.
10. National Policy on Safety, Health and Environment at Work Place, Ministry of Labour and Employment, GoI.

Specific Provisions:

11. CRZ Regulations: The Central Government vide its notification number S.O.114 (E), dated the 19th February, 1991, has declared Coastal Regulation Zone and imposed certain restrictions on the setting up and expansion of industries, operations and processes in the said Zones. The Act prescribes several activities that are declared as prohibited activities within the CRZ such as setting up of new industries and expansion of existing industries. However this excludes facilities for generating power by non-conventional energy sources and setting up of desalination plants in the areas not classified as CRZ-I (i).

12. Office Memorandum No. J-11013/41/2006-IA.II(I) dated June 30, 2011 - Environmental clearance for setting up of Solar Thermal Power Plants under JNNSM-applicability of EIA Notification 2006
It is clarified that Solar Thermal Power Projects do not fall under the EIA notification 2006. However, it should (i) seek consent to establish from SPCB under Air and Water Acts, forest clearance under FC Act, (ii) conform to CRZ notifications, (iii) restricted land use to Solar Thermal, and (iv) any other rules such as HSM Rules etc.

13. Solar Power Policy 2009: Government of Gujarat dated January 6, 2009 vide G.R. No. SLR-11-2008-2176-B for promotion of generation of green and clean power in the state using Solar Energy.

Physical Features of the Site

Charanka Solar Park and adjoining Area

(Source: EIT and DPR of Mott MacDonald 2011)

Village: Charanka, Santalpur taluka, Patan district, Gujarat
GPS coordinates: 23 54’36.19” N, 71 12’13.87” E

Land Requirement of CSP Project site: 140 Hectares
Government land to be acquired by GujaratPower Corporation Limited (GPCL).

Charanka Solar Park Site development for an area 5400 acres with development of storm water drainage and filing of low area with rehabilitation of main nalla running in site.

Master Plan studies:
Masterplan of the solar park done by MottMcDonald.

The State has commissioned the Asia's biggest solar park at Charanka village. The park is already generating 214 MW solar power out of its total power generation capacity of 500 MW

Power Evacuation:
1. Charanka 400/220/132/66 kV GSS,
2. 400 kV Charanka –Shankhari (proposed 400/220 kV Valod Moti GSS) Line,
3. 220 kV Charanka – Jangral Line, and
   are under construction for power evacuation to the Grid for the Charanka Solar Park.

Water:
Sardar Sarovar Canal is passing 45 km away from the site. SSNL agreed to provide water to GPCL's Solar Park Phase I&II. There is no water body in the vicinity of the site and water for the project is to be procured from a canal (Govt. as per initial impressions has allocated water for usage in the proposed project). From preliminary enquiry it seems the ground water is at a depth of about 150-400m. from the surface.

Formation of raw water reservoir for storing 7.2 lakhs cum of water. 45 km water supply pipe line from Narmada branch canal within take structure. Water treatment plant and water distribution network inside the solar park.

Habitation:
1. 1000 people live in Charanka village within the radius of 5 km.
2. Approach road to the park from state highway (17 km).
3. Internal road network with helipad (45 km).
4. Internal fencing, patrol road, forest buffer zone, compound wall with security towers. (Length 20 km).

Other Industries:
The area is generally barren.

Forest:
None

National park and Sanctuaries:
The Wild Ass Sanctuary is located in the Little Rann of Kutch of the Gujarat State in India (Coordinates: 220 55 N to 240 35 N - 700 30 E to 710 45 E). It covers an area of 4954 km^2. The Wild Ass Sanctuary of Little Rann of Kutch (LRK) was established on 12th January 1973. The desert links with four districts, 11 Tehsils and 107 villages along the Little Rann of Kutch. The elevation of the sanctuary is about 2 to 3 m above sea level.

The Sanctuary is named after the last population of sub species of wild ass (Equus hemionus khur). The Rann is one of the most remarkable and unique landscapes of its kind in the entire world. It is a vast desiccated, unbroken bare surface of dark silt, encrusted with salts which transforms into a spectacular coastal wetland after the rains. The present saline desert of the Little Rann (saline desert-cum-seasonal wetland) of Kutch is believed to have been shallow sea. The variety of the geomorphic facets of Kutch such as the present surface configuration, its landforms, drainage characteristics and relief pattern clearly reveals a complex interplay of tectonics, sea-level changes and lithology as also erosion and deposition. The Rann can be considered a large ecotone, a transitional area between marine and terrestrial ecosystems. During monsoon, the Rann gets inundated for a period of about one month. It is dotted with about 74 elevated plateaus or islands, locally called 'bets'. The largest plateau called Pung Bet has an area of 30.5 km^2 and the highest island Mardak is 55 m.

Name and Location	Area (sq. km)	Forest type	Characteristic biological wealth.

Wild Ass Sanctuary Little Rann of Kutch	4954	Saline Desert scrubs	Wild Ass, birds like Hoopoe, Desert lark, Courser, Wheatear, Sand-grouse and other migratory birds like Cranes, Flamingos, Pelicans, Spoon bill, Ducks, Harrier, Vulture, Eagle, Hubara Bustards, Cream courser

Data required

Specific phase-wise activities required for Environmental Impact Mitigation baseline development, mitigation and monitoring are given below:

Planning phase
- Assessment of all Environmental Impacts.
- Consent of Establishment (COE).
- No objections certificates from Wildlife department (sanctuary buffer zones, forest areas, etc.).
- State Pollution Control Board Approvals and Consultation.
- Permissions for any boreholes for water.
- Listing of trees from Forest Department.
- Technical layouts, power evacuation map (TRANSCO), associated facilities.
- Waste disposal planning – construction etc.
- Hazardous waste disposal planning – land fill site, batteries, panels, inorganic toxic waste, SF6, leakages and contingency plans.
- Baseline parameters measurements – water, air, noise, soil (150 ha -> 2 samples; 35 ha -> 1 sample).
- Soil levelling – soil displacement management plan.
- Health and safety planning.
- Power Grid in case of export of power.
- Load centre consumer base list.

Construction phase
- Availability of public amenities – water and sanitation
- Availability of construction camp with electricity, water, toilets
- Hazardous waste disposal implementation
- Waste disposal implementation
- Health and safety implementation

Operation phase
- Compliance with statutory requirement of GOI and State, Support to inspection visits
- Monitoring report

Data required for Environmental safeguards
The impact will be assessed on assumptions derived from site visits and physical survey of the land. The land belongs to the government and/or forest therefore no resettlement issues are envisioned. However, unforeseen impacts may arise during construction for which provision for mitigation and compensation needs to be made. Consultations will be needed to be carried out with relevant stake holders about 5 km from the site. The impacts for CSP plant currently seem to be limited to cutting and lopping of non-forest or forest trees during the construction. The power evacuation lines would normally avoid any forest area, ecologically sensitive areas such as national parks and sanctuary/buffer zone as well any tribal areas.

Data required:
- Alternative analysis of CSP site.
- Contour/Topography report of the project site with drainage, waste disposal site etc.
- Map marked with project and all other project related facilities along with other environmental features using Auto-cad software using Survey of India toposheet (1:50,000 scale) and satellite maps as base map.
- Forest Diversion and Land acquisition case.
- Water availability and quality, environmental air, water, soil, and noise parameters for baseline development.
- Disposal of Hazardous and non-hazardous wastes given the site is pristine in nature.

ADB Specific Guidelines for Environmental Safeguards

The pilot CSP will require preparation of an environmental assessment and review framework (EARF), resettlement framework (RF) and indigenous people's planning (IPPF) framework. Furthermore, it will require initial environmental examination (IEE) and resettlement plan (RP). Because retroactive financing is envisaged, safeguard documents will be prepared before contract awards, necessary clauses will be included in contracts and the EA will be held responsible for implementation of EMP.

Environment Documents

The Environment Assessment and Review Framework (EARF) and Initial Environment Examination (IEE) document prepared for the CSP would normally contain:

- Project description, district data, project related maps and site details etc.
- Site Surveys and preparation, Site selection criteria,
- Environment Management Plan (EMP) and budget,
- Suitable Mitigation measures that are consistent with state Government and ADB policies,
- Environment Monitoring Plan with budget; and contractors requirements,
- Institutional arrangement and staffing requirements, and
- Forest diversion cases (if any).

Roles and Responsibilities

The Project will establish an organization to manage environmental, occupational health, and safety aspects during construction and commercial operation of the power plant. An Environmental and Social Unit at SECI or any Monitoring Agency will have to be established during the project implementation and monitoring period to ensure compliance with safeguards requirement of ADB, state government and GOI.

There will be various stages in the project preparation and implementation. Each stage will require specific activities to be completed for which appropriate institutional arrangements are to be in place. The major responsibilities for the planning and implementation of these activities will be with the project developer along with managing the environmental and social safeguards issues. Additionally, construction contractor will be responsible for mitigating environmental and social issues if found during the construction.

Appendix 1: Major Assumptions

Assumption Head	Sub-Head	Sub-Head (2)	Unit	Assumptions
Power Generation				
	Capacity			
		Installed Power Generation Capacity	MW	35
		Capacity Utilization Factor	%	30.0%
		Auxiliary Consumption Factor	%	10.0%
		Useful Life	Years	25
Project Cost				
	Capital Cost/MW	Power Plant Cost	Rs Lacs/MW	1800
Sources of Fund				
		Tariff Period	Years	25
	Debt: Equity			
		Debt	%	70%
		Equity	%	30%
	Debt Component			
		Moratorium Period	years	0
		Repayment Period(incld Moratorium)	years	12
		Interest Rate	%	6% (ADB Loan for 50% of project cost) and 12 % (commercial bank loan for 20% of project cost)
	Equity			
		Return on Equity	% p.a	22.40%
		Discount Rate		9.2%
Financial				
	Fiscal			
		Income Tax	%	32.45%
		MAT Rate (for first 10 years)	%	19.00%
		80 IA benefits	Yes/No	Yes
	Depreciation			
		Depreciation Rate for first 12 years	%	5.83%
		Depreciation Rate 12th year onwards	%	1.54%
Working Capital				
	For Fixed Charges			
	O&M Charges		Months	1
	Maintenance Spare	(% of O&M expenses)		15%
	Receivables for Debtors		Months	2

	For Variable		
	Interest On Working Capital	%	12.80%
Operation & Maintenance			
	power plant (FY11-12)		1% of project cost
	Total O & M	%	5.72%

Prefeasibility Report

Nennala (Andhra Pradesh)

May 2012

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Chapter 1: Introduction

Central level initiative to promote solar power

National Action Plan on Climate Change

The National Action Plan for Climate Change (NAPCC), announced by the Hon. Prime Minister of India on June 30, 2008, envisions several measures to address global warming. One of the important measures identified involves increasing the share of renewable energy in total electricity consumption in the country. NAPCC has set the target of 5% as dynamic minimum renewable purchase standard (DMRPS) for FY 2009-10, with the target increasing by 1% for next 10 years.

The action plan specifically mentions issues related to power generation from biomass, small hydro and wind technologies. The NAPCC also identifies various regulatory, measures for mainstreaming power generation based on renewable energy sources like:

- A dynamic minimum renewable purchase standard at the national level with escalation a year.
- A mechanism for verification of procurement of renewable based power is also suggested along with a scheme of tradable renewable energy certificates.

Further, in order to ensure compliance with the DMRPS target, NAPCC envisages transaction of renewable energy from surplus regions to deficit regions through policy instruments.

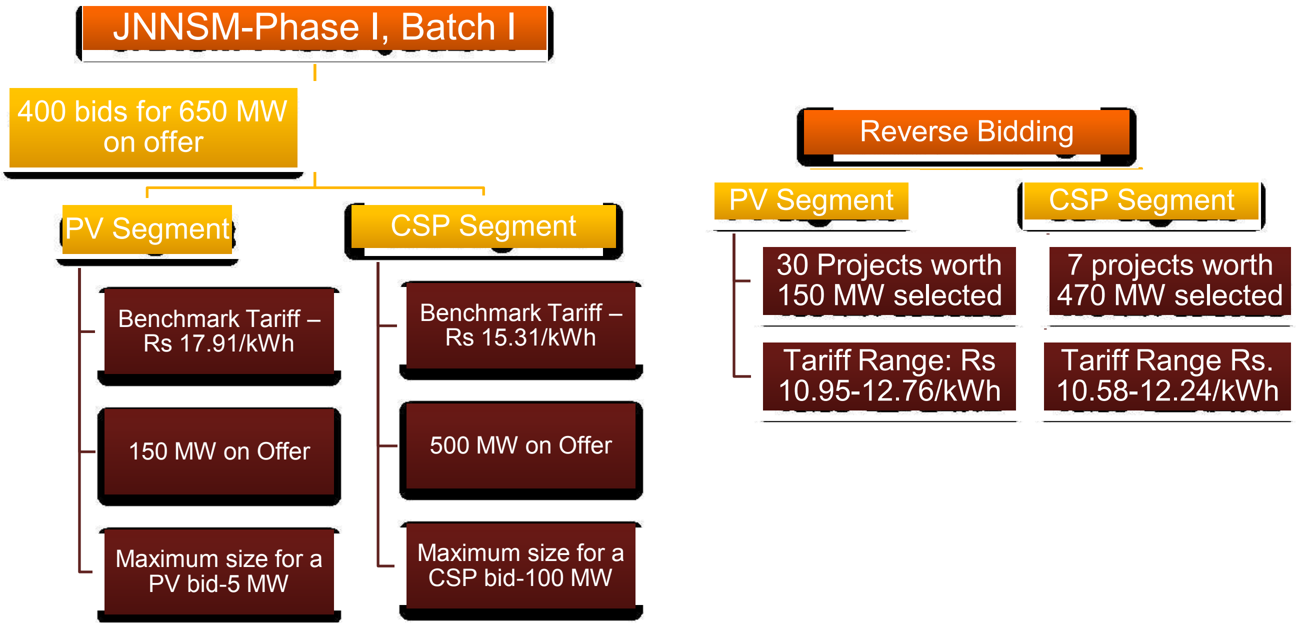
Jawaharlal Nehru National Solar Mission - Aims and Objectives

NAPCC announced by the Hon. Prime Minister of India envisages increasing the share of renewable energy in total electricity consumption in the country and has given special consideration to encourage the base of Solar Power in India. In order to promote the development and use of solar energy for power generation and other uses, the Government of India has launched the Jawaharlal Nehru National Solar Mission (JNNSM) during November 2009. JNNSM is one of the eight key National Missions envisaged under India's NAPCC. The mission has a twin objective - to contribute to India's long term energy security as well as its ecological security. The JNNSM would be implemented in 3 stages and aims to have an installed capacity of 20,000 MW by the end of the 13th Five Year Plan in 2022. It is envisaged that as a result of rapid scale up as well as technological developments, the price of solar power will attain parity with grid power at the end of the Mission, enabling accelerated and large-scale expansion thereafter. The mission includes a major initiative for promoting rooftop solar photovoltaic (PV) applications. The solar tariff announced by the regulators will be applicable for such installations.

The objectives of JNNSM are below:

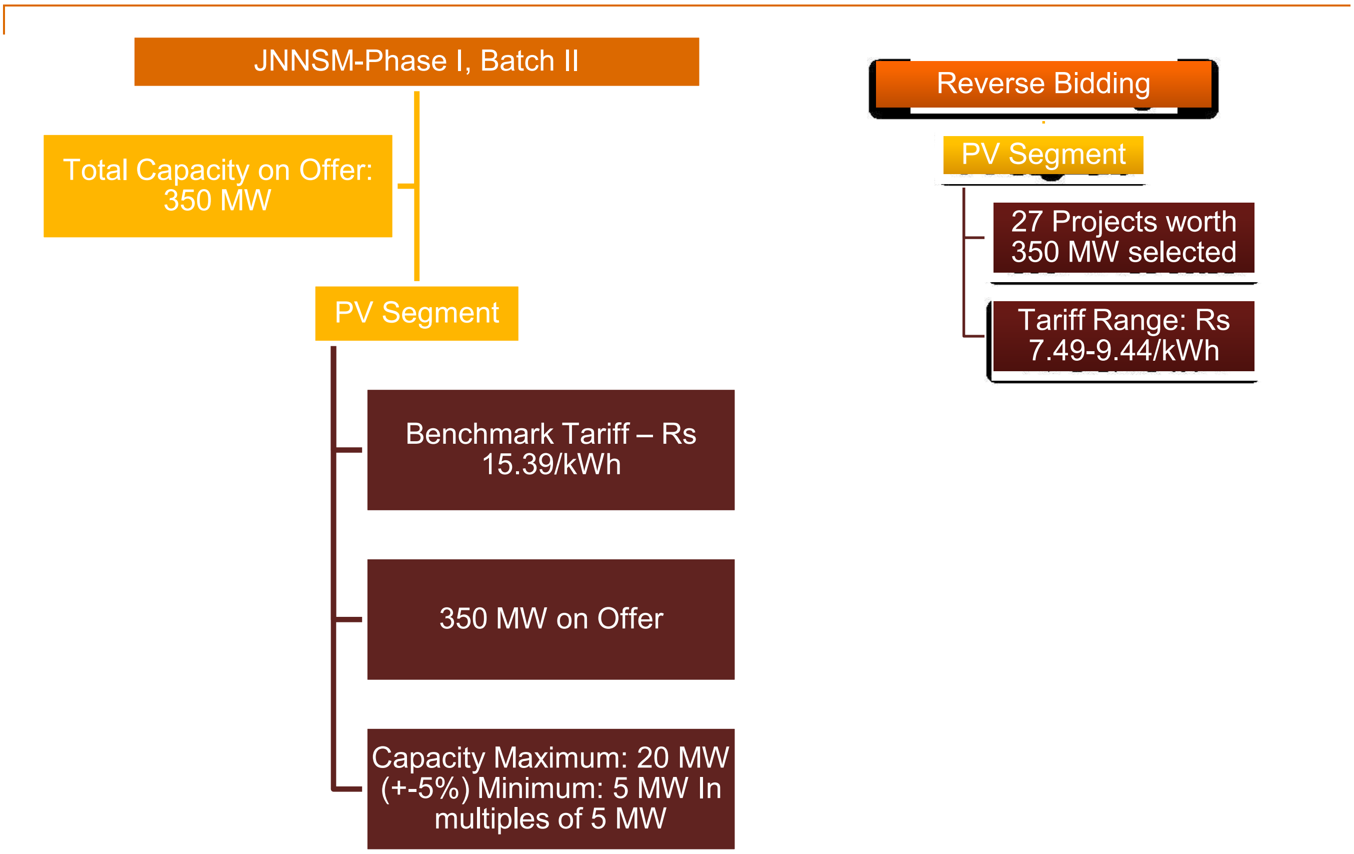
- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To increase capacity of grid-connected solar power generation to 1000 MW within three years – by 2013; an additional 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000MW installed power by 2017 or more, based on the enhanced and enabled international finance and technology transfer.
- The target of 20000MW by 2022 will primarily be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power. The transition could be appropriately up scaled, based on availability of international finance and technology.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programs for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.
- To achieve 15 million square meters solar thermal collector area by 2017 and 20 million square meters solar thermal collector area by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

Based on the objectives as laid in the National Solar Mission (NSM), over 1000MW of solar projects under the first phase, having affiliation to different solar technologies was allotted to the interested bidders. An approach of allowing 'discounted bidding' on the CERC approved 'benchmark tariff' for various solar technologies was envisaged as an instrument for selecting the prospective developers. The Bidding process under the first phase of the National Solar Mission was split into two batches with the understanding that this circumspect approach would leave enough room for rectification if some flaws or shortcomings that may emerge in the first batch of bidding. The following diagrammatic representation gives a snapshot of the bidding process that ensued in the first batch of bidding under the first phase of the Mission. Under the first batch, a total of 30 solar PV projects, each with an individual capacity of 5 MW (total capacity of 150 MW) and solar thermal projects (CSP Segment) with a total capacity of 470 MW were allocated. In addition to the 30 solar PV projects, capacity worth another 84 MW was contributed through the Migration Scheme that permits projects planned before the Mission was launched, to migrate into it and enjoy the incentives offered there under.



As the pictorial representation also suggests, there was substantial oversubscription for projects to start with, and then the government invited reverse bids asking for discounts on the initial benchmark tariff of Rs 17.91/ kWh for PV projects and Rs 15.31/ kWh on CSP projects. Thirty PV projects worth a cumulative capacity of 150 MW and seven CSP projects worth a cumulative capacity of 470MW were selected under Batch I of the scheme. Remarkably, the bidding process did result in exceedingly competitive bids. PPAs have been signed at an average levelized tariff of Rs. 12.16 / kWh for PV projects and Rs. 11.48/ kWh for CSP (thermal) projects, i.e., the government has secured 32.1% and 25% discount respectively in PV and CSP projects.

Building further on the lessons learnt from the first batch of bidding, bids were invited for a cumulative capacity of 350MW in the second batch of Phase I. The entire quota of 350MW was for capacity in solar PV only. CERC revised the benchmark tariff for solar PV in light of the dropping trends in solar equipment prices. The following diagrammatic representation further illustrates the Batch II bidding process and its outcome.



The lowest bid submitted in Batch II, offered more than 50% discount on the CERC benchmark tariff. This lowest bid submitted was for a 5 MW capacity project and the quoted tariff was Rs. 7.49 per KWh. [1]The tariffs quoted by winning bidders in Batch II bidding ranged from Rs. 7.49 to Rs. 9.44 per kWh. This tariff range is remarkably lower than the one discovered in Batch I. In fact, the highest winning tariff in Batch II is almost Rs 1.5 lower than the lowest winning tariff in Batch I. Such a steep drop in tariffs, that too within a short of one year, augurs well for the Indian solar industry and may to some extent be attributed to the adaptive policy framework.

JNNSM thrust towards R&D Initiatives-Development of CSP demonstration projects

Further, JNNSM envisages development of pilot projects of those solar technologies which are not commercially proven. Also, these Pilot demonstration projects are closely aligned with the Mission's R & D priorities and designed to promote technology development and cost reduction. The Mission, therefore, envisages the setting up of the following demonstration projects in Phase I, in addition to those already initiated by MNRE and those, which may be set up by corporate investors:

- 50-100 MW Solar thermal plant with 4-6 hours' storage (which can meet both morning and evening peak loads and double plant load factor up to 40%).
- A 100-MW capacity parabolic trough technology based solar thermal plant.
- A 100-150 MW Solar hybrid plant with coal, gas or bio-mass to address variability and space-constraints.
- 20-50 MW solar plants with/without storage, based on central receiver technology with molten salt/steam as the working fluid and other emerging technologies.

It is further contemplated that such pilot demonstration projects would be allocated to the interested developers who would be showcasing the adequate 'financial and technical' criteria. Further, it is envisaged that 'Generation based Incentive' would be provided to such projects. This initiative would be in the line of Government of India's previous initiative of providing GBI benefits to develop 50MW of solar projects during 2009-10.

[1] EQ International Magazine : www.eqmqglive.com

CERC RE Tariff Regulations -Salient Features

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 61and section 178(2) of the Electricity Act, 2003 had notified the CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources), Regulations, 2012. Applicability of these regulations shall be confined to Central Sector and Inter State Generation projects, however, under Section 61 of EA 2003; these regulations would be guiding principles for State Electricity Regulatory Commissions while dealing with the matters related to energy generation from RE sources. The salient features of the Tariff Regulations applicable for the Solar Projects are as follows:

Salient Features of Tariff Regulations for Solar Energy Projects

Solar PV and Solar Thermal Projects – Based on technologies approved by MNRE	
General Principles	
Resolution	**Provisions in Regulation**
Control Period	Five (5) years
Tariff Period	Solar PV and Solar Thermal Projects – 25 years
Tariff Structure	Single Part Tariff- Fixed components shall be: • Return on Equity • Interest on loan capital • Depreciation • Interest on working capital • Operation and maintenance expense
Tariff Design	The generic tariff shall be on levellised basis for the Tariff Period
Dispatch Principles	a. All plant with installed capacity of 10MW and above shall be treated as 'MUST RUN' power plants and shall not be subjected to 'MOD'
Financial Principles	
Capital Cost	Benchmark Capital Cost for Solar PV and Solar Thermal Projects shall be reviewed annually
Discounting Factor	Weighted Average of Cost of Capital
Debt Equity Ratio	70:30
Loan and Finance Charges	Loan Tenure – 12 years
Interest Rate	a. Average long term prime lending rate (LTPLR) of SBI prevalent during the first six months plus 300 basis points. b. Repayment of loan shall be considered from the first year of COD
Return on Equity	Pre - Tax 20% for first ten years and Pre - Tax24% from eleventh year onward till useful life
Depreciation	a. Value base shall be Capital cost of the asset b. 5.83% for the first twelve years and the rate of depreciation from the 13th year onwards has been spread over useful life
Interest on Working Capital	a. O&M for 1 month b. Receivables for 2 months of energy charge on normative CUF

	c. Maintenance spare @ 15% of O&M expense
Operation and Maintenance Expense	R&M expense + A&G expense + Employee expense Escalated at 5.72% per annum over first year of control period
Rebate	For payment of bills through letter of credit, a rebate of 2% shall be allowed Payments made other than through letter of credit within 1 month of presentation of bills by the generating company, a rebate of 1% will be allowed
Late payment surcharge	Delay beyond the period of 60 days from the date of billing attracts late payment surcharge of 1.25% per month
Sharing of CDM benefits	100% of the gross proceeds to be retained by the developer in the first year In second year, the share of beneficiaries shall be 10% which shall be progressively increased by 10% every year until it reaches 50%, where after the proceeds shall be shared in equal proportion, by generating company and the beneficiaries
Subsidy or incentive	Accelerated depreciation or generation based incentive shall be factored in while determining the tariff
Taxes and duties	Taxes and duties shall be passing through on actual incurred basis.

The RE Tariff Regulations specifies that the benchmark capital cost norm for Solar Power projects shall be reviewed annually. Accordingly, the Commission has specified the benchmark capital cost norm for Solar PV and Solar Thermal projects as Rs. 1000lakh/MW and Rs.1300lakh/MW respectively for 2012-13.

Keeping into consideration the benchmark capital cost norm and other norms specified by CERC, the tariff applicable for Solar PV and Thermal Projects commissioned during 2012-13 stands as Rs. 10.39/kWh and Rs. 12.46/kWh respectively.

CERC IEGC Regulations, 2010 - Analysis of the specific provision

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 79(1) (h) and section 178(2) (g) of the Electricity Act, 2003 had notified the CERC (Indian Electricity Grid Code), Regulations, 2010. This code will be applicable to NLDC, RLDC/SLDCs, ISGS, and Distribution Licensees/SEBs/STUs/regional entities, Power Exchanges and Wind and Solar Generating Stations.

In order to encourage the solar based generation into the electricity grid, the IEGC has given due consideration for such segment. The Grid Code provides that in case the generation from solar power project deviates from the schedule the financial burden shall be borne by all the users of the Inter-State Grid, instead of the concerned solar project developer. The IEGC provides the methodology for rescheduling of solar energy on three (3) hours and the methodology of compensating the solar energy rich state for dealing with variable generation through Renewable Regulatory Charge. In pursuance of this, appropriate meters and data acquisition systems facility shall be provided for accounting of UI charges and transfer of information to SLDC and RLDC. The provisions of the IEGC shall be applicable from January 1, 2011, for new solar generating plants with capacity of 5MW and above connected to 33kV and above who have not signed any PPA with States or others. Some of the key and enabling provisions for solar energy in IEGC are as below,

Provision for Solar Energy under IEGC

Provisions in IEGC,2010	Description
Special conditions for solar (Reg 5.2(u):System security Aspects	• System Operator (SLDC/RLDC) shall make all efforts to evaluate the solar and wind power and treat as a '**Must Run'** Plant. • System Operator may instruct the solar generator to back down generation on consideration of grid security or safety of any equipment or personnel is endangered and solar generator shall comply with same. • For this, data acquisition system facility shall be provided for transfer of information to concerned SLDC and RLDC.
Scheduling of Solar Power (Reg. 6.5(23)(i))	• Schedule of the Solar generation shall be given by generator based on the availability of the generator, weather forecasting, solar insolation, season and normal generation curve and shall be vetted by RLDC and incorporated in inter-state schedule. • If the RLDC is of opinion that the schedule is not realistic, it may ask the solar generator to modify the schedule
Implications of Scheduling	• In case of solar generation no UI shall be payable/receivable by the generator for any deviation in actual generation fro schedule. • The host state shall bear the UI charges for deviation in the actual generation from schedule. • The net UI charges borne by the host state due to solar generation, shall be shared among all the states of the country in ration of their peak demands in previous month based on the data published by CEA, in form of regulatory charge known as Renewable Regulatory Charge operated through the Renewable Regulatory Fund. • The provision shall be applicable, with effect from 1.1.2011 for new solar generating plants with capacity of 5MW and above and connected at 33Kv level and above and who have not signed PPA with states or others as on date of coming into force of this IEGC.

CERC Initiative for Transmission/Evacuation of Solar Power

Under the mandate of statutory provisions of Section 61 of the Electricity Act, 2003 inter-alia para 5.3.4 and para 7.2(1) of the National Electricity Policy and Tariff Policy respectively, Central Electricity Regulatory Commission (CERC) has undertaken the exercise to frame regulations on sharing of transmission charges and losses among the users.

The regulations facilitate the solar based generation by allowing zero transmission access charges for the use of the Inter State Transmission System and allocating no transmission loss to the solar based generation. Solar power generators shall be benefited in event of use of the ISTS. Since such generation would normally be connected at 33 kV, the power generated by such generators would most likely be absorbed locally. This would cause no / minimal use of 400 kV ISTS network and might also lead to reduction of losses in the 400 kV network by doing away the need for power from distant generators. The cost of energy from solar based generation is perceived to be costly as compared to other sources, including renewable energy sources, and further application of ISTS charges and losses would further reduce the acceptability of power generated from solar sources. This regulation thus encourages solar based generation and inter-state transactions based on solar energy.

State Level Initiatives and Development Targets

Spurred by national level initiatives and policy push, several states like Gujarat, Rajasthan, Madhya Pradesh, Karnataka and Jammu & Kashmir have also formulated and adopted solar policies for development of solar energy projects in their respective states. Salient Features of these policies have been discussed herewith.

Gujarat

- Gujarat, among all the other states, has taken the lead and already allotted projects worth a cumulative capacity of 716 MW to 34 national and international project developers against the declared 500 MW in their policy. Of the 716 MW, 365 MW has been allocated to Solar PV and the remaining 351 MW to Solar Thermal Power plants.
- Major players in the state include AES Solar, Astonfield Solar, Azure Power Ltd. with allotments ranging from 5 to 50 MW.

Rajasthan (Draft)

- Rajasthan has set a target of developing 10,000-12,000MW solar power capacity in the next 10-12 years.
- It has been mandated that 200MW of solar power shall be developed till 2012-13 and an additional 400MW power shall be developed between 2014 and 2017. The State also plans to develop 1000MW of solar parks

Madhya Pradesh (Draft)

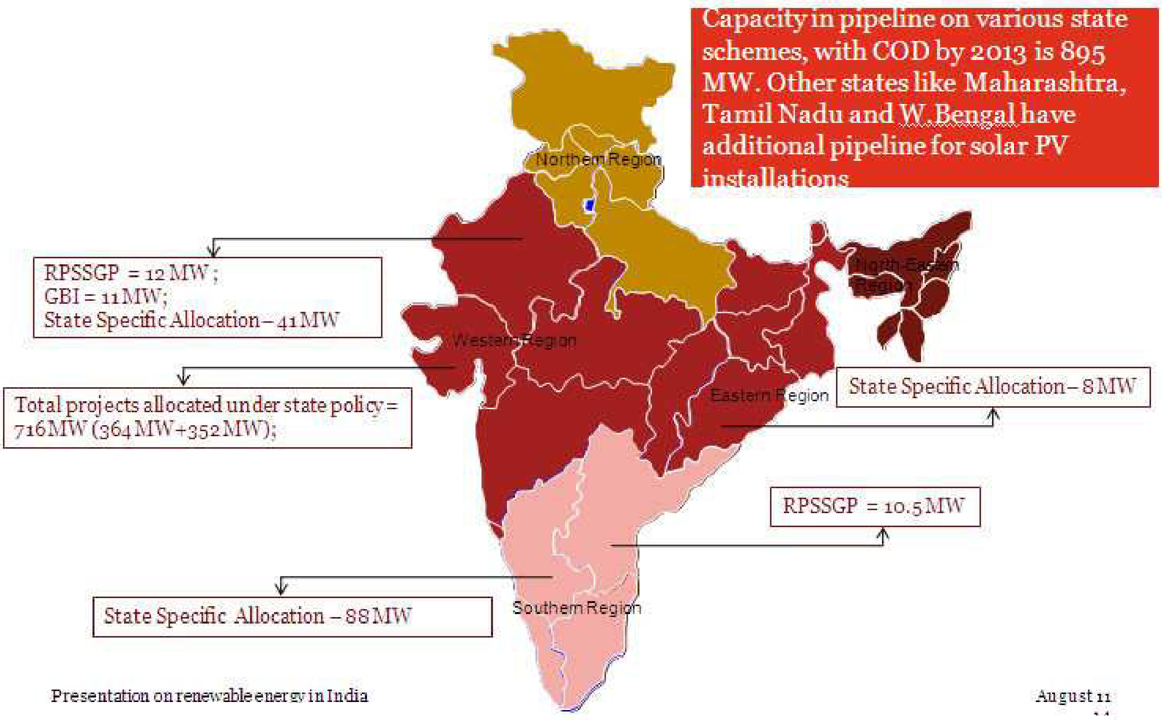
- Madhya Pradesh targets a total solar power capacity development of 500MW.
- The facility of wheeling solar power, exemption of open access charges and electricity duty shall be extended to developers and distributors
- Power evacuation facility shall also be extended to concerned licensees.

Jammu & Kashmir

- Under this policy, prior weightages to be given to financial capacity, technical capability, past experience and other relevant attributes of the applicants, the sub-categories of these attributes to be evaluated and their inter-se weightage, the guidelines for evaluation and the passing score on attributes /in aggregate required for pre-qualification shall be specified in the bid documents inviting bids for pre-qualification.
- The minimum project capacity shall be 1 MW. However, if MNRE launches any scheme for lower capacity power plant then that shall also be considered.

Karnataka

- Karnataka targets a total solar power capacity development of targeting capacity addition in solar power projects by 350 megawatts by 2016.
- The solar PV projects that plan to sell their electricity to state utilities at preferential tariff have to have a capacity of between three and 10 MW.
- To keep the costs lower, policy allows developers to inject power at 11kV and above.



Solar Thermal Technology- An Introduction

Concentrating solar power (CSP) plants produce electricity by converting the infrared part of solar radiation into high temperature heat using various mirror/reflector and receiver configurations. The heat is then channelled through a conventional generator. The plants consist of two parts: one that collects solar energy and converts it to heat, commonly known as 'solar field' and another that converts heat energy to electricity, known as 'power block'.

CSP plants use the high-temperature heat from concentrating solar collectors to drive conventional types of engines turbines. For power generation, temperatures more than 200 °C are preferred. All CSP are based on four basic essential sub systems namely collector, receiver (absorber), transport/ storage and power conversion.In solar collectors of such systems, the incoming radiation is tracked by mirror fields/lenses which concentrate the energy towards absorbers. The absorbers receive the concentrated radiation and transfer it thermally to the working medium, hereby transferring the heat energy to it. The heated fluid may reach high temperatures and may be used for driving the turbine to generate power. The heat carrier in these systems can be oil, molten salts, pressurized water or steam.

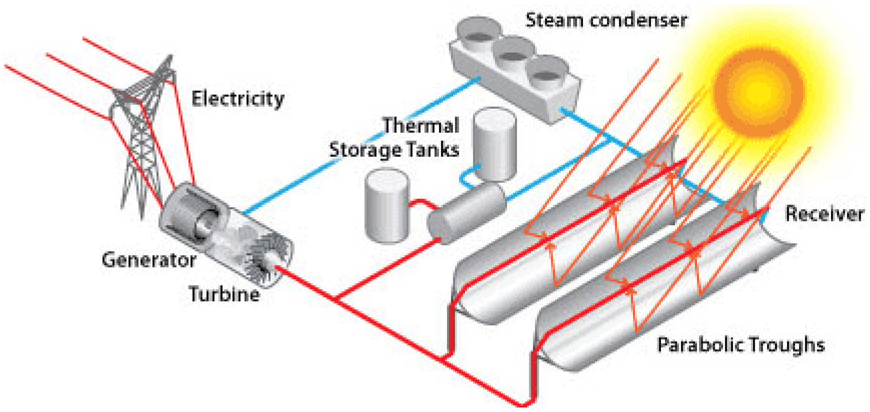
Different concentrating technologies have been developed or are currently under development for various commercial and Industrial applications as well as power generation. Such solar thermal concentrating systems can significantly contribute to efficient and economical, renewable and clean energy supply.

Following four CSP technologies have either reached commercialisation stage or are near it:

- Parabolic Trough
- Power towers
- Parabolic Dishes (Dish-Stirling)
- Compound Linear Fresnel Reflectors (CLFR)

Parabolic Trough

The parabolic-trough solar concentrators are one of the basic elements of a concentrating solar power plant. The main elements of the plant based on the parabolic trough technology are: the solar field, the storage system, the steam generator and the auxiliary systems for starting and controlling the plant.



(Source: NREL)

Several collector elements of the solar field are composed in series to create the single collector line. The collected thermal energy is determined by the total number of collector elements which are characterized by a reflecting parabolic section (the concentrator), collecting and continuously concentrating the direct solar radiation by means of a sun-tracking control system to a linear receiver located on the focus of the parabolas. Parabola has the property of focussing the incoming radiation as its focus. Working on this principle, linear concentrators of parabolic shape are usually mirrors or highly reflective surfaces and can be turned in angular movements towards the sun position and concentrate the incoming solar radiation onto a long-line receiving absorber tube. The mirror is anchored at four points to the steel structure. The mirrors, mountings and adhesives all have the same expansion coefficient, guaranteeing durability even under extreme temperature fluctuations. The mounting elements are made from special ceramics giving them a high level of mechanical strength and are non-corrosive. The absorber pipe is composed of a multi-layered stainless-steel pipe, with an absorption level of around 95% and radiation level of approximately 14% of its heat at temperatures of around 400 degrees Celsius. The steel pipe is surrounded by a vacuum-isolated concentric borosilicate glass cladding tube with anti-reflective coating, which allows for over 96% penetration of solar radiation.

A heat transfer fluid, circulating in the pipe, is used to transfer the absorbed solar energy, which is then piped to an exchanger or a conventional conversion system. 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. Parabolic trough systems cannot make use of diffuse irradiation as they use only direct-beam sunlight and require tracking systems to keep them focused toward the sun and are best suited to areas with high direct solar radiation. Most systems are oriented north-south with single-axis tracking during the day. The integration of heat storage allows the power plant to function at full capacity both on overcast days and at night

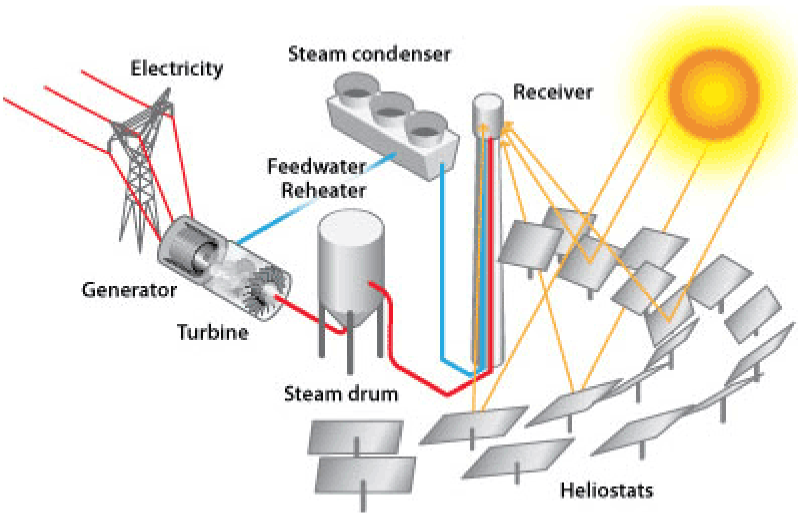
Storage system is the integral and an important part of the parabolic trough based power plants. Thermal Energy Storage (TES) option can collect energy in order to shift its use to later times. Hence, the functional operativeness of a solar thermal power plant can be extended beyond periods of no solar radiation without the need of burning fossil fuel. The most advanced technology for heat storage in trough collector plants considers the use of a two-tank molten salt system which functions like a thermos flask and are able to assure that the salt maintains its temperature and decrease the thermal losses. The used power conversion systems are based on the conventional Rankine-cycle steam turbine generator.

Several Parabolic trough based power generation plants are in operation. SEGS, California is a collection of 9 plants with a combined capacity of 350 MW. Nevada Solar, completed in 2007 has a capacity of 64MW. Andasol, Spain has 4 power plants with a combined capacity of 50MW.

Solar Tower (Central Receiver Systems)

Central receiver systems use heliostats to track the sun by two axes mechanisms following the azimuth and elevation angles with the purpose to reflect the sunlight from many heliostats oriented around a tower and concentrate it towards a central receiver situated atop the tower. A heat-transfer medium is employed in the central receivers to absorb the highly concentrated radiation reflected by the heliostats and converts it into thermal energy, which is used to generate superheated steam for the turbine.

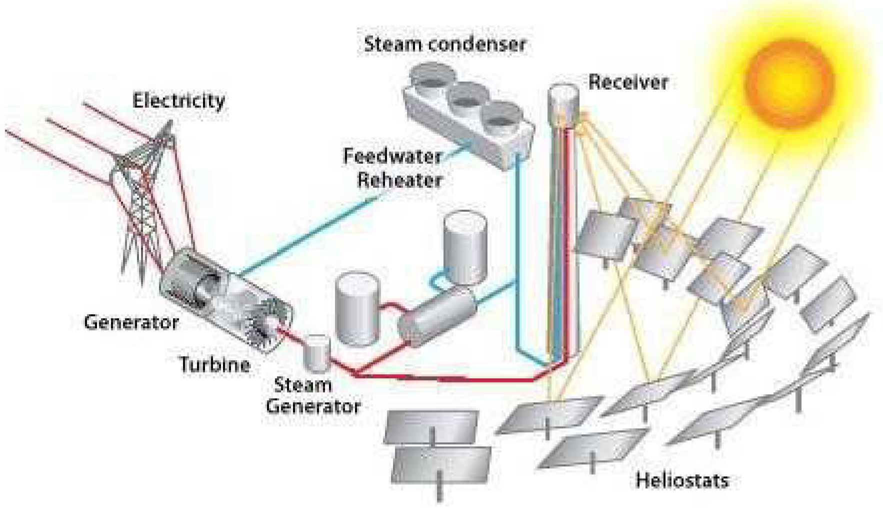
This technology has the advantage of transferring solar energy very efficiently by optical means and of delivering highly concentrated sunlight to one central receiver unit, serving as energy input to the power conversion system. In spite of the elegant design concept and in spite of the future prospects of high concentration and high efficiencies, the central receiver technology needs still more research and development efforts and demonstration of up-scaled plant operation to come up to commercial use in Indian conditions. Its main attraction is the prospect of achieving higher process temperatures than other CSP technologies, by concentrating solar irradiation to supply energy to the topping cycle of any power conversion system. This technology can also increase the efficiency of energy storage systems.



(Source: NREL)

Different receiver heat transfer media that have been successfully used are water/steam, liquid sodium, molten salt, ambient air, oil. To date, the heat transfer media demonstrated include water/steam, molten salts and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to have an early energy conversion cycle as in a combined cycle power plant, increasing the global efficiency.

The diagram above illustrates the layout of a central receiver based CSP plant with direct steam production and steam drum storage. A more efficient approach is using molten salt as the heat transfer fluid and for storage. Liquid salt, after absorbing heat through the receiver can withstand and effectively transfer heat at temperature range 200°C - 700°C and can be stored for use during night. Hot salt can be pumped to a steam generating system that produces superheated steam through conventional Rankine cycle. Storage tanks can be designed with sufficient capacity to power a turbine at full output for up to 13 hours. The process layout for solar tower with storage is shown below:



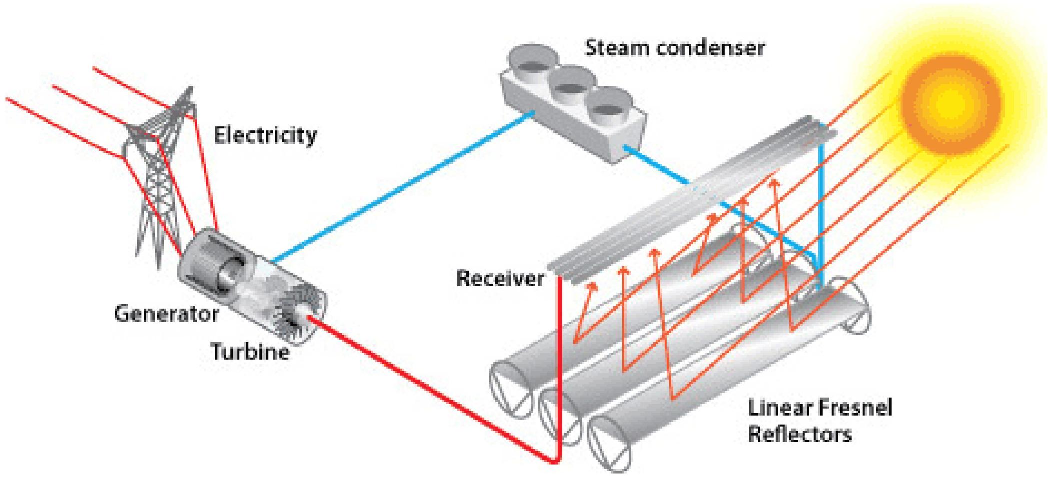
Heliostats that track the sun and reflect the rays to the absorber are to be designed and laid out carefully to optimize the annual performance of the plant. The energy collection in the tower is directly proportional to the heliostat field which is in turn determined by the number of heliostats and their area. The project has to be designed such that steam requirement of the turbine is fulfilled and there is enough energy left to consequently charge the thermal storage system for power production during non sunny weather. Future solar tower plants have the good long-term perspective for high conversion efficiencies and for use of very efficient energy storage systems by utilization of high temperatures in order to enlarge the solar capacity or solar share.

In 2008, a 4-6 MW a solar power plant came up in Israel's Negev Desert. The site features more than 1,600 heliostats that track the sun and reflect light onto a 60 meter-high tower. The concentrated energy is then used to heat a boiler atop the tower to 550 °C, generating superheated steam. A working tower power plant is PS10 in Spain with a capacity of 11 MW; composed of 624 heliostats and a field area of 75,000 m^2, concentrating the radiation onto a receiver located on tower that is 115 m tall. Subsequently, PS20 was also build with thermal storage to boost power production under non-sunny conditions. The PS20 solar field has 1,255 heliostats and tower of 160 m.

The 15MW Solar Tres plant with heat storage is under construction in Spain. A 10MW power plant in Cloncurry, Australia uses Graphite for heat storage. Morocco is building five solar thermal power plants. The sites will produce about 2000 MW by 2012.

Linear Fresnel

The Linear Fresnel technology uses long, flat or slightly curved mirrors to focus sunlight onto a linear receiver located at a common focal point of the reflectors. The receiver runs parallel to and above the reflectors and collects the heat to boil water in the tubes, generating high-pressure steam to power the steam turbine (water/direct steam generation, no need for heat exchangers). The heat thus generated is then channelled through a conventional steam generator to generate electricity.



(Source: NREL)

The reflectors make use of the Fresnel lens effect, which allows for a concentrating mirror with a large aperture and short focal length. This reduces the plant costs since sagged-glass parabolic reflectors are typically much more expensive. The collector field comprises mirrors in parallel rows aligned on a north-south axis which enables the single-axis mirrors to track the sun from east-west direction to ensure that the sun is continuously focused on the receiver pipes/absorber tubes. The amount of power generated by the Linear Fresnel plant depends on the amount of direct sunlight and these technologies use only direct-beam sunlight, rather than global horizontal irradiation. The plant configuration and the layout depends on the project developer but initial installations had mirrors having a width of 0.5 m, arranged in rows and focusing the rays on a fixed receiver tube, along the length of the mirrors.

Since the optical efficiency as well as the working temperatures are considerably lower than with other CSP concepts, saturated steam conditions are mostly considered for this technology. Alternatively, heat could be stored in high-temperature storage mediums and superheated to ultimately drive steam turbines, thus providing greater efficiencies. The receiver is stationary and so fluid couplings are not required (as in troughs and dishes). The mirrors also do not need to support the receiver, so they are structurally simpler. When suitable aiming strategies are used (mirrors aimed at different receivers at different times of day), this can allow a denser packing of mirrors on available land area.

Linear Fresnel plants can also be "hybrids," and can supplement the solar output during periods of low solar radiation and in night through fossil fuels, normally with a natural gas-fired heat or a gas steam boiler. CLFR can also be integrated with existing coal-fired plants.

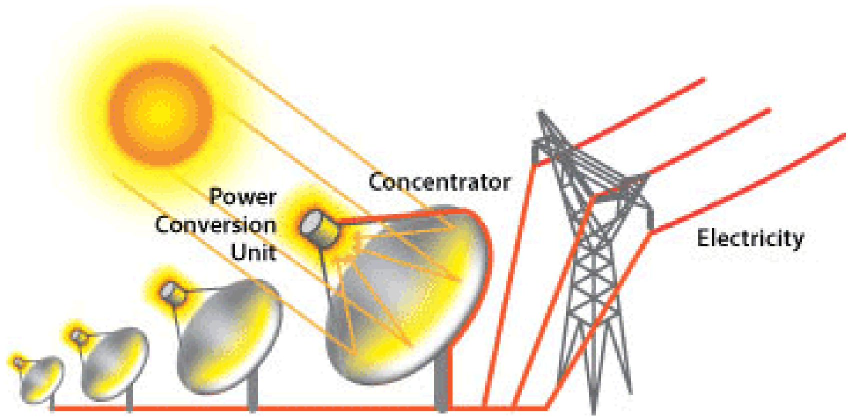
Unlike other CSP technologies, the material requirements for CLFR are very simple and the structure is lighter, leading to reduced setup costs and operational costs. Also, the mirrors are packed closer, have simpler tracking system, and are less affected by higher wind speeds and rain. Fresnel mirrors are simple, cheaper and lighter than parabolic trough mirrors, leading to a simplified plant design compared to other CSP technologies.

Major CLFR Project developers include AREVA Solar (Ausra), Novatec Solar, SPG etc. In 2008, the German Solar Power Group GmbH started execution of a solar thermal power plant in central Spain, the first commercial solar thermal power plant in Spain based on the Fresnel collector technology. The planned size of the power plant will be 10 MW.

Since 2009, the Fresnel solar power plant of Novatec Biosol is in commercial operation in southern Spain. The solar thermal power plant is based on linear Fresnel collector technology where the absorber tube is positioned in the focal line of the mirror field in which water is evaporated directly into saturated steam at 270 °C and at a pressure of 55 bar by the concentrated solar energy. Ausra has finished construction of the 5 MW Kimberlina Solar Thermal Energy plant in Bakersfield, California and also built a linear fresnel reflector plant in New South Wales, Australia to supplement a coal fired plant.

Parabolic Dish Systems

Dish/engine systems convert the thermal energy in solar radiation to mechanical energy and then to electrical energy in much the same way that conventional power plants convert thermal energy from combustion of a fossil fuel to electricity. A paraboloid dish-shaped reflector (commonly called as parabolic dish) concentrates sunlight on to a receiver located at the focal point of the dish. Dish systems use these parabolic reflectors to focus the sun's rays onto a dish-mounted receiver at its focal point. This requires that the dish track the sun in two axes. In the receiver, a heat-transfer medium takes over the solar energy and transfers it to the power conversion system, which may be mounted in one unit together with the receiver (e. g. receiver/Stirling engine generator unit) or at the ground. Due to its ideal optical parabolic configuration and its two axes control for tracking the sun, dish collectors achieve the highest solar flux concentration, and therefore the highest performance of all concentrator types in terms of peak solar concentration and of system efficiency.



(Source: NREL)

Dish systems may optionally be arranged in large dish arrays in order to accumulate the power output from the kWe capacity up to the MWe range. The power conversion subsystem of dish systems is mainly based on the Stirling engine generator system, but also on the water/steam powered turbine or piston engine generator system or on the gas turbine generator system.

Dish/engine systems utilize concentrating solar collectors that track the sun in two axes. A mirror or a reflective surface reflects incident solar radiation to a small region called the focus. The size of the solar concentrator for dish/engine systems is determined by the engine. At a nominal maximum direct normal solar insolation of 1000 W/m^2, a 25-kW dish/Stirling system's concentrator has a diameter of approximately 10 meters. The most durable reflective surfaces have been silver/glass mirrors, similar to decorative mirrors used in the home. Attempts to develop low-cost reflective polymer films have had limited success. Because dish concentrators have short focal lengths, relatively thin glass mirrors (thickness of approximately 1 mm) are required to accommodate the required curvatures. In addition, glass with low-iron content is desirable to improve reflectance. Depending on the thickness and iron content, silvered solar mirrors have solar reflectance values in the range of 90 to 94%.

The ideal concentrator shape is a paraboloid of revolution. Some solar concentrators approximate this shape with multiple, spherically-shaped mirrors supported with a truss structure. An innovation in solar concentrator design is the use of stretched-membranes in which a thin reflective membrane is stretched across a rim or hoop.

Dish system also utilise receivers which absorbs energy reflected by the concentrator and transfers it to the engine's working fluid. The absorbing surface is usually placed behind the focus of the concentrator to reduce the flux intensity incident on it. Stirling engine receivers are the most commonly used engine receivers where the concentrated solar energy is transferred to a high-pressure oscillating gas, usually helium or hydrogen. Generally there are two types of Stirling receivers, direct-illumination receivers (DIR) and indirect receivers where intermediate heat-transfer fluid is being used. Directly-illuminated Stirling receivers adapt the heater tubes of the Stirling engine to absorb the concentrated solar flux. Because of the high heat transfer capability of high-velocity, high-pressure helium or hydrogen; direct-illumination receivers are capable of absorbing high levels of solar flux.

The engine employed in the dish system converts heat to mechanical power in a manner similar to conventional engines, that is by compressing a working fluid when it is cold, heating the compressed working fluid, and then expanding it through a turbine or with a piston to produce work. The mechanical power is converted to electrical power by an electric generator or alternator. A number of thermodynamic cycles and working fluids have been considered for dish/engine systems. These include Rankine cycles, using water or an organic working fluid; Brayton, both open and closed cycles; and Stirling cycles.

Dish systems with supplementary combustion of fossil fuels integrated into the receiver component are a better solution for Industries as solar energy is not available 24 hours a day, even with thermal storage. Such systems are currently under development and are expected to be available for first demonstration projects in the near-term run.

Dish/engine systems are characterized by high efficiency, modularity, autonomous operation, and an inherent hybrid capability (the ability to operate on either solar energy or a fossil fuel, or both). Of all solar technologies, dish/engine systems have demonstrated the highest solar-to-electric conversion efficiency. The modularity of dish/engine systems allows them to be deployed individually for remote applications, or grouped together for small-grid (village power) or end-of-line utility applications.

In January 2010, Stirling Energy Systems commissioned a 1.5-megawatt power plant using Stirling technology in Peoria, Arizona.

Comparison of various CSP technologies

	Parabolic trough	Solar Dish	Solar Tower	Linear Fresnel
Working Temp.	150- 600 °C	Upto 1000 °C	Upto 1000 °C	Upto 400 °C
Conversion Efficiency	Around 20 %	Around 30 %	Around 20-25 %	Around 15-20 %
Concentration ratio	10-100	1000-4000	600-1000	10-100
Storage	Possible	Not possible	Possible	Possible
Area required (Acre/MW)	7-8	7-10	8-12	4-5
Commercial status	Commercial	Some pilot projects in the country	Only prototypes under Demo	Pre-commercial
Thermodynamic power cycle	Rankine	Stirling, Brayton	Brayton, Rankine	Rankine
Tracking	Single axis	Double axis	Double axis	Single axis
Advantages	Long-term proven reliability and durability	High temperature allows high efficiency of power cycle	High temperature allows high efficiency of power cycle	Simplified plant design, lower investment and operational costs
	Storage options available	High tolerance of variation in land slope	Tolerates non-flat sites	Tolerance for slight slopes, modularity in system
	Direct steam generation proven	High Modularity	Possibility of combined power cycles	Direct steam generation proven
	Highest number of commercial installations	High efficiency	Ability to provide high-temperature steam, higher generation efficiencies	minimized structural costs, low wind loads, and lower maintenance costs
	Better R&D experience; hybridization and storage optional	Great modular system; hybridization is optional	High conversion efficiency; storage and hybridization option	Small operation experience; storage and hybridization option
Disadvantages	Limited temperature of heat transfer fluid hampering efficiency and effectiveness	Not commercially proven in India	High maintenance and equipment costs	Storage for direct steam generating systems (phase change material) in very early stage
	Complex structure, high precision required during construction	High complexity compared to stand-alone PV	High land requirements	Larger area requirement cannot be placed close to process setup.
	Requires flat land area			Low efficiency

The above sections provide insight about the salient features of the CSP technology required for generating power. It needs pertinent mentioning some of the components, sub-systems used in all the aforementioned technologies are common in nature and play an important role in the functioning of the systems. Some of the typical components of the CSP plant which have a common bearing with all the technologies are as follows:

CSP Plant			
Solar Block		Power Block	Balance of Plant (BOP)
Solar Field	Thermal Storage	• Steam Generator • Turbine • Power Generator • Condensers • Transformer • Cooling Tower	• Pipes • Electric cables • Pressure Vessels • Water tanks
• Receiver • Reflecting Panels (Heliostats, mirrors) • Tracking System • Heat transfer fluid (Water, oil, salt, air) • Hydraulic drive • Supporting structures • Civil Works	• Storage medium ✓ Molten salts ✓ Metals ✓ Ceramic/porcelain • Circulation pump • Storage tanks • Insulation		

Solar field is not particular to any project. Typically in all technologies solar field is made of:

- Receiver: Receivers are either made of evacuated tubes, normal steel pipes or special cavities. The receiver tube has the co-axial structure made of external glass tube and concentric steel tube where heat transfer fluid flows. Coating on the steel tube ensures maximum absorption of the solar light spectrum with maximum re-emission by the hot tube surface. Vacuum stability in the room between glass and the steel tube is guaranteed by getter material stratified on the glass surface.
- Heliostats, mirrors and reflecting surfaces: Parabolic troughs, Fresnel mirrors, heliostats or parabolic dishes all are mirror based. The mirrors are either curved or flat and either glass-silver or high-reflectivity aluminium surfaces. A heliostat usually uses a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky. In the heliostat reflective surface of the heliostat is kept perpendicular to the bisector of the angle between the directions of the sun and the target as seen from the mirror. In almost every case, the target is stationary relative to the heliostat, so the light is reflected in a fixed direction. Heliostats are essentially distinguished from solar trackers or sun-trackers that point directly at the sun in the sky. However, some older types of heliostat incorporate solar trackers, together with additional components to bisect the sun-mirror-target angle. A conventional design for the heliostat's reflective components utilizes a second surface mirror. The sandwich-like mirror structure generally consists of a steel structural support, an adhesive layer, a protective copper layer, a layer of reflective silver, and a top layer of tempered float glass. Conventional heliostat is often referred to as a glass/metal heliostat. Alternative designs incorporate recent adhesive, composite, and thin film research to bring about materials costs and weight reduction.
- Tracking System: A solar tracker is a kind of device that exhibits the property of orienting various payloads toward the sun. Payloads can be any type of optical devices. The primary benefit of a tracking system is to collect solar energy for the longest period of the day, and with the most accurate alignment as the Sun's position shifts with the seasons. In addition, the greater the level of concentration employed the more important accurate tracking becomes, because the proportion of energy derived from direct radiation is higher, and the region where that concentrated energy is focused becomes smaller. Generally the tracking system can be classified as the single axis tracking system and the double axis tracking system. Single axis trackers have one degree of freedom that acts as an axis of rotation. Single axis system can be aligned in any direction with advanced tracking algorithms. There are several common implementations of single axis trackers. These include horizontal single axis trackers (HSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT). Dual axis trackers have the flexibility for two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis. Dual axis systems are classified by the orientation of their primary

axes with respect to the ground. Two common implementations are tip-tilt dual axis trackers (TTDAT) and azimuth-altitude dual axis trackers (AADAT).

- Heat Transfer fluid: HTF are usually artificial oils with altered boiling and/or freezing points, water - deaerated – air, gases and molten salts – phase changing materials that become liquid when heated. Traditionally mineral oil is being used as the heat transfer fuel which is also inflammable and toxic in nature. This type of heat transfer fluid has low specific heat and temperature restrictions to operate which further limits the operating temperature of the plant. Molten salt as the heat transfer fluid is specially formulated for solar applications that demand the optimum purity and performance. It has superior heat transfer compared to other fluids in its class. It also exhibits high thermal stability but however it has high freezing point rendering it difficult to operate it at regions with high ambient temperature. Improved heat transfer efficiency reduces a system's total energy requirements, and increases system longevity. The more efficient the heat transfer system is, the less energy that is required to maintain the bulk operating temperature of the fluid.
- Hydraulic Drives: Collector units of the solar field has its own solar sensors and the hydraulic drives which enables the mirrors to track the position of the sun and also allows the collector unit to track the sun along with its changing path. The hydraulic drives can adjust the 150 meter long collector chains with a precision of up to a tenth of millimeter allowing them to follow the sun on its daily course from east to west along a single axis.

Thermal storage section constitutes the important section of the CSP based power projects. Storage system can allow the operation of the plants to take place on the continous and regular basis. Moreover, it also helps in increasing the operational temperature of the plant and thereby contributing towards enhancement of operational efficiency of the power plant. Important constituents of the storage section are as follows:

- Heat storage systems/tanks: Thermal Energy Storage (TES) option can collect energy in order to shift its use to later times, or to smooth out the plant output during irregularly cloudy weather conditions. Hence, the functional operativeness of a solar thermal power plant can be extended beyond periods of no solar radiation without the need of burning fossil fuel. Periods of mismatch among energy supplied by the sun and energy demand can be reduced. Concrete based heat storage systems are the most effective heat storage systems in the operation.

  Generally the Thermal Storage System is largely composed of two tanks, the cold tank that contains the storage medium at lower temperature and the hot tank that contains the storage medium at a higher temperature. Other components of the heat storage system are:
  - ✓ Storage medium inventory;
  - ✓ circulation pumps;
  - ✓ Piping.

  In presence of direct solar radiation the medium is pumped out from the cold tank to circulate in the solar field and is finally heated up to a higher temperature to be accumulated in the hot tank. When steam production is requested a medium flow is taken from the hot tank, circulated through the steam generator and finally re-collected in the cold tank.

- Storage medium: Storage of the heat on the short term basis can be provided by the fire-bricks, ceramic oxides, fused salts which melts at higher temperature Hitech, a fused salt mixture which is stable upto 540 °C is also identified as the promising energy storage medium. Current work is also carried by rocks, eutectic salts, and some synthetic organic materials of low pressure such as Gilotherm. For choosing a conventional storage material, its energy density, thermal conductivity, corrosion characteristics, cost and convenience to use as well as operating temperature of the fluid is diagnosed. The storage space must be also well insulated against heat losses.

Rationale for site selection for CSP projects

In order to select the optimal sites for the CSP demo projects, the Ministry of New and Renewable Energy (MNRE) sent invitations to states and asked for recommendations for the projects. The recommendations were based on meeting site requirements for two categories of CSP projects. The first category contained 3 of the 7 projects which had specific requirements which could be met only at specific sites, and the second category contained the remaining 4 of 7 projects which had no site specific requirements and could be located anywhere. The following table lists these two types of projects.

Site Specific Projects	Non-site Specific Projects
CSP project with storage (>= 10 hours)	CSP project with biomass support (Solar >= 60%)
CSP project with high operating temperature (>=500°C)	CSP project with gas support (Gas usage <= 30%)
CSP project with hybrid cooling (water <= 30%)	CSP project augmenting a coal fired power plant
	CSP project using Stirling Engines

MNRE laid out a detailed information template that had to be filled out for each recommended site. These requirements included parameters like status of land ownership, power evacuation facilities, water and road availability and geographical parameters like average ambient temperature, humidity, rainfall, endemic flora and fauna etc.

In response to MNRE's invitation of recommendations, 5 states – Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh and Karnataka - responded with potential locations along with the information described above. Based on this data, MNRE conducted a short-listing exercise to select the final candidate sites for the projects. This short listing was based on a quantitative scoring scale with specific points being assigned to specific site-attributes, as described below.

#	Site Attribute	Evaluation Criteria
1	Power evacuation	Not constructed = excluded; constructed/under construction = 5 points
2	GSS Type	no 110 KV or 132 KV GSS = excluded; otherwise: 5 points
3	Distance to the site	less than 1 km = 5 points <10 km = 4 points <20 km = 3 points and so forth with >50 km = 0 points

4	Water availability	Not available = excluded;
		with limitations = 2 points;
		no limitations = 5 points;

5	Acquired land	acquired = 5 points;
		under acquisition = 3 points;
		not acquired/to be acquired = 0 points

6	Area	less than 50 hectares = excluded; largest area: 5 points (all the rest proportionally scored)
7	Access to the site	no access = excluded; otherwise = 5 points
8	Populations nearby	< 1000 = 5 points; < 2000 = 4 points and so forth with < 50000 = 1 point
9	DNI	less than 5 KWh/m2 = excluded; highest DNI = 5 points (all the rest proportionally scored)
10	Solar Park	in existing/construction Solar Park = 5 points; in solar park being planned = 3 points

Based on this scoring metric, the following table shows the final candidate sites.

State	Proposed Location	Included	Reasons for exclusion
Rajasthan	Bhadla	Yes	Ok*
Rajasthan	Mathnia		no water
Rajasthan	Ramgarh		small size
Gujarat	Harshad		not ready
Gujarat	Charanka	Yes	Ok
Tamil Nadu	Kulathur		land issues
Tamil Nadu	Terkuveerapandiyapuram	Yes	Ok
AP	Gadwal		big boulders
AP	Ramagundam		not ready
AP	Nennal	Yes	Ok
AP	Gurajala		limestone slabs and river embankment
AP	Rajamundry		low DNI
Karnataka	Tulasigere		stone and rocky soil

* site has a GSS under construction, but will use a nearby existing GSS in the meantime

For each of the 4 selected sites, the respective state government is asked to provide a letter of comfort stating that:

- Land will be allotted
- Power evacuation will be available
- Water will be available
- Accesses will be made available, if required

These aspects along with the technical short-listing process described above will ensure that the sites selected for the demo projects are optimal choices.

Chapter 2: Technical Feasibility assessment

Project specific site details

Based on a quantitative scoring scale with specific points being assigned to specific site-attributes, and through field visits of the probable sites, the optimal sites selected for the demonstration projects were Bhadla (Rajasthan), Charanka (Gujarat), Terkuveerapandiyapuram (Tamil Nadu) and Nennala(Andhra Pradesh). Based on a careful consideration of physical and technical attributes like solar radiation level, availability of water, evacuation infrastructure, land area requirement etc., each of these four sites had to be selected for any of the following three proposed configurations:

Project configurations	Size of project (MW)	Maximum No. of Projects
CSP project with storage (>= 10 hours)	10-100	2
CSP project with high operating temperature (>=500°C)	20-100	1
CSP project with hybrid cooling (water <= 30%)	20-100	1

CSP is viable only in regions with high level of solar irradiance. CSP technologies, other than Stirling dish use Rankine cycle to convert heat energy to electricity through use of conventional steam generators. Water is consumed for steam production as well as for cooling/condensation. Thus water requirement is an important issue with CSP plants because areas with high DNI i.e. with higher sun intensity mostly correspond to places where there is scarcity of water. Considering the fact that water is the primary issue in Bhadla, hybrid cooling has been selected for this location. Hybrid cooling thus employed will reduce water consumption in the plant and the higher DNI will compensate for the reduced efficiency that hybrid cooling plants have compared to conventional wet cooling.

The size of the collector field for CSP plant, particularly one designed to provide heat-storage is high. The land requirement for a plant with thermal storage is almost 3 times and may go even higher than a plant without storage. Additionally there is some area requirement for storage equipments/mediums which may be as high as 15 % of the entire area. All the four sites have almost the same available land area with Nennala and Terkuveerapandiyapuram, having 160 hect. available area which is slightly more than 140 hect. available in Charanka. Also, the CUF is higher with plants with storage provisions as the hours of operation increase by the storage time and hence the water requirement increases drastically. Availability of water is thus a critical issue that needs to be addressed while considering storage for CSP plants. CSP plants require continual water supply for steam generation, cooling and cleaning solar mirrors. Considering these two factors, Nennala (Andhra Pradesh) and Terkuveerapandiyapuram (Tamil Nadu) were chosen for large storage configurations. Nennala benefits from a natural availability of water and is a green land bordered by agricultural lands.

Terkuveerapandiyapuram benefits from a natural availability of water and is a green land bordered by some patches of agricultural lands and several thermal power plants. The DNI is quite good and may provide a good source for power generation, on the other hand the ambient temperatures are high and a successful project under these conditions would show the possibility to deploy CSP with large storage in areas that are likely to be rich in DNI.

CSP technologies use direct sunlight, measured as Direct Normal Irradiation (DNI); which is the sunlight that is not diffused or deviated by clouds, fumes or dust in the atmosphere and which reaches the Earth's surface in parallel beams for concentration. All these four locations have DNI greater than 5 KWh/m^2 and hence high operating temperature configuration (>=500°C) can be assigned to any of the remaining sites. Charanka, the first solar park in India is already harbouring several PV projects; totalling nearly 300 MW out of the total park capacity is 590 MW. The masterplan of the solar park outlined a water body (man made lake) to be constructed at the site to prevent lack of water during canal unavailability. That lake is already constructed and so water is not a major issue at Charanka. Considering the fact that Gujarat is endowed with abundant solar intensity and

that high operating temperature requires high hourly DNI values it seems a natural choice that Charanka be the location for a high operating temperature project.

The following information was collected on the Nennala site:

State	**Andhra Pradesh**
Location	Nennal, Adilabad District
Qualification	Agriculture/Govt. waste land. Coal is nearby. Lots of trees and even forest area. Through Telengana
Nearest city (name and distance in km)	Karimnagar-100 KM, Hyderabad-180 KM
- At least state two GPS coordinates at the borders	19.074 N 79.632 E
Area (hectares)	160
Ownership of the land	Govt / Private/APIIC (solar park being developed)- Weak position, but interested
- Options: acquired by the state or private or to be acquired	Under acquisition
- If to be acquired, please state the necessary time	6 months
Power evacuation facilities	Existing
Type of sub-station (voltages)	220/132/33 KV at Bellampalli
Distance of the sub-station to site	12 km from project site
Soil analysis	Not done
- If completed, name of company that did the soil analysis	
Water availability	Penganga river. Lake also nearby (rain water).
- Quantity (cusec -cubic meter per second)	Pipeline will be laid along the road
- If Ground water at what depth?	
- If canal, what is the distance to the land?	20 km
- Any other source	
- Any restrictions in the use of the water	Water is available whole year. April-June filter beds can be used to retrieve the water
Access roads	Existing
- Name of the road, if exists	Nearer State High way
- Type of road – width	Good accesses, next to the field, wide roads.
- Type of road - pavement type	Asphalt
- Connection from and to (in km)	
Solar radiation - DNI - Direct Normal irradiation	5283.2
Solar radiation - GHI - Global Horizontal irradiation	5631.5
Solar radiation - Diffuse irradiation	1957
Ambient temperature	
- Options: ground measured data, no ground measured data	Average Temperature-27.40° C
Humidity	

- Options: ground measured data, no ground measured data	Annual Average - 52.2%
Wind speed	
- Options: ground measured data, no ground measured data	3.76 m/sec at 100 M height
Wind direction	
- Options: ground measured data, no ground measured data	
Rainfall	
- Options: ground measured data, no ground measured data	Annual average 3.00 mm/day
Populations nearby?	
- State the number of people and the distance to the land up to a 5 km radius of the land	30.000
- Main ocupation	Agriculture
Endemic fauna in the site	Environmental assessment undertaken, Chapter 5
Endemic flora in the site	Environmental assessment undertaken, Chapter 5

The summary of the evaluation data is given below:

Power evacuation	Existing
Type	220/132/33 KV at Bellampalli
Distance to the site	12 km from project site
Water availability	Penganga river. Lake also nearby (rain water).
water limitations	Water is available whole year. April-June filter beds can be used to retrieve the water
Acquired land	Under acquisition
Área	160
Access to the site	Existing
Populations nearby	30000
DNI (per day)	5.28
Solar Park	Planned

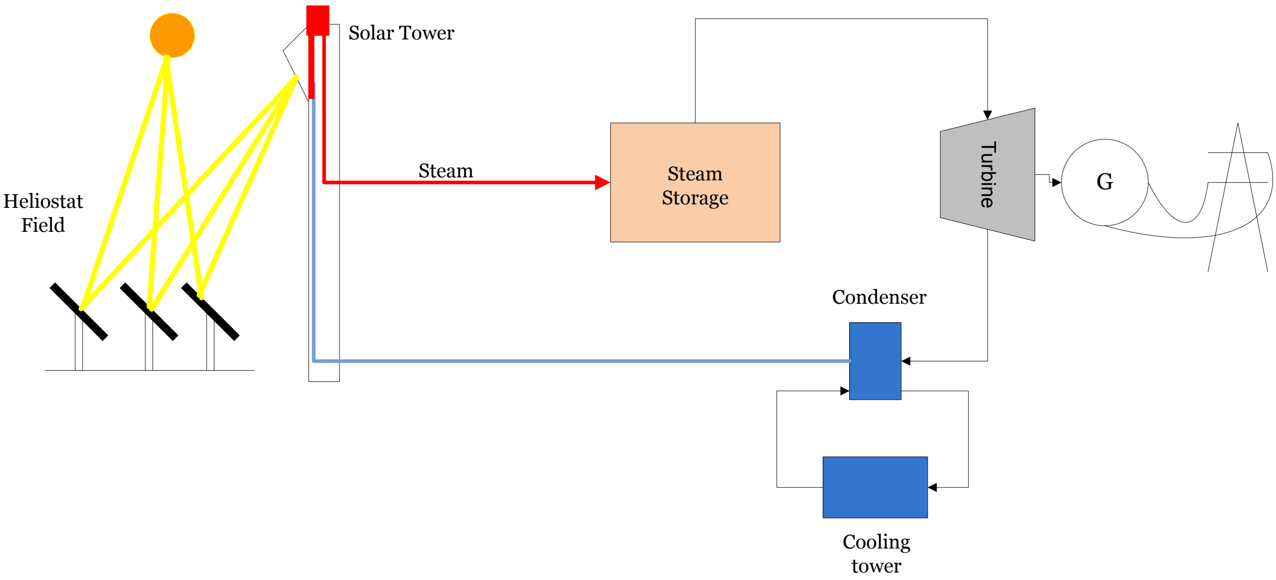
Technology Configuration

A primary benefit of the CSP technology is that it is grid-friendly and provides power during peak hours. Thermal storage allows CSP plant to overcome the problem of grid intermittency and to inject power into the grid during night, making them even more attractive to utilities when compared to other renewable technologies that lack this advantage. Thermal storage can be integrated with Parabolic trough, Linear Fresnel and Central Receivers (Solar Towers) to enhance dispatchability, allowing the solar plant to produce electricity in non-sunny hours to meet the power demand. With favourable conditions like clear weather and good solar irradiation, plants with thermal storage can operate at nearly 100% capacity factor, similar to conventional power plants (fossil fuel based). Also, from the economic sense; thermal storage will avoid the loss of time which would otherwise occur after occasional shutdown due to lack of solar irradiation.

Another benefit of storage is that it can adapt the profile of power produced throughout the day to demand and the total power output of the plant with given maximum turbine capacity can be increased. Various methods of storage include:

- Storage using concrete, ceramics etc.
- Storage through molten salts
- Storage in phase-change medium.

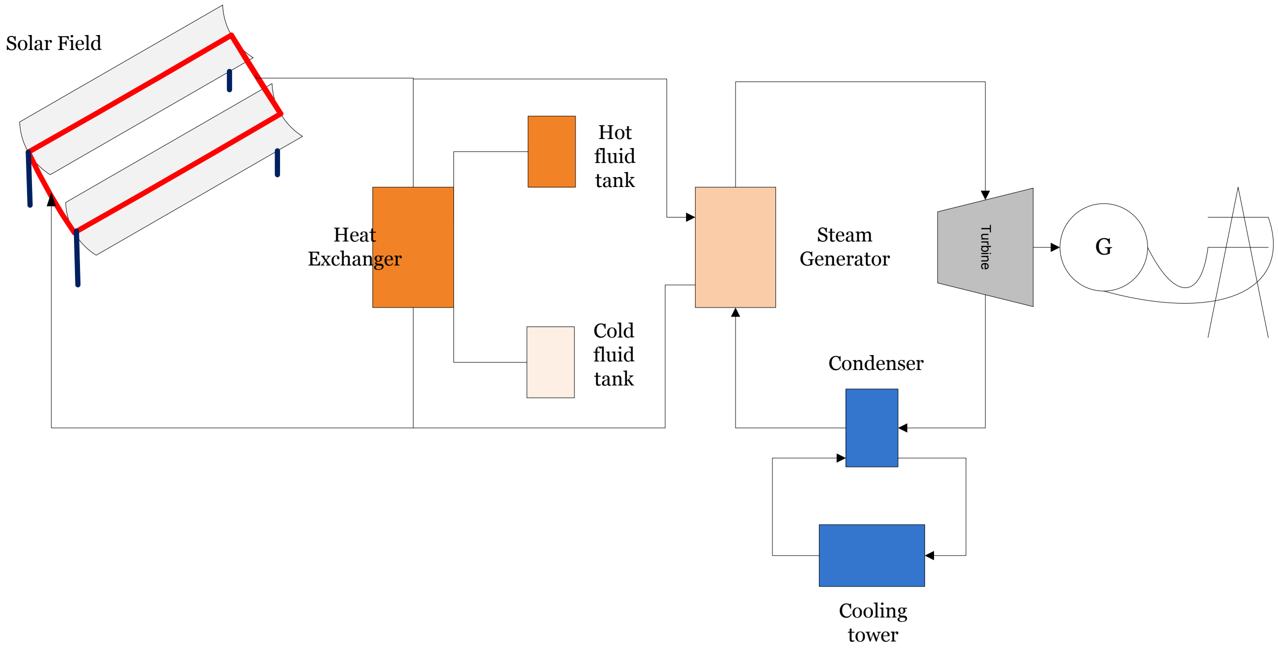
Various factors that determine the choice of storage medium are Energy density, Thermal conductivity, corrosion characteristics, cost, convenience of use, operating temperature of working fluid etc. With high temperature steam as the working fluid, the excess steam is utilised for heat storage within the storage medium, which is thermally insulated. Pressurised vessels provide limited capacity for storage as the cost is high and the additional operational time provided through storage is very less. Direct operation on steam i.e. coupling the receiver directly with the turbine has its disadvantages as the turbine drops offline as soon as an obstruction like a cloud comes by. The layout with steam storage is shown below:



Another evolving thermal storage technique is using concrete to store heat. Concrete offers very low thermal conductivity and is used for storing the heat of the operating fluid operates, even at temperatures higher than 500°C. Concrete storage is modular and scalable and is less expensive than molten salt storage.

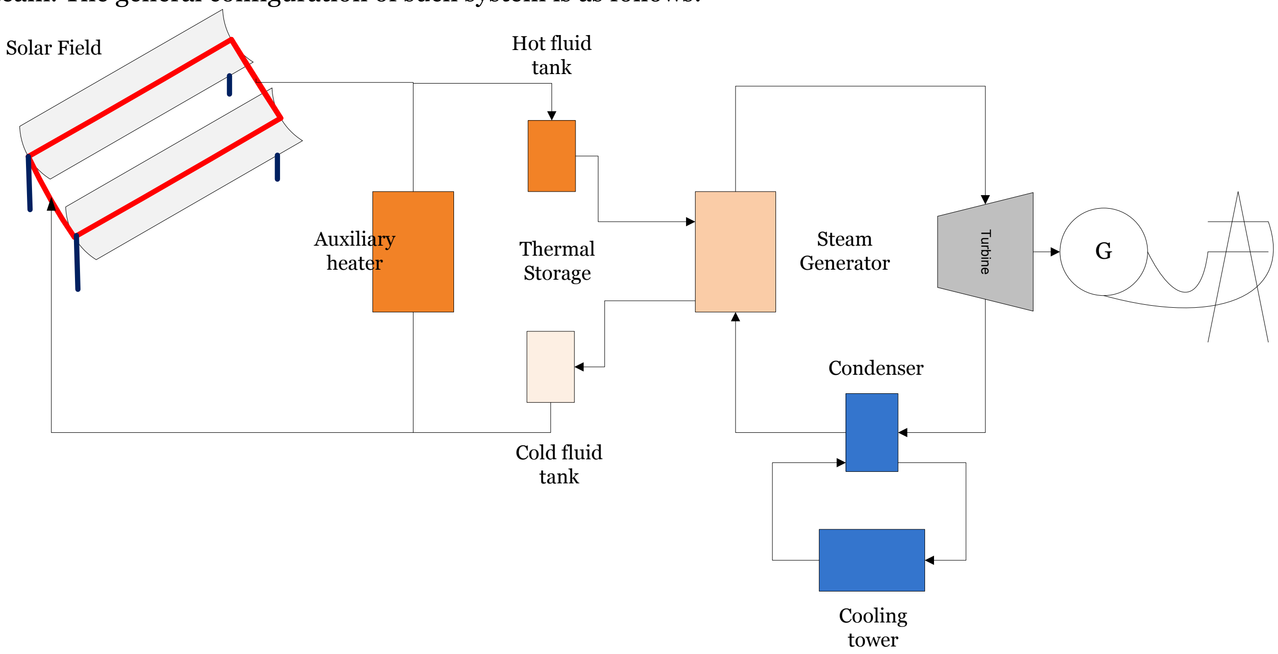
Another technology that is being developed for thermal storage is Indirect storage in a phase-changing medium. This method uses the melting/freezing points of salts such as sodium or potassium nitrates to store and deliver heat for condensation and evaporation of steam in direct steam plants. In this system, hot heat transfer fluid flows through a manifold embedded in the phase-changing materials, transferring its heat to the storage material. Various combinations of phase change materials include LiNO3 – NaNO3, KNO3 – NaNO3 etc. The main advantage of this technology is its volumetric density and the low cost of the storage materials. There are some developmental challenges of this method that need to be overcome before it becomes a commercially-viable solution.

Salt storage is the most prevalent storage technique in CSP power plants. The cool salt is passed through a heat exchanger with the oil that is heated by the concentrator, and then stored in the hot tank for later use. Alternatively, salt can be used as the heat transfer fluid and maybe stored in the storage tanks for future use. Various storage solutions in this category include include Metal oxides (eg. MgO), Molten salts, Metals (Mercury, Lithium, Sodium etc.). A few molten salts are Nitrate salts ($NaNO_3$ + KNO3), Hitec ($NaNO_2$ + NaNO3+KNO_3). Molten salt has a low viscosity and has corrosive properties and hence careful consideration has to be given for storage and transportation through use of suitable pumps, valves, pipes, and gasket materials that will work with molten salt. A typical layout of a CSP plant with storage is shown below:



The thermal storage may be done using a single tank (thermocline) or using a dual tank configuration, with one tank hot and the other one cold. In single tank system, the hot storage fluid is taken from the top of the storage tank and the cold fluid is taken back to the receivers, thus maintaining thermal stability in the tank. Using only one tank reduces the cost of this system relative to two-tank systems.

Sometimes, the same fluid is used as a storage medium as well as the thermal fluid. Such fluid must have low thermal conductivity and high thermal heat capacity and heat may be extracted from the fluid using heat exchangers. In dual tank storage, hot fluid is kept in one tank and the cold fluid in another. During day time, the cold fluid is heated and shifted to the hot tank and the heat is extracted from the hot tank whenever required. Moreover, an auxiliary medium may be used to provide additional heat to the working fluid of to superheat the steam. The general configuration of such system is as follows:



The working fluid may or may not be the same as the heat transfer fluid. When the same fluid, after getting heated through the solar collector or receiver flows to the high-temperature tank for storage and then through a

heat exchanger to generate steam; it is called a two tank direct system. Most of the existing parabolic trough plants use mineral oil as the heat-transfer and storage fluid while molten salt is finding use in most of the plants based on Central receiver technology.

In an indirect system, different fluids are used for heat-transfer and for storage. The working is almost the same as a direct system but with an additional heat exchanger where the HTF transfers the heat to the storage fluid which in turn is used for storage and for generating steam. Indirect system is used mostly when the HTF is not suited for storage or when cost of HTF is high.

Solar thermal storage in Andasol Plants

The Andasol Plan was built in southern Spain with 624 Parabolic Trough collectors, arranged in 168 parallel loops. The Andasol 1 was commissioned in 2008, followed by Andasol 2 and 3 and collectively have a gross electricity output of around 180 GWh a year and a collector surface area of over 510,000 m^2. Each power plant has an electricity output of 50 megawatts and operates with Dual tank, indirect thermal storage. The plant is designed to optimise heat exchange between the heat transfer fluid circulating in the solar field and the molten salt storage medium and the water/steam cycle. With a full thermal reservoir the turbines can run for about 7.5 hours at full-load, even if it rains or long after the sun has set. The heat reservoirs are two tanks 14 metres in height and 36 metres in diameter, and contain liquid salt. Each provides 28,500 tons of storage medium. Andasol 1 will supply up to 200,000 people with electricity and save about 149,000 tons of CO_2 a year compared with a modern coal-fired power plant.

The cost of electricity generated from CSP plants is coming down. The cost of generation is almost comparable to Diesel generators and it will soon be cost-competitive with thermal generation from mid-sized gas plants. The factors affecting the cost of CSP electricity are the solar resource, grid connection and local infrastructure and project development costs. Energy storage is very important for the success of solar power tower technology, and molten salt is believed to be the key to cost effective energy storage. Cost efficiency would increase due to research and development advances, effects of large scale deployment, increased market competition, construction efficiency improvements and scaling up of current capacities.

Simulation with potential technology

The configuration specifics for this site have described in the previous section. Number of hours of storage required is higher than 10 hours with a minimum CUF of 40%. The idea is to test dispatchability in a higher scale that impacts the power generation substantially. There is no upper limit on the hours of storage and base load configurations are welcomed. In technological terms it is expected that a larger solar field will be installed as part of this demonstration project and commercial or off-the-shelf solutions are expected, thus special considerations have been incorporated in the specific technical evaluation criteria.

In terms of the main areas in the project we have:

Solar field	Balance of Plant
- Heliostats, Mirrors or reflective surfaces - Receivers (evacuated tubes, steel pipes, cavities) - Collector Frames - Corrosion (applicable to any metallic structure) - Foundations - Tracking motors and algorithm - Electrical cables - HTF (water, oils, molten salts, air)	- Pressure vessels (Steam drum, expansion vessel, blow-down, deaerator) - Piping and pumps (pipes, pumps and feed heaters) - Electrical cables - Heat exchanger - Water Tanks or reservoirs (demineralization plant) - Heat storage tanks - Turbine (with alternator and step transformer) - Cooling tower

In terms of design and engineering no evaluation will be performed, since the whole nature of these projects is to allow innovative designs and engineering to be used, so all solar thermal technologies are allowed with an exception of Stirling engines which currently do not offer any storage solution. The area available for the project is 160 hectares which encompasses solar field plus Balance of Plant to fit in, which obviously limits the power plant rating and the consequent power generation. An exercise was done to design the maximum power plant

that would fit in such area obeying the CUF limitations and based on the radiation data supplied by the NREL/MNRE database that is available online. A privately developed model was used that uses an energy balance on an hourly basis, takes into consideration the solar field and the concentration factor, the optical and thermal losses of the solar field, the amount of energy necessary to vaporize water at the defined temperature, the amount of energy necessary to generate steam and based on the energy available from the solar field a certain amount of steam is generated and based on the efficiency of the turbine considered thus a power yield is obtained. Storage is considered and accounted for so that maximum and minimum number of hours of storage and thus average and peak CUF can be obtained. Additionally the heat exchanger efficiency as well as the IAM (Incident Angle Modifier) is also an input as well as the latitude of the place that adds some end losses on the collector (basically decreases the area available). Some differences apply to parabolic trough and Solar tower in terms of the way the solar field is emulated. The main outputs are the following and they were compared with the SAM model (in what can be compared):

Variables	Troughs (500ºC)	Towers (350ºC)	Towers (400ºC)	Towers (500ºC)
Total power rating	19 MW	22.5 MW	23 MW	21.5 MW
Total yearly generation	114 GWH	134.5 GWH	132 GWh	121 GWh
Average CUF	68%	68%	66%	64%
Peak CUF achieved (at least in one day)	99%	99%	97%	98%
Hours of storage	14.44	14.35	13.99	15.19
Total area of the power plant considering a 3x factor, that is the total size of the plant = 3 x solar field	147.7 hect	146.5 hect	146.5 hect	146.5 hect
Total area of the solar field (no spaces)	49.2 hect	48.8 hect	48.8 hect	48.8 hect
Average total efficiency	**16.2%**	**18.3%**	**19.1%**	**19.4%**

These results are not to be treated as benchmark for the project site as the purpose of the study was to get a better understanding of the system efficiency under available conditions. Hence, these results indicative, since the DNI was not locally measured and all the considerations used on the model were not specific to any technology but from benchmarks and known parameters of solar fields and Balance of Plant. A conservative view should be used and 10 to 15% less output is expected even if the DNI was exactly the same as the one used for the simulation.

Based on the site specific details and simulations with various technology configurations, Nennala has been selected for pilot baseload CSP plant with a minimum of 15 hours storage.

Chapter 3: Financial feasibility assessment

Project financing structure

The proposed CSP demo plants are designed to be one-of-kind, innovative pilot projects that will highlight the technical, commercial and economic viability of these technologies. Due to the highly experimental natural of these pilot plants, the Government of India is planning to make available specialized sources of funding for these projects. These funding sources are designed to facilitate CSP projects by offering longer term financing at extremely competitive rates, while only requiring the developer to contribute 20% of the total project cost as own equity.

While the exact quantum and terms of availability of these funds cannot be ascertained accurately at this stage, the following table highlights the potential project financing options that these CSP demo plants can be expected to employ for debt funding.

#	Funding Source	Cost of borrowing	Tenure	Clauses/Covenants
1	Asian Development Bank (ADB)	LIBOR plus 0.5% mark-up = ~1.45% + commitment charges. Assumed at 4% to include other spreads	5 years moratorium and 20 years repayment	ADB can only provide this loan to a sovereign Govt. Of India entity. Mechanisms to pass this on from GoI to private developers will have to be considered.
2	Clean Technology Fund	0.25% non-escalating	10 years moratorium and 30 years repayment	Only accessible through ADB. Needs to have a 1 is to 5 leverage ratio and must be for a demonstrable innovative use – CSP pilot projects fulfil this second criteria
3	Commercial loans	Risk weighted market rate = ~ 9-12%	1 year moratorium and 8 to 10 year repayment	Commercial lenders will perceive CSP demo projects to be highly risk, and will require some kind of collateral/assurance which is likely to raise cost of borrowing and/or limit availability

Based on these sources and characteristics of financing, the following funding mix has been assumed for the projects:

Mode of funding and its features	Interest rate	Repayment tenure (years)	Moratorium period (years)	Proportion of total capital cost
ADB and CTF blended loan	6.0%	20	5	40%
Developer's equity	Return on equity at 22.4% as per prevailing CERC norms			20%

In addition to the debt financing option listed above, the Government of India will also support the demo projects by offering a viability gap funding in the form of a grant. The amount of grant required by a project is fixed at 40% of the total project cost. The grant will be made available as three staggered payments each year since the start of the project construction (assumed to be 3 year). The grant will be paid out in unequal proportions:- 10% in the 1st year, and 45% each in the following two years.

The following presents the expected project (financial and economic) and equity returns for the project assuming a flat tariff of Rs. 5.82/kWh.

Project specific details

The following are the project specific financial and technical details that form the basis of our estimations. All other assumptions not mentioned below are assumed to be as per the prevailing CERC norms for solar thermal projects (please see appendix 1 for details). It is important to note that these details are merely representative and in no way suggest the likely configuration that might come up.

#	Parameter	Value
1	Capital Cost	Rs. 330 million per MW
2	CUF	65%
3	Capacity	20 MW

VGF estimation

Allowed Tariff (INR/kWh)	5.82
Project IRR	7.01%
Equity IRR	12.46%
Economic IRR	10.31%

Chapter 4: Social feasibility assessment

Social & Poverty Impact

Nennala subproject is located in Adilabad district of Andhra Pradesh. The project is to be set up in the Telengana area which is socially sensitive in the current context as the monitoring station could not be set up due to regional issues. The site is 100 km away from Karimnagar-and about 180km from Hyderabad. The proposed sub-project site is connected with access road. Nennala village is two kilometers away from the proposed CSP site. The total population of Nennala village is approximately 8,000 having a total of approximately 2000 households. This is a rural cum semi urban area with due access to other places through approach roads. Most of the people live in rural areas and the major occupation of the villager is daily wage and farming. Cultivation is done only one season. Rice and cotton are the main crops. Water supply is managed through bore well and government supply. The village has junior school and public health care facility.

The Project will contribute both directly and indirectly to poverty reduction through economic development. A Poverty and Social Analysis will be conducted to assess and identify ways in which the project might best address poverty reduction and social development issues. A social impact assessment report will be prepared. The poverty and social analysis will be undertaken addressing the key social issues in accordance with ADB's Guidelines for Incorporation of Social Dimensions in Bank Operations and ADB's Handbook on Poverty and Social Analysis The analysis will broadly cover various components such as (i) identifying the affected population and potential beneficiaries including minorities (indigenous people), (ii) assess the stage of development of different groups of the population, (iii) assess the gender impact of the Project, (iv) assess the needs of the affected population and their expectations from the Project, (v) assess the affected population's absorptive capacity to receive benefits from the Project, and potential to participate in implementing the Project. The methodology to be adopted in conducting poverty and social analysis will include both primary and secondary data. All available secondary socioeconomic data will be collected for the project areas through proper sources which will be reviewed and compiled. In addition to the secondary data, primary data will be collected through survey which will have both quantitative and qualitative methods. A sample socioeconomic survey will be conducted in the project area (CSP site) to collect the baseline information using a structured soco-economic questionnaire. The qualitative methodology will include but not limited to focused group discussions, key informant interviews and informal discussions with stakeholders. The survey will aim at collecting information pertaining to issues related to social, poverty, gender, indigenous people, and health issues especially HIV/AIDS, trafficking and labour etc. The findings of the social and poverty analysis will be presented as Summary Poverty Reduction and Social Strategy (SPRSS), in accordance with the ADB format.

Impact on Land Acquisition and Involuntary Resettlement

The site is situated on the government land. Approximately 400 acres of land is required which is government barren land. The land survey has yet to be done. The land will be acquired by Andhra Pradesh Industrial Investment Corporation Limited (APIIC). Detailed land survey will reveal whether the land is free from encroachment and squatters. No physical displacement is foreseen. Therefore, the sub project will be categorized as C as far as the resettlement issues are concerned. However, if any non titleholders (encroachers and squatters) are found during the detailed land survey, necessary mitigation plan will be prepared as per ADB's Safeguard Policy Statement (SPS), 2009.

Impact on Indigenous People

The screening survey revealed that the sub project site is situated near to the industrial area which is almost a rural cum semi urban area. There are no such tribal populations found in the area which.

There are no demarcated tribal areas found in the sub project area. No household or group belonging to scheduled tribes will lose housing, strip of land, or other fixed assets. Therefore, the IP issues are insignificant in the sub project area. Based on the assessment, the sub project can be categorized as C as far as the IP issues are concerned. However, necessary steps and mitigations will be taken during the detailed survey. If any IP is found during the detailed survey based on the final design, it will be addressed suitably as per ADB's Safeguard Policy Statement (SPS), 2009.

Impact on Gender

Women are largely responsible for household energy management, such as collecting, chopping and storing firewood. Therefore access to energy has a specific gender dimension. Renewable energy projects in India have demonstrated that renewable energy can directly contribute to poverty alleviation and gender benefits. Installing solar lights in homes enables children to study in the evenings and improve school performance. Solar lanterns have made the business of many women entrepreneurs profitable. Solar driers are a boon in remote areas for drying of fruit and vegetables. Even garment workers have been using solar energy to save electricity costs while running their sewing machines. Vocational trades involving the NGOs may be initiated for women to empower them by providing skills on tailoring, embroidery, food products etc. All these activities do have a direct link with the availability of energy. The EA will ensure that women are consulted and invited to participate in group based activities and where possible, women will be given the opportunity to learn new skills that may provide alternative forms of income generation and livelihood. Efforts will be made during the detailed assessment to assess the possible gender benefits of the project. If required, a gender action plan will be formulated to maximise project benefits for women through gender mainstreaming in the project and a gender responsive participation framework. Gender mainstreaming will include activities associated with empowerment, skills training, capacity building and gender sensitisation.

Other Social Issues (Labour and Health etc)

Temporary employment opportunities will be available for skilled and unskilled labour during project implementation and operation. Standard assurance on labour will be included in civil work contracts. Necessary health safety measures will be taken by the construction contractor to combat any disease like, HIV, STD due to the influx of migratory labour from outside.

Public Consultation and Stakeholders' Participation

Initial consultations have been carried out with the project authorities. Preliminary consultations were also carried out in the sub project sites. The Consultations will be continued involving all the stakeholders all through the project planning and implementation.

An initial Poverty and Social Analysis has been prepared as per ADB's format and presented below.

INITIAL POVERTY AND SOCIAL ANALYSIS (IPSA)

Country:	**India**	**Project Title:**	**Concentrating Solar Power Project (Nennala)**

Lending/Financing Modality:	**XXX**	**Department / Division:**	**SARD/SAEN**

I.	**POVERTY ISSUES**

A. Links to the National Poverty Reduction Strategy and Country Partnership Strategy
Achieving "poverty reduction and social development through faster and more inclusive growth" is a priority in India's 11th Five Year Plan (FYP) (2007-2012). The Planning Commission's approach paper to the 11th FYP identifies infrastructure bottlenecks and lack of adequate long-term funds for infrastructure as key binding constraints to realizing more equitable and sustainable growth and bridging the gender divide in the country. In addition, the Paper states that "good quality infrastructure is the most critical physical requirement for attaining faster growth in a competitive world and also for ensuring investment in backward regions". ADB's Country Partnership Strategy (CPS) for 2009 – 2012 aims to tackle poverty by supporting faster, more inclusive and gender equitable economic growth through job creation; improvement in the education, health and other social sectors; the provision of basic essential services to the poor; and bridging the divide between regions, sectors, and gender in the state. India is bestowed with good solar irradiation across the country. In January 2010, the Government of India (GOI) launched Jawaharlal Nehru National Solar Mission (JNNSM). The targets of the JNNSM are, among others, to (i) create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022; (ii) ramp up capacity of grid-connected solar power generation to 1,000 MW within three years; and an additional 3,000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff; (iii) deploy 20 million solar lighting systems to rural areas by 2022; and (iv) create favorable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership. Availability of clean and reliable sources of energy is expected to catalyze economic growth in the service areas of future renewable energy projects and thereby create more economic opportunity for the population including the poor. The Project's impact would be the development of long-term sustainable energy sources in a cost-effective manner in India. The Project is aligned with the India Country Partnership Strategy (CPS) 2009-2012. One of the four strategy pillars of the CPS is the support for inclusive and environmentally sustainable growth, through the continued focus on infrastructure development and the enhanced focus on renewable energy. The Project will contribute to achieving the targeted capacity for solar power generation through 2012. The Project will contribute to the economic development of Andhra Pradesh through increased employment opportunities and increased tax revenues. Direct impact to local employment is expected during the construction and operation stage, while the tax revenues from the Project during operation stage can be used to fund social development projects that will benefit the poor and vulnerable and will have indirect impact
B. Targeting Classification
☒General Intervention ☐Individual or Household (TI-H) ☐Geographic (TI-G) ☐Non-Income MDGs (TI-M1, M2, etc.)
Explain the basis for the target classification: The Project is classified as General Intervention as power produced will be evacuated in the main grid where it will be available to the broad power users. The availability of electric power has an indirect but strong link with reducing poverty and encouraging economic growth.Though the Project will have a number of indirect benefits to end users in terms of investment and improvements to local public infrastructure, creation of economic potential and activity, greater wealth and opportunity in communities – all of which have a catalyst effect in directly improving peoples general well being and quality of life; despite this, power sector interventions are not considered as the single contributing factor to achieving more generalized and sustainable poverty reduction and alleviation. The classification therefore recognizes that while power itself will not implicitly decrease poverty, it is a critical stepping stone to attracting other means of economic investment and development that will provide the foundation for concrete poverty reduction strategies in the future.
C. Poverty Analysis
1. If the project is classified as TI-H, or if it is policy-based, what type of poverty impact analysis is needed? Not applicable.
2. What resources are allocated in the PPTA/due diligence? Social and gender analysis will be carried out by social development / safeguard specialist. Analysis will include the collection of baseline data (e.g., household surveys,

including gender disaggregated data), assessment of primary and secondary data, and focus group discussions and public consultation with project affected peoples. Funds for social and gender analysis will be made available through the project PPTA.

3. If GI, is there any opportunity for pro-poor design (e.g., social inclusion subcomponents, cross subsidy, pro-poor governance, and pro-poor growth)? Not at present.

II. SOCIAL DEVELOPMENT ISSUES

A. Initial Social Analysis

Based on existing Information:

1. Who are the potential primary beneficiaries of the project? How do the poor and the socially excluded benefit from the project? The primary beneficiaries of the Project are - those who will receive clean renewable electricity from the project (these could be local, regional or even national and are therefore deemed as indirect beneficiaries); - those who will be temporarily be employed during construction and permanently employed for operations of the project; - and –women, who will benefit from: a) household electricity and street lighting, reduced time burdens from domestic chores and increased safety and security during night hours ;b) improved living standards and health condition.

2. What are the potential needs of beneficiaries in relation to the proposed project? The primary needs of poor and vulnerable stakeholders are jobs during construction and operation, access to markets in remote areas, and improved infrastructure and basic services like health, education and sanitation in the project area.

3. What are the potential constraints in accessing the proposed benefits and services, and how will the project address them? Remoteness of the project location.

B. Consultation and Participation

Indicate the potential initial stakeholders.

1. Primary stakeholders are peoples living in the direct area of influence of the project and its associated facilities. Other stakeholders include public & private sector shareholders and Government of Andhra Pradesh and Government of India.

2. What type of consultation and participation (C&P) is required during the PPTA or project processing (e.g., workshops, community mobilization, involvement of nongovernment organizations and community-based organizations, etc.)? Public consultations and focus group discussions will be carried out with project stakeholders during the project planning and implementation stages of development.

3. What level of participation is envisaged for project design?

☒ Information sharing ☒ Consultation ☐ Collaborative decision making ☒ Empowerment

4. Will a C&P plan be prepared during the project design for project implementation? ☐ Yes ☒ No

Consultations will be managed through a mix of formal and informal consultations with the affected communities – on an as needed basis. The nature and scale of impacts and the number of affected peoples is expected to be limited, thereby exempting the need for a structured and systematic process of engagement. Social assessment will nonetheless include gender sensitive and targeted consultation to ensure that women's needs are analyzed and opportunities considered.

C. Gender and Development: Proposed Gender Mainstreaming Category: Some Gender Benefits

1. What are the key gender issues in the sector/subsector that are likely to be relevant to this project/program? Opportunities to benefit and improve the quality of life and well being of women will be assessed during project

appraisal. Where opportunity exists, these will be funded under a specific gender and community based technical assistance fund. The main (indirect) benefits expected to women will be in the form of access to new, improved or more reliable lighting in homes and villages. This will reduce women's time and burden on household and domestic activities; - improve their health and well being, as this will replace the need for more costly, less clean and efficient sources of energy(e.g., firewood, kerosene) for household heating and lighting. Opportunities may also focus on creating new or alternative forms of livelihoods, provision of skilled training and/or education.

2. Does the proposed project/program have the potential to promote gender equality and/or women's empowerment by improving women's access to and use of opportunities, services, resources, assets, and participation in decision making? ☒ Yes ☐ No

Please explain. The benefits to women will be felt and seen locally, within their family and community structures.

3. Could the proposed project have an adverse impact on women and/or girls or to widen gender inequality?

☐ Yes ☒ No Please explain Women are expected to benefit from the intended outcomes of the project.

III. SOCIAL SAFEGUARD ISSUES AND OTHER SOCIAL RISKS

Issue	**Nature of Social Issue**	**Significant/Limited/ No Impact/Not Known**	**Plan or Other Action Required**
Involuntary Resettlement	Construction of CSP will require approximately 400 Hectares of land which is primarily government owned barren land. Therefore no private land acquisition is foreseen.	**No Impact**	☐ Resettlement Plan ☐ Resettlement Framework ☒ Environmental and Social Management System Arrangement ☐ None ☐ Uncertain
Indigenous Peoples	The area where the project will be constructed is not owned/used/claimed by any IP or scheduled tribe.	**No Impact**	☐ Indigenous Peoples Plan ☐ Indigenous Peoples Planning Framework ☒ Environmental and Social Management System Arrangement ☐ None ☐ Uncertain
Labor ☒ Employment Opportunities ☐ Labor Retrenchment ☒ Core Labor Standards	Temporary employment opportunities will be available for skilled and unskilled labor during project implementation and operation. Standard assurance on labor will be included in civil work Contracts.	**Limited Impacts**	☐ Plan ☐ Other Action ☒ No Action ☐ Uncertain
Affordability	Power will be sold directly to the grid. No affordability issue is expected. Power tariff will be determined by	**No Impact**	☐ Action ☒ No Action ☐ Uncertain

	Competent authority.		
Other Risks and/or Vulnerabilities ☒ HIV/AIDS ☐ Human Trafficking ☒ Others (conflict, political instability, etc.), please specify	• The project will minimize the risk of HIV/AIDS among the migratory and local workforce through awareness raising initiatives. • The project is to be set up in the Telengana area which is socially sensitive in the current context as the proposed solar monitoring station could not be set up due to regional issues	**Limited** This will be further assessed during the social due diligence under PPTA	☐ Plan ☐ Other Action ☐ No Action ☒ Uncertain
IV. PPTA/DUE DILIGENCE RESOURCE REQUIREMENT			
1. Does the TOR for the PPTA (or other due diligence) include poverty, social and gender analysis and the relevant specialist/s? ☒ Yes ☐ No			
2. Are resources (consultants, survey budget, and workshop) allocated for conducting poverty, social and/or gender analysis, and C&P during the PPTA/due diligence? ☒ Yes ☐ No Consulting requirements include the use of individual consultants which include international social development /safeguards specialist for more immediate due diligence tasks including necessary costs for carrying out the social surveys etc.			

Chapter 5: Environmental feasibility assessment

Legal Regulatory Framework

It is important that the CSP projects that will emerge from the MNRE project are in tune with the legal framework in the country and state. The existing laws and regulations concerning environmental conservation may restrict certain developmental activities. It is important that the Environmental Management Framework prepared for the CSP project remains responsive to the changing legal framework. The following laws, regulations and policies have been reviewed in this chapter for their relevance to the CSP project context.

National Environmental Laws

The Environmental regulations, legislation, policy guidelines that may impact this project, are the responsibility of a variety of government agencies. The principal Environment Regulatory Agency in India is the Ministry of Environment and Forests (MoEF). MoEF formulates environmental policies and accords environmental clearances for different projects. The relevant environmental legislations in India are mentioned below

(i) The Water (Prevention and Control of Pollution) Act, 1974, amended 1988.
(ii) The Water (Prevention and Control of Pollution) Rules, 1975.
(iii) The Air (Prevention and Control of Pollution) Act 1981, amended 1987.
(iv) The Air (Prevention and Control of Pollution) Rules, 1982.
(v) The Environment (Protection) Act, 1986, amended 1991 and including the following Rules/Notification issued under this Act.
- The Environment (Protection) Rules, 1986, including amendments.
- The Municipal Solid Wastes (Management and Handling) Rules, 2000.
- The Hazardous Wastes (Management and Handling) Rules, 2003.
- The Hazardous Wastes (management, handling and transboundary movement) Rules 2009.
- The Bio-Medical Waste (Management and Handling) Rules, 1998.
- Noise Pollution (Regulation and Control) Rules, 2000.
- Wild Life (Protection) Amendment Act, 2002.
- Ozone Depleting Substances (Regulation & Control) Rules, 2000.
- The Biological Diversity Act, 2002.
- The Environment Impact Assessment Notification, 1994; amended up to 2009;
- Batteries (Management & Handling) Rules, 2001.
- The Environmental Clearance Notification, 1994.

(vi) Noise Pollution (Regulation and Control) Rules, 2000.
(vii) The Indian Wildlife (Protection) Act, 1972, amended 1993.
(viii) The Wildlife (Protection) Rules, 1995.
(ix) The Indian Forest Act, 1927.
(x) Forest (Conservation) Act, 1980, amended 1988 (National Forest Policy, 1988).
- Forest (Conservation) Rules, 1981 amended 1992 and 2003.
- Guidelines for diversion of forest lands for non-forest purpose under the Forest (Conservation) Act, 1980.

(xi) The National Environmental Appellate Authority Act, 1997.
(xii) The National Green Tribunal Act, 2010.

Other National Policy Acts

The Indian policy framework consists of following main regulations:

1. The Electricity Act, 2003.
2. National Resettlement & Rehabilitation Policy, 2007 (NRRP) (MoRD, DoLR).
3. Right of Way and Compensation under Electricity Laws.
4. Land Acquisition Act, 1894.
5. The Indian Telegraph Act (ITA), 1885.
6. Indian Treasure Trove Act, 1878 as amended in 1949.
7. Provisions of the Panchayats (Extension to the Scheduled Area) Act, 1996.
8. The Right to Information Act, 2005.
9. National Policy on HIV/AIDS and the World of Work, Ministry of Labour and Employment, GoI.

10. National Policy on Safety, Health and Environment at Work Place, Ministry of Labour and Employment, GoI.

Relevant AP State Government Laws and Regulations

1. The Andhra Pradesh Forest Act 1967.
2. Andhra Pradesh Protected Forest Rules, 1970.
3. The Andhra Pradesh Water, Land and Trees Act, 2002 and the Andhra Pradesh Water, Land and Trees Rules, 2002.
4. The Andhra Pradesh Saw Mills (Regulation) Rules, 1969.
5. Andhra Pradesh Forest Produce Transit Rules, 1970.
6. The Andhra Pradesh Minor Forest Produce (Regulation of Trade) Act, 1971.
7. The Andhra Pradesh Scheduled Areas Minor Forest Produce (Regulation of Trade) Regulation, 1979.
8. The Andhra Pradesh Preservation of Private Forest Rules, 1978.
9. Andhra Pradesh (Protection of Trees and Timber in Public Premises) Rules, 1989.
10. The Andhra Pradesh Charcoal (Production and Transport) Rules, 1992.

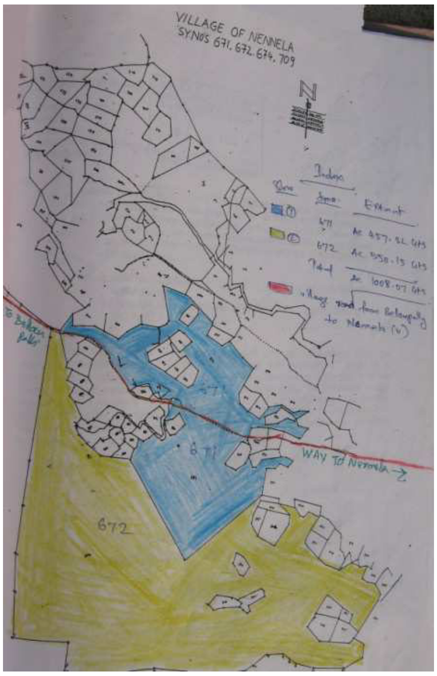
Specific Provisions:

11. CRZ Regulations: The Central Government vide its notification number S.O.114 (E), dated the 19th February, 1991, has declared Coastal Regulation Zone and imposed certain restrictions on the setting up and expansion of industries, operations and processes in the said Zones. The Act prescribes several activities that are declared as prohibited activities within the CRZ such as setting up of new industries and expansion of existing industries. However this excludes facilities for generating power by non-conventional energy sources and setting up of desalination plants in the areas not classified as CRZ-I (i).

12. Office Memorandum No. J-11013/41/2006-IA.II(I) dated June 30, 2011 - Environmental clearance for setting up of Solar Thermal Power Plants under JNNSM-applicability of EIA Notification 2006
It is clarified that Solar Thermal Power Projects do not fall under the EIA notification 2006. However, it should (i) seek consent to establish from SPCB under Air and Water Acts, forest clearance under FC Act, (ii) conform to CRZ notifications, (iii) restricted land use to Solar Thermal, and (iv) any other rules such as HSM Rules etc.

Physical Features of the Site

Land:



Village: Nennala, Adilabad District
GPS Coordinate: 19.074 N 79.632 E
The project is set up in the Telengana area which is socially sensitive in the current context as the monitoring station could not be set up due to regional issues. The site is 100 km away from Karimnagar- and about 180km from Hyderabad.

Land Requirement of CSP Project site: 160 hect
The land is generally agriculture or government waste land but there could be forest land. The land survey has yet to be done. The land will be acquired by APIIC (Andhra Pradesh Industrial Investment Corporation Limited).

Master Plan studies: None.

Power Evacuation:
Power evacuation – Bellampalli GSS (12 km away; already online). Details will be collected during detailed survey.

Water:
Water – available from Penganga River (20 km away)
There is no water body in the vicinity of the site and water for the sub project is to be procured from a canal (Govt. as per initial impressions has allocated water for usage in the proposed sub-project) flowing at a distance of about 14 kms from the project. From preliminary enquiry it seems the ground water is at a depth of about 900 ft. from the surface.

Habitation:
15 km from Bellampalli town. Nenella Village has 2000 families.
A total of 30000 people live on a 5 km radius, mainly farmers

Other Industries:
The area is generally barren. Lots of coal mines in the region.

Forest:
The area consists of trees which are scrubs, could be from the designated forest area (the details can only be ascertained after land survey starts and completes in three months from now).

National park and Sanctuaries:
Andhra Pradesh has 20 wildlife sanctuaries and four national parks. These protected areas are habitat to several endangered and endemic species of flora and fauna. Habitat degradation, management strategies and problems such as poaching are the major threats to this natural wealth. The distance from the following sanctuaries and their impacts (if any) will have to be studied.

Name and Location	Area (sq. km)	Forest type	Characteristic biological wealth.
Kawal Wildlife Sanctuary, Adilabad district	893	Dry Deciduous	Tiger, panther, gaur, cheetal, sambar, nilgai, barking deer, mouse deer, sloth bear and a variety of birds
Pranahita Sanctuary, Adilabad district (along tributary of River	136	Dry Deciduous	Tiger, panther, cheetal, black buck, Nilgai, sloth bear and a variety of birds such as ducks, teals, storks and herons
Sivaram Sanctuary, Adilabad and Karimnagar district	37	Riverine forest	Cheetal, sambar, nilgai, monkeys, langurs, jackals, wild of birds such as ducks, teals, boars, python, sloth bear, panther, tiger, marsh crocodile.

There is apparently no conservation area in the vicinity of the proposed project site. A detailed assessment will be conducted later on based on the available baseline data.

Data required

Specific phase-wise activities required for Environmental Impact Mitigation baseline development, mitigation and monitoring are given below:

Planning phase
- Assessment of all Environmental Impacts.
- Consent of Establishment (COE).
- No objections certificates from Wildlife department (sanctuary buffer zones, forest areas, etc.).
- State Pollution Control Board Approvals and Consultation.
- Permissions for any boreholes for water.
- Listing of trees from Forest Department.
- Technical layouts, power evacuation map (TRANSCO), associated facilities.
- Waste disposal planning – construction etc.
- Hazardous waste disposal planning – land fill site, batteries, panels, inorganic toxic waste, SF6, leakages and contingency plans.
- Baseline parameters measurements – water, air, noise, soil (150 ha -> 2 samples; 35 ha -> 1 sample).
- Soil levelling – soil displacement management plan.
- Health and safety planning.
- Power Grid in case of export of power.
- Load centre consumer base list.

Construction phase
- Availability of public amenities – water and sanitation.
- Availability of construction camp with electricity, water, toilets.
- Hazardous waste disposal implementation.

- Waste disposal implementation.
- Health and safety implementation.

Operation phase
- Compliance with statutory requirement of GOI and State, Support to inspection visits.
- Monitoring report.

Data required for Environmental safeguards
The impact will be assessed on assumptions derived from site visits and physical survey of the land. The land belongs to the government and/or forest therefore no resettlement issues are envisioned. However, unforeseen impacts may arise during construction for which provision for mitigation and compensation needs to be made. Consultations will be needed to be carried out with relevant stake holders about 5 km from the site. The impacts for CSP plant currently seem to be limited to cutting and lopping of non-forest or forest trees during the construction. The power evacuation lines would normally avoid any forest area, ecologically sensitive areas such as national parks and sanctuary/buffer zone as well any tribal areas.

Data required:
- Alternative analysis of CSP site.
- Contour/Topography report of the project site with drainage, waste disposal site etc.
- Map marked with project and all other project related facilities along with other environmental features using Auto-cad software using Survey of India toposheet (1:50,000 scale) and satellite maps as base map.
- Forest Diversion and Land acquisition case.
- Water availability and quality, environmental air, water, soil, and noise parameters for baseline development.
- Disposal of Hazardous and non-hazardous wastes given the site is pristine in nature.

ADB Specific Guidelines for Environmental Safeguards
The pilot CSP will require preparation of an environmental assessment and review framework (EARF), resettlement framework (RF) and indigenous people's planning (IPPF) framework. Furthermore, it will require initial environmental examination (IEE) and resettlement plan (RP). Because retroactive financing is envisaged, safeguard documents will be prepared before contract awards, necessary clauses will be included in contracts and the EA will be held responsible for implementation of EMP.

Environment Documents
The Environment Assessment and Review Framework (EARF) and Initial Environment Examination (IEE) document prepared for the CSP would normally contain:
- Project description, district data, project related maps and site details etc.
- Site Surveys and preparation, Site selection criteria,
- Environment Management Plan (EMP) and budget,
- Suitable Mitigation measures that are consistent with state Government and ADB policies,
- Environment Monitoring Plan with budget; and contractors requirements,
- Institutional arrangement and staffing requirements, and
- Forest diversion cases (if any).

Roles and Responsibilities
The Project will establish an organization to manage environmental, occupational health, and safety aspects during construction and commercial operation of the power plant. An Environmental and Social Unit at SECI or any Monitoring Agency will have to be established during the project implementation and monitoring period to ensure compliance with safeguards requirement of ADB, state government and GOI.

There will be various stages in the project preparation and implementation. Each stage will require specific activities to be completed for which appropriate institutional arrangements are to be in place. The major responsibilities for the planning and implementation of these activities will be with the project developer along with managing the environmental and social safeguards issues. Additionally, construction contractor will be responsible for mitigating environmental and social issues if found during the construction.

Appendix 1: Major Assumptions

Assumption Head	Sub-Head	Sub-Head (2)	Unit	Assumptions
Power Generation				
	Capacity			
		Installed Power Generation Capacity	MW	20
		Capacity Utilization Factor	%	65.0%
		Auxiliary Consumption Factor	%	10.0%
		Useful Life	Years	25
Project Cost				
	Capital Cost/MW	Power Plant Cost	Rs Lacs/MW	3300
Sources of Fund				
		Tariff Period	Years	25
	Debt: Equity			
		Debt	%	70%
		Equity	%	30%
	Debt Component			
		Moratorium Period	years	0
		Repayment Period(incld Moratorium)	years	12
		Interest Rate	%	6% (ADB Loan for 50% of project cost) and 12 % (commercial bank loan for 20% of project cost)
	Equity			
		Return on Equity	% p.a	22.40%
		Discount Rate		9.2%
Financial				
	Fiscal			
		Income Tax	%	32.45%
		MAT Rate (for first 10 years)	%	19.00%
		80 IA benefits	Yes/No	Yes
	Depreciation			
		Depreciation Rate for first 12 years	%	5.83%
		Depreciation Rate 12th year onwards	%	1.54%
Working Capital				
	For Fixed Charges			
	O&M Charges		Months	1
	Maintenance Spare	(% of O&M expenses)		15%
	Receivables for Debtors		Months	2

	For Variable		
	Interest On Working Capital	%	12.80%
Operation & Maintenance			
	power plant (FY11-12)		1% of project cost
	Total O & M	%	5.72%

Prefeasibility Report

Terkuveerapandiyapuram (Tamil Nadu)

May 2012

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Chapter 1: Introduction

Central level initiative to promote solar power

National Action Plan on Climate Change

The National Action Plan for Climate Change (NAPCC), announced by the Hon. Prime Minister of India on June 30, 2008, envisions several measures to address global warming. One of the important measures identified involves increasing the share of renewable energy in total electricity consumption in the country. NAPCC has set the target of 5% as dynamic minimum renewable purchase standard (DMRPS) for FY 2009-10, with the target increasing by 1% for next 10 years.

The action plan specifically mentions issues related to power generation from biomass, small hydro and wind technologies. The NAPCC also identifies various regulatory, measures for mainstreaming power generation based on renewable energy sources like:

- A dynamic minimum renewable purchase standard at the national level with escalation a year.
- A mechanism for verification of procurement of renewable based power is also suggested along with a scheme of tradable renewable energy certificates.

Further, in order to ensure compliance with the DMRPS target, NAPCC envisages transaction of renewable energy from surplus regions to deficit regions through policy instruments.

Jawaharlal Nehru National Solar Mission - Aims and Objectives

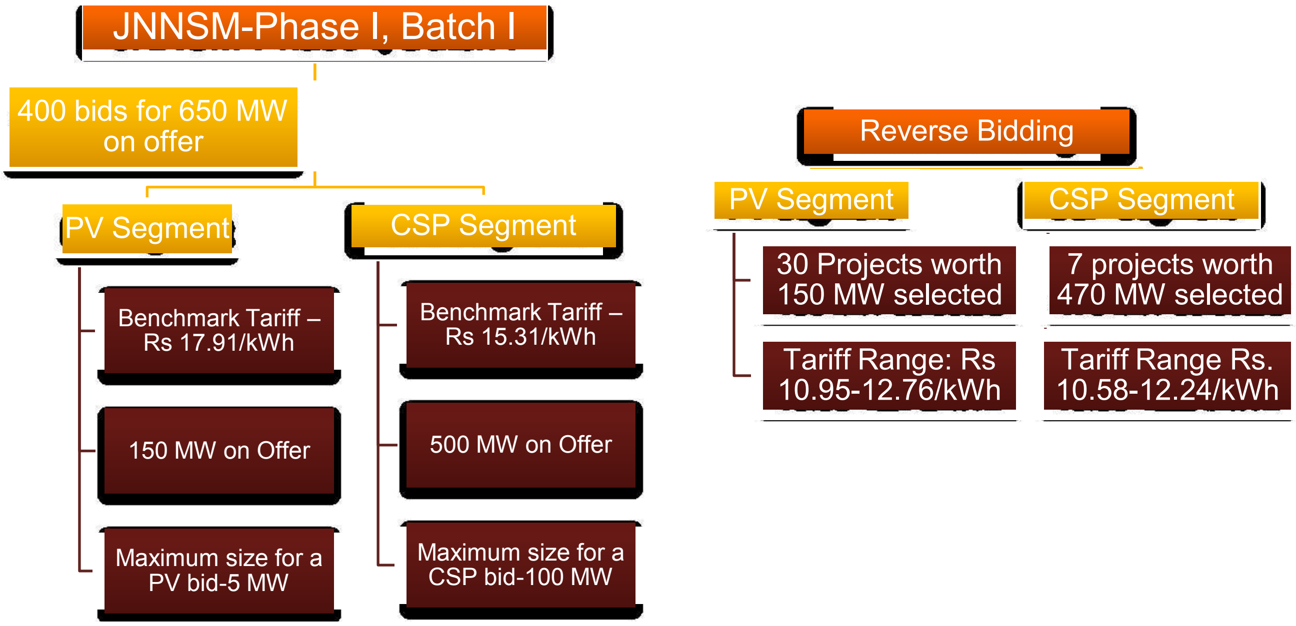
NAPCC announced by the Hon. Prime Minister of India envisages increasing the share of renewable energy in total electricity consumption in the country and has given special consideration to encourage the base of Solar Power in India. In order to promote the development and use of solar energy for power generation and other uses, the Government of India has launched the Jawaharlal Nehru National Solar Mission (JNNSM) during November 2009. JNNSM is one of the eight key National Missions envisaged under India's NAPCC. The mission has a twin objective - to contribute to India's long term energy security as well as its ecological security. The JNNSM would be implemented in 3 stages and aims to have an installed capacity of 20,000 MW by the end of the 13th Five Year Plan in 2022. It is envisaged that as a result of rapid scale up as well as technological developments, the price of solar power will attain parity with grid power at the end of the Mission, enabling accelerated and large-scale expansion thereafter. The mission includes a major initiative for promoting rooftop solar photovoltaic (PV) applications. The solar tariff announced by the regulators will be applicable for such installations.

The objectives of JNNSM are below:

- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To increase capacity of grid-connected solar power generation to 1000 MW within three years – by 2013; an additional 3000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000MW installed power by 2017 or more, based on the enhanced and enabled international finance and technology transfer.
- The target of 20000MW by 2022 will primarily be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power. The transition could be appropriately up scaled, based on availability of international finance and technology.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programs for off grid applications, reaching 1000 MW by 2017 and 2000 MW by 2022.
- To achieve 15 million square meters solar thermal collector area by 2017 and 20 million square meters solar thermal collector area by 2022.

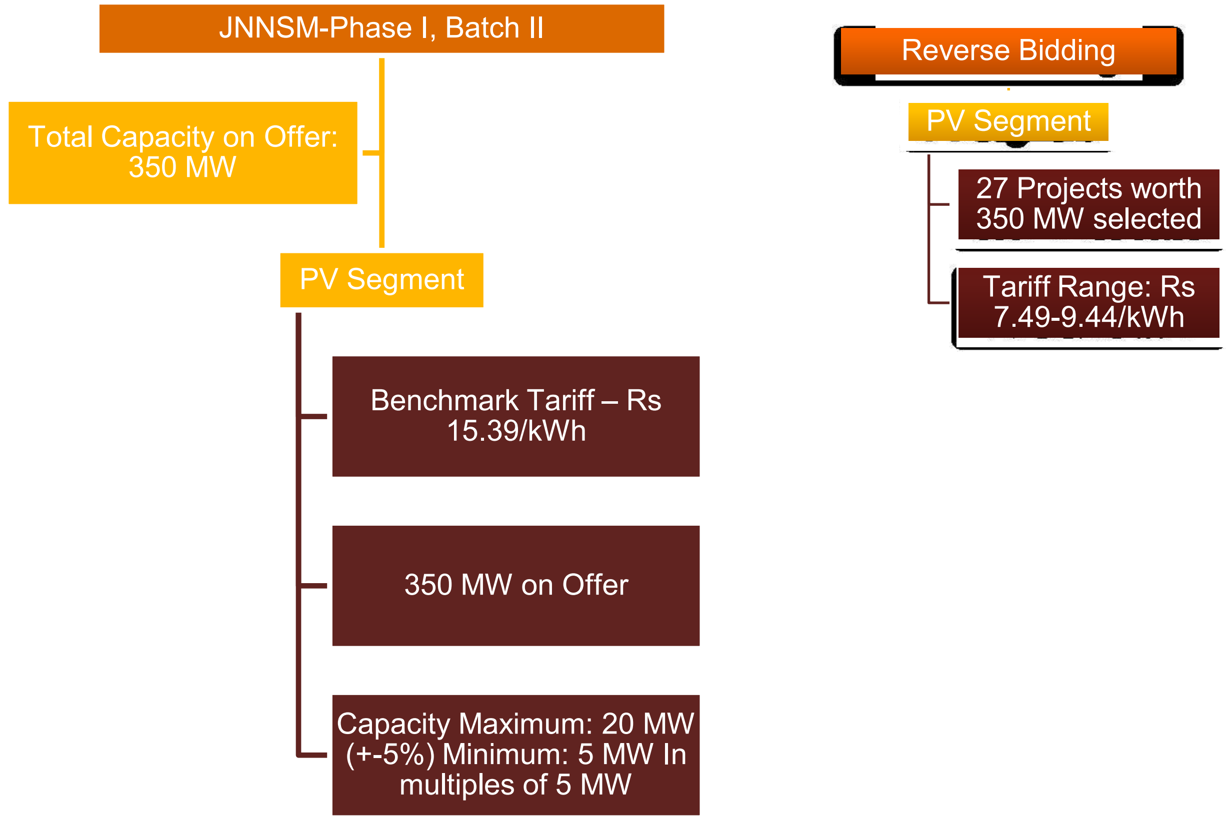
❖ To deploy 20 million solar lighting systems for rural areas by 2022.

Based on the objectives as laid in the National Solar Mission (NSM), over 1000MW of solar projects under the first phase, having affiliation to different solar technologies was allotted to the interested bidders. An approach of allowing 'discounted bidding' on the CERC approved 'benchmark tariff' for various solar technologies was envisaged as an instrument for selecting the prospective developers. The Bidding process under the first phase of the National Solar Mission was split into two batches with the understanding that this circumspect approach would leave enough room for rectification if some flaws or shortcomings that may emerge in the first batch of bidding. The following diagrammatic representation gives a snapshot of the bidding process that ensued in the first batch of bidding under the first phase of the Mission. Under the first batch, a total of 30 solar PV projects, each with an individual capacity of 5 MW (total capacity of 150 MW) and solar thermal projects (CSP Segment) with a total capacity of 470 MW were allocated. In addition to the 30 solar PV projects, capacity worth another 84 MW was contributed through the Migration Scheme that permits projects planned before the Mission was launched, to migrate into it and enjoy the incentives offered there under.



As the pictorial representation also suggests, there was substantial oversubscription for projects to start with, and then the government invited reverse bids asking for discounts on the initial benchmark tariff of Rs 17.91/ kWh for PV projects and Rs 15.31/ kWh on CSP projects. Thirty PV projects worth a cumulative capacity of 150 MW and seven CSP projects worth a cumulative capacity of 470MW were selected under Batch I of the scheme. Remarkably, the bidding process did result in exceedingly competitive bids. PPAs have been signed at an average levelized tariff of Rs. 12.16 / kWh for PV projects and Rs. 11.48/ kWh (for CSP (thermal) projects, i.e., the government has secured 32.1% and 25% discount respectively in PV and CSP projects.

Building further on the lessons learnt from the first batch of bidding, bids were invited for a cumulative capacity of 350MW in the second batch of Phase I. The entire quota of 350MW was for capacity in solar PV only. CERC revised the benchmark tariff for solar PV in light of the dropping trends in solar equipment prices. The following diagrammatic representation further illustrates the Batch II bidding process and its outcome.



The lowest bid submitted in Batch II, offered more than 50% discount on the CERC benchmark tariff. This lowest bid submitted was for a 5 MW capacity project and the quoted tariff was Rs. 7.49 per KWh. [1]The tariffs quoted by winning bidders in Batch II bidding ranged from Rs. 7.49 to Rs. 9.44 per kWh. This tariff range is remarkably lower than the one discovered in Batch I. In fact, the highest winning tariff in Batch II is almost Rs 1.5 lower than the lowest winning tariff in Batch I. Such a steep drop in tariffs, that too within a short of one year, augurs well for the Indian solar industry and may to some extent be attributed to the adaptive policy framework.

JNNSM thrust towards R&D Initiatives-Development of CSP demonstration projects

Further, JNNSM envisages development of pilot projects of those solar technologies which are not commercially proven. Also, these Pilot demonstration projects are closely aligned with the Mission's R & D priorities and designed to promote technology development and cost reduction. The Mission, therefore, envisages the setting up of the following demonstration projects in Phase I, in addition to those already initiated by MNRE and those, which may be set up by corporate investors:

- 50-100 MW Solar thermal plant with 4-6 hours' storage (which can meet both morning and evening peak loads and double plant load factor up to 40%).
- A 100-MW capacity parabolic trough technology based solar thermal plant.
- A 100-150 MW Solar hybrid plant with coal, gas or bio-mass to address variability and space-constraints.
- 20-50 MW solar plants with/without storage, based on central receiver technology with molten salt/steam as the working fluid and other emerging technologies.

It is further contemplated that such pilot demonstration projects would be allocated to the interested developers who would be showcasing the adequate 'financial and technical' criteria. Further, it is envisaged that 'Generation based Incentive' would be provided to such projects. This initiative would be in the line of Government of India's previous initiative of providing GBI benefits to develop 50MW of solar projects during 2009-10.

[1] EQ International Magazine : www.eqmqglive.com

CERC RE Tariff Regulations -Salient Features

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 61and section 178(2) of the Electricity Act, 2003 had notified the CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources), Regulations, 2012. Applicability of these regulations shall be confined to Central Sector and Inter State Generation projects, however, under Section 61 of EA 2003; these regulations would be guiding principles for State Electricity Regulatory Commissions while dealing with the matters related to energy generation from RE sources. The salient features of the Tariff Regulations applicable for the Solar Projects are as follows:

Salient Features of Tariff Regulations for Solar Energy Projects

Solar PV and Solar Thermal Projects – Based on technologies approved by MNRE	
General Principles	
Resolution	**Provisions in Regulation**
Control Period	Five (5) years
Tariff Period	Solar PV and Solar Thermal Projects – 25 years
Tariff Structure	Single Part Tariff- Fixed components shall be: • Return on Equity • Interest on loan capital • Depreciation • Interest on working capital • Operation and maintenance expense
Tariff Design	The generic tariff shall be on levelised basis for the Tariff Period
Dispatch Principles	a. All plant with installed capacity of 10MW and above shall be treated as 'MUST RUN' power plants and shall not be subjected to 'MOD'
Financial Principles	
Capital Cost	Benchmark Capital Cost for Solar PV and Solar Thermal Projects shall be reviewed annually
Discounting Factor	Weighted Average of Cost of Capital
Debt Equity Ratio	70:30
Loan and Finance Charges	Loan Tenure – 12 years
Interest Rate	a. Average long term prime lending rate (LTPLR) of SBI prevalent during the first six months plus 300 basis points. b. Repayment of loan shall be considered from the first year of COD
Return on Equity	Pre - Tax 20% for first ten years and Pre - Tax24% from eleventh year onward till useful life
Depreciation	a. Value base shall be Capital cost of the asset b. 5.83% for the first twelve years and the rate of depreciation from the 13th year onwards has been spread over useful life
Interest on Working Capital	a. O&M for 1 month b. Receivables for 2 months of energy charge on normative CUF

	c. Maintenance spare @ 15% of O&M expense
Operation and Maintenance Expense	R&M expense + A&G expense + Employee expense Escalated at 5.72% per annum over first year of control period
Rebate	For payment of bills through letter of credit, a rebate of 2% shall be allowed Payments made other than through letter of credit within 1 month of presentation of bills by the generating company, a rebate of 1% will be allowed
Late payment surcharge	Delay beyond the period of 60 days from the date of billing attracts late payment surcharge of 1.25% per month
Sharing of CDM benefits	100% of the gross proceeds to be retained by the developer in the first year In second year, the share of beneficiaries shall be 10% which shall be progressively increased by 10% every year until it reaches 50%, where after the proceeds shall be shared in equal proportion, by generating company and the beneficiaries
Subsidy or incentive	Accelerated depreciation or generation based incentive shall be factored in while determining the tariff
Taxes and duties	Taxes and duties shall be passing through on actual incurred basis.

The RE Tariff Regulations specifies that the benchmark capital cost norm for Solar Power projects shall be reviewed annually. Accordingly, the Commission has specified the benchmark capital cost norm for Solar PV and Solar Thermal projects as Rs. 1000lakh/MW and Rs.1300lakh/MW respectively for 2012-13.

Keeping into consideration the benchmark capital cost norm and other norms specified by CERC, the tariff applicable for Solar PV and Thermal Projects commissioned during 2012-13 stands as Rs. 10.39/kWh and Rs. 12.46/kWh respectively.

<u>CERC IEGC Regulations, 2010 - Analysis of the specific provision</u>

The Central Electricity Regulatory Commission (CERC) exercising its power conferred under Section 79(1) (h) and section 178(2) (g) of the Electricity Act, 2003 had notified the CERC (Indian Electricity Grid Code), Regulations, 2010. This code will be applicable to NLDC, RLDC/SLDCs, ISGS, and Distribution Licensees/SEBs/STUs/regional entities, Power Exchanges and Wind and Solar Generating Stations.

In order to encourage the solar based generation into the electricity grid, the IEGC has given due consideration for such segment. The Grid Code provides that in case the generation from solar power project deviates from the schedule the financial burden shall be borne by all the users of the Inter-State Grid, instead of the concerned solar project developer. The IEGC provides the methodology for rescheduling of solar energy on three (3) hours and the methodology of compensating the solar energy rich state for dealing with variable generation through Renewable Regulatory Charge. In pursuance of this, appropriate meters and data acquisition systems facility shall be provided for accounting of UI charges and transfer of information to SLDC and RLDC. The provisions of the IEGC shall be applicable from January 1, 2011, for new solar generating plants with capacity of 5MW and above connected to 33kV and above who have not signed any PPA with States or others. Some of the key and enabling provisions for solar energy in IEGC are as below,

Provision for Solar Energy under IEGC

Provisions in IEGC,2010	Description
Special conditions for solar (Reg 5.2(u):System security Aspects	• System Operator (SLDC/RLDC) shall make all efforts to evaluate the solar and wind power and treat as a '**Must Run'** Plant. • System Operator may instruct the solar generator to back down generation on consideration of grid security or safety of any equipment or personnel is endangered and solar generator shall comply with same. • For this, data acquisition system facility shall be provided for transfer of information to concerned SLDC and RLDC.
Scheduling of Solar Power (Reg. 6.5(23)(i))	• Schedule of the Solar generation shall be given by generator based on the availability of the generator, weather forecasting, solar insolation, season and normal generation curve and shall be vetted by RLDC and incorporated in inter-state schedule. • If the RLDC is of opinion that the schedule is not realistic, it may ask the solar generator to modify the schedule
Implications of Scheduling	• In case of solar generation no UI shall be payable/receivable by the generator for any deviation in actual generation fro schedule. • The host state shall bear the UI charges for deviation in the actual generation from schedule. • The net UI charges borne by the host state due to solar generation, shall be shared among all the states of the country in ration of their peak demands in previous month based on the data published by CEA, in form of regulatory charge known as Renewable Regulatory Charge operated through the Renewable Regulatory Fund. • The provision shall be applicable, with effect from 1.1.2011 for new solar generating plants with capacity of 5MW and above and connected at 33Kv level and above and who have not signed PPA with states or others as on date of coming into force of this IEGC.

<u>CERC Initiative for Transmission/Evacuation of Solar Power</u>

Under the mandate of statutory provisions of Section 61 of the Electricity Act, 2003 inter-alia para 5.3.4 and para 7.2(1) of the National Electricity Policy and Tariff Policy respectively, Central Electricity Regulatory Commission (CERC) has undertaken the exercise to frame regulations on sharing of transmission charges and losses among the users.

The regulations facilitate the solar based generation by allowing zero transmission access charges for the use of the Inter State Transmission System and allocating no transmission loss to the solar based generation. Solar power generators shall be benefited in event of use of the ISTS. Since such generation would normally be connected at 33 kV, the power generated by such generators would most likely be absorbed locally. This would cause no / minimal use of 400 kV ISTS network and might also lead to reduction of losses in the 400 kV network by doing away the need for power from distant generators. The cost of energy from solar based generation is perceived to be costly as compared to other sources, including renewable energy sources, and further application of ISTS charges and losses would further reduce the acceptability of power generated from solar sources. This regulation thus encourages solar based generation and inter-state transactions based on solar energy.

State Level Initiatives and Development Targets

Spurred by national level initiatives and policy push, several states like Gujarat, Rajasthan, Madhya Pradesh, Karnataka and Jammu & Kashmir have also formulated and adopted solar policies for development of solar energy projects in their respective states. Salient Features of these policies have been discussed herewith.

Gujarat

- Gujarat, among all the other states, has taken the lead and already allotted projects worth a cumulative capacity of 716 MW to 34 national and international project developers against the declared 500 MW in their policy. Of the 716 MW, 365 MW has been allocated to Solar PV and the remaining 351 MW to Solar Thermal Power plants.
- Major players in the state include AES Solar, Astonfield Solar, Azure Power Ltd. with allotments ranging from 5 to 50 MW.

Rajasthan (Draft)

- Rajasthan has set a target of developing 10,000-12,000MW solar power capacity in the next 10-12 years.
- It has been mandated that 200MW of solar power shall be developed till 2012-13 and an additional 400MW power shall be developed between 2014 and 2017. The State also plans to develop 1000MW of solar parks

Madhya Pradesh (Draft)

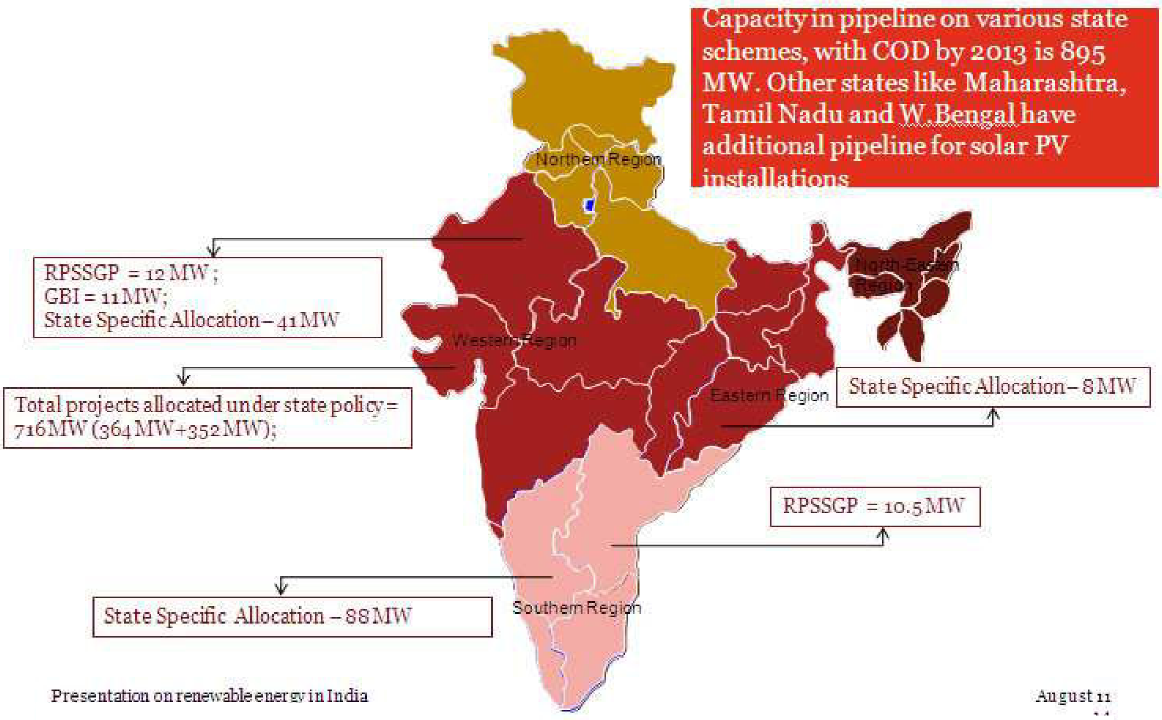
- Madhya Pradesh targets a total solar power capacity development of 500MW.
- The facility of wheeling solar power, exemption of open access charges and electricity duty shall be extended to developers and distributors
- Power evacuation facility shall also be extended to concerned licensees.

Jammu & Kashmir

- Under this policy, prior weightages to be given to financial capacity, technical capability, past experience and other relevant attributes of the applicants, the sub-categories of these attributes to be evaluated and their inter-se weightage, the guidelines for evaluation and the passing score on attributes /in aggregate required for pre-qualification shall be specified in the bid documents inviting bids for pre-qualification.
- The minimum project capacity shall be 1 MW. However, if MNRE launches any scheme for lower capacity power plant then that shall also be considered.

Karnataka

- Karnataka targets a total solar power capacity development of targeting capacity addition in solar power projects by 350 megawatts by 2016.
- The solar PV projects that plan to sell their electricity to state utilities at preferential tariff have to have a capacity of between three and 10 MW.
- To keep the costs lower, policy allows developers to inject power at 11kV and above.



Solar Thermal Technology- An Introduction

Concentrating solar power (CSP) plants produce electricity by converting the infrared part of solar radiation into high temperature heat using various mirror/reflector and receiver configurations. The heat is then channelled through a conventional generator. The plants consist of two parts: one that collects solar energy and converts it to heat, commonly known as 'solar field' and another that converts heat energy to electricity, known as 'power block'.

CSP plants use the high-temperature heat from concentrating solar collectors to drive conventional types of engines turbines. For power generation, temperatures more than 200 °C are preferred. All CSP are based on four basic essential sub systems namely collector, receiver (absorber), transport/ storage and power conversion.In solar collectors of such systems, the incoming radiation is tracked by mirror fields/lenses which concentrate the energy towards absorbers. The absorbers receive the concentrated radiation and transfer it thermally to the working medium, hereby transferring the heat energy to it. The heated fluid may reach high temperatures and may be used for driving the turbine to generate power. The heat carrier in these systems can be oil, molten salts, pressurized water or steam.

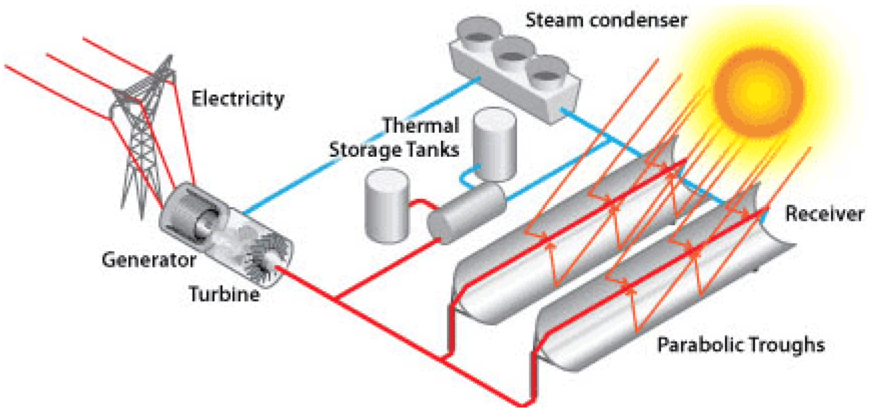
Different concentrating technologies have been developed or are currently under development for various commercial and Industrial applications as well as power generation. Such solar thermal concentrating systems can significantly contribute to efficient and economical, renewable and clean energy supply.

Following four CSP technologies have either reached commercialisation stage or are near it:

- Parabolic Trough
- Power towers
- Parabolic Dishes (Dish-Stirling)
- Compound Linear Fresnel Reflectors (CLFR)

Parabolic Trough

The parabolic-trough solar concentrators are one of the basic elements of a concentrating solar power plant. The main elements of the plant based on the parabolic trough technology are: the solar field, the storage system, the steam generator and the auxiliary systems for starting and controlling the plant.



(Source: NREL)

Several collector elements of the solar field are composed in series to create the single collector line. The collected thermal energy is determined by the total number of collector elements which are characterized by a reflecting parabolic section (the concentrator), collecting and continuously concentrating the direct solar radiation by means of a sun-tracking control system to a linear receiver located on the focus of the parabolas. Parabola has the property of focussing the incoming radiation as its focus. Working on this principle, linear concentrators of parabolic shape are usually mirrors or highly reflective surfaces and can be turned in angular movements towards the sun position and concentrate the incoming solar radiation onto a long-line receiving absorber tube. The mirror is anchored at four points to the steel structure. The mirrors, mountings and adhesives all have the same expansion coefficient, guaranteeing durability even under extreme temperature fluctuations. The mounting elements are made from special ceramics giving them a high level of mechanical strength and are non-corrosive. The absorber pipe is composed of a multi-layered stainless-steel pipe, with an absorption level of around 95% and radiation level of approximately 14% of its heat at temperatures of around 400 degrees Celsius. The steel pipe is surrounded by a vacuum-isolated concentric borosilicate glass cladding tube with anti-reflective coating, which allows for over 96% penetration of solar radiation.

A heat transfer fluid, circulating in the pipe, is used to transfer the absorbed solar energy, which is then piped to an exchanger or a conventional conversion system. 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. Parabolic trough systems cannot make use of diffuse irradiation as they use only direct-beam sunlight and require tracking systems to keep them focused toward the sun and are best suited to areas with high direct solar radiation. Most systems are oriented north-south with single-axis tracking during the day. The integration of heat storage allows the power plant to function at full capacity both on overcast days and at night

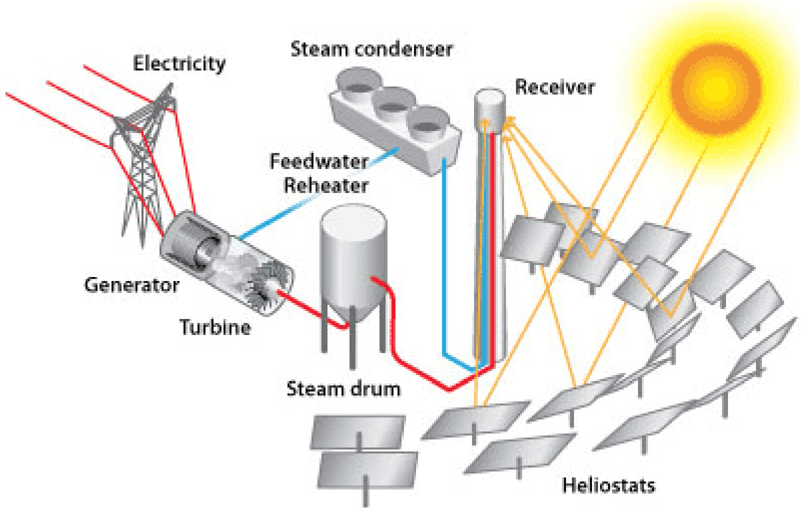
Storage system is the integral and an important part of the parabolic trough based power plants. Thermal Energy Storage (TES) option can collect energy in order to shift its use to later times. Hence, the functional operativeness of a solar thermal power plant can be extended beyond periods of no solar radiation without the need of burning fossil fuel. The most advanced technology for heat storage in trough collector plants considers the use of a two-tank molten salt system which functions like a thermos flask and are able to assure that the salt maintains its temperature and decrease the thermal losses. The used power conversion systems are based on the conventional Rankine-cycle steam turbine generator.

Several Parabolic trough based power generation plants are in operation. SEGS, California is a collection of 9 plants with a combined capacity of 350 MW. Nevada Solar, completed in 2007 has a capacity of 64MW. Andasol, Spain has 4 power plants with a combined capacity of 50MW.

Solar Tower (Central Receiver Systems)

Central receiver systems use heliostats to track the sun by two axes mechanisms following the azimuth and elevation angles with the purpose to reflect the sunlight from many heliostats oriented around a tower and concentrate it towards a central receiver situated atop the tower. A heat-transfer medium is employed in the central receivers to absorb the highly concentrated radiation reflected by the heliostats and converts it into thermal energy, which is used to generate superheated steam for the turbine.

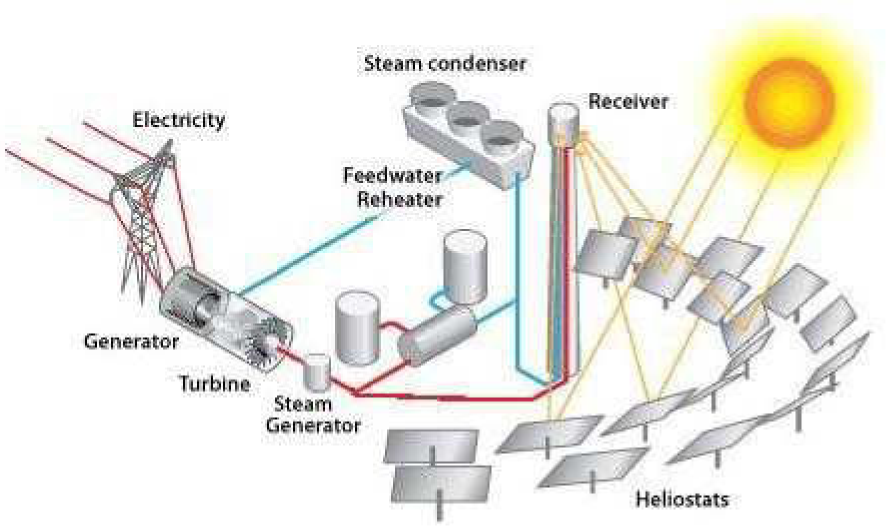
This technology has the advantage of transferring solar energy very efficiently by optical means and of delivering highly concentrated sunlight to one central receiver unit, serving as energy input to the power conversion system. In spite of the elegant design concept and in spite of the future prospects of high concentration and high efficiencies, the central receiver technology needs still more research and development efforts and demonstration of up-scaled plant operation to come up to commercial use in Indian conditions. Its main attraction is the prospect of achieving higher process temperatures than other CSP technologies, by concentrating solar irradiation to supply energy to the topping cycle of any power conversion system. This technology can also increase the efficiency of energy storage systems.



(Source: NREL)

Different receiver heat transfer media that have been successfully used are water/steam, liquid sodium, molten salt, ambient air, oil. To date, the heat transfer media demonstrated include water/steam, molten salts and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to have an early energy conversion cycle as in a combined cycle power plant, increasing the global efficiency.

The diagram above illustrates the layout of a central receiver based CSP plant with direct steam production and steam drum storage. A more efficient approach is using molten salt as the heat transfer fluid and for storage. Liquid salt, after absorbing heat through the receiver can withstand and effectively transfer heat at temperature range 200°C - 700°C and can be stored for use during night. Hot salt can be pumped to a steam generating system that produces superheated steam through conventional Rankine cycle. Storage tanks can be designed with sufficient capacity to power a turbine at full output for up to 13 hours. The process layout for solar tower with storage is shown below:



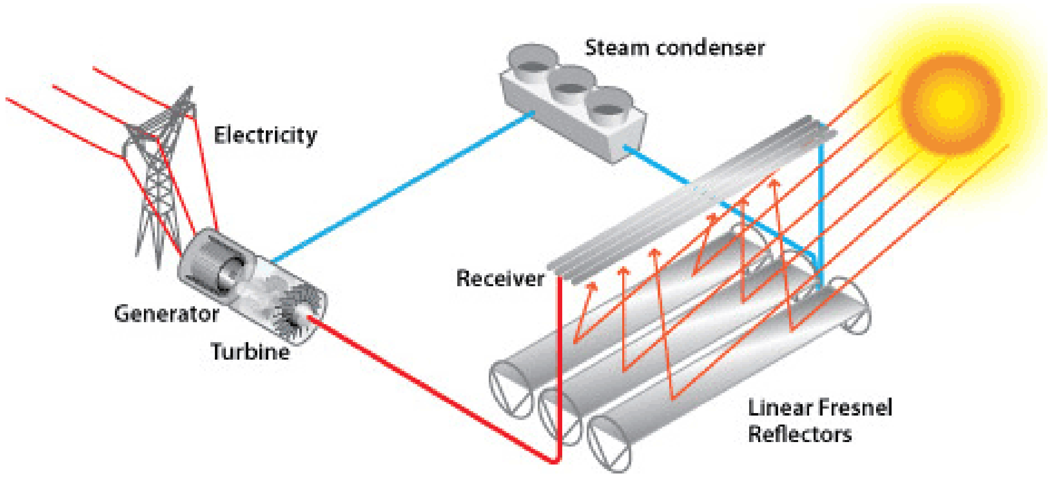
Heliostats that track the sun and reflect the rays to the absorber are to be designed and laid out carefully to optimize the annual performance of the plant. The energy collection in the tower is directly proportional to the heliostat field which is in turn determined by the number of heliostats and their area. The project has to be designed such that steam requirement of the turbine is fulfilled and there is enough energy left to consequently charge the thermal storage system for power production during non sunny weather. Future solar tower plants have the good long-term perspective for high conversion efficiencies and for use of very efficient energy storage systems by utilization of high temperatures in order to enlarge the solar capacity or solar share.

In 2008, a 4-6 MW a solar power plant came up in Israel's Negev Desert. The site features more than 1,600 heliostats that track the sun and reflect light onto a 60 meter-high tower. The concentrated energy is then used to heat a boiler atop the tower to 550 °C, generating superheated steam. A working tower power plant is PS10 in Spain with a capacity of 11 MW; composed of 624 heliostats and a field area of 75,000 m^2, concentrating the radiation onto a receiver located on tower that is 115 m tall. Subsequently, PS20 was also build with thermal storage to boost power production under non-sunny conditions. The PS20 solar field has 1,255 heliostats and tower of 160 m.

The 15MW Solar Tres plant with heat storage is under construction in Spain. A 10MW power plant in Cloncurry, Australia uses Graphite for heat storage. Morocco is building five solar thermal power plants. The sites will produce about 2000 MW by 2012.

Linear Fresnel

The Linear Fresnel technology uses long, flat or slightly curved mirrors to focus sunlight onto a linear receiver located at a common focal point of the reflectors. The receiver runs parallel to and above the reflectors and collects the heat to boil water in the tubes, generating high-pressure steam to power the steam turbine (water/direct steam generation, no need for heat exchangers). The heat thus generated is then channelled through a conventional steam generator to generate electricity.



(Source: NREL)

The reflectors make use of the Fresnel lens effect, which allows for a concentrating mirror with a large aperture and short focal length. This reduces the plant costs since sagged-glass parabolic reflectors are typically much more expensive. The collector field comprises mirrors in parallel rows aligned on a north-south axis which enables the single-axis mirrors to track the sun from east-west direction to ensure that the sun is continuously focused on the receiver pipes/absorber tubes. The amount of power generated by the Linear Fresnel plant depends on the amount of direct sunlight and these technologies use only direct-beam sunlight, rather than global horizontal irradiation. The plant configuration and the layout depends on the project developer but initial installations had mirrors having a width of 0.5 m, arranged in rows and focusing the rays on a fixed receiver tube, along the length of the mirrors.

Since the optical efficiency as well as the working temperatures are considerably lower than with other CSP concepts, saturated steam conditions are mostly considered for this technology. Alternatively, heat could be stored in high-temperature storage mediums and superheated to ultimately drive steam turbines, thus providing greater efficiencies. The receiver is stationary and so fluid couplings are not required (as in troughs and dishes). The mirrors also do not need to support the receiver, so they are structurally simpler. When suitable aiming strategies are used (mirrors aimed at different receivers at different times of day), this can allow a denser packing of mirrors on available land area.

Linear Fresnel plants can also be "hybrids," and can supplement the solar output during periods of low solar radiation and in night through fossil fuels, normally with a natural gas-fired heat or a gas steam boiler. CLFR can also be integrated with existing coal-fired plants.

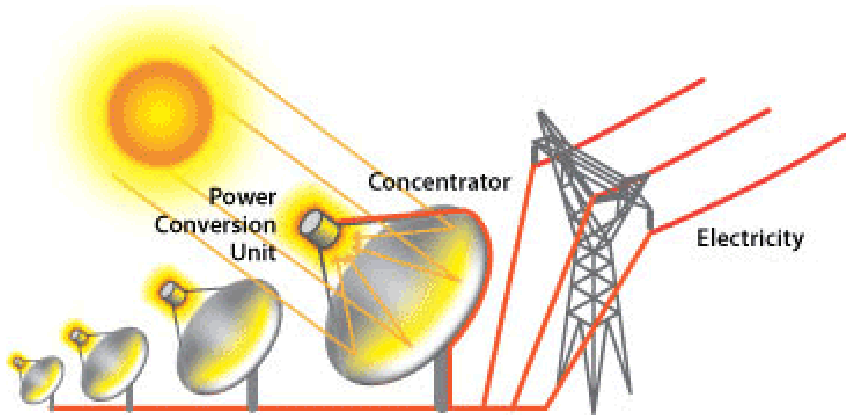
Unlike other CSP technologies, the material requirements for CLFR are very simple and the structure is lighter, leading to reduced setup costs and operational costs. Also, the mirrors are packed closer, have simpler tracking system, and are less affected by higher wind speeds and rain. Fresnel mirrors are simple, cheaper and lighter than parabolic trough mirrors, leading to a simplified plant design compared to other CSP technologies.

Major CLFR Project developers include AREVA Solar (Ausra), Novatec Solar, SPG etc. In 2008, the German Solar Power Group GmbH started execution of a solar thermal power plant in central Spain, the first commercial solar thermal power plant in Spain based on the Fresnel collector technology. The planned size of the power plant will be 10 MW.

Since 2009, the Fresnel solar power plant of Novatec Biosol is in commercial operation in southern Spain. The solar thermal power plant is based on linear Fresnel collector technology where the absorber tube is positioned in the focal line of the mirror field in which water is evaporated directly into saturated steam at 270 °C and at a pressure of 55 bar by the concentrated solar energy. Ausra has finished construction of the 5 MW Kimberlina Solar Thermal Energy plant in Bakersfield, California and also built a linear fresnel reflector plant in New South Wales, Australia to supplement a coal fired plant.

Parabolic Dish Systems

Dish/engine systems convert the thermal energy in solar radiation to mechanical energy and then to electrical energy in much the same way that conventional power plants convert thermal energy from combustion of a fossil fuel to electricity. A paraboloid dish-shaped reflector (commonly called as parabolic dish) concentrates sunlight on to a receiver located at the focal point of the dish. Dish systems use these parabolic reflectors to focus the sun's rays onto a dish-mounted receiver at its focal point. This requires that the dish track the sun in two axes. In the receiver, a heat-transfer medium takes over the solar energy and transfers it to the power conversion system, which may be mounted in one unit together with the receiver (e. g. receiver/Stirling engine generator unit) or at the ground. Due to its ideal optical parabolic configuration and its two axes control for tracking the sun, dish collectors achieve the highest solar flux concentration, and therefore the highest performance of all concentrator types in terms of peak solar concentration and of system efficiency.



(Source: NREL)

Dish systems may optionally be arranged in large dish arrays in order to accumulate the power output from the kWe capacity up to the MWe range. The power conversion subsystem of dish systems is mainly based on the Stirling engine generator system, but also on the water/steam powered turbine or piston engine generator system or on the gas turbine generator system.

Dish/engine systems utilize concentrating solar collectors that track the sun in two axes. A mirror or a reflective surface reflects incident solar radiation to a small region called the focus. The size of the solar concentrator for dish/engine systems is determined by the engine. At a nominal maximum direct normal solar insolation of 1000 W/m^2, a 25-kW dish/Stirling system's concentrator has a diameter of approximately 10 meters. The most durable reflective surfaces have been silver/glass mirrors, similar to decorative mirrors used in the home. Attempts to develop low-cost reflective polymer films have had limited success. Because dish concentrators have short focal lengths, relatively thin glass mirrors (thickness of approximately 1 mm) are required to accommodate the required curvatures. In addition, glass with low-iron content is desirable to improve reflectance. Depending on the thickness and iron content, silvered solar mirrors have solar reflectance values in the range of 90 to 94%.

The ideal concentrator shape is a paraboloid of revolution. Some solar concentrators approximate this shape with multiple, spherically-shaped mirrors supported with a truss structure. An innovation in solar concentrator design is the use of stretched-membranes in which a thin reflective membrane is stretched across a rim or hoop.

Dish system also utilise receivers which absorbs energy reflected by the concentrator and transfers it to the engine's working fluid. The absorbing surface is usually placed behind the focus of the concentrator to reduce the flux intensity incident on it. Stirling engine receivers are the most commonly used engine receivers where the concentrated solar energy is transferred to a high-pressure oscillating gas, usually helium or hydrogen. Generally there are two types of Stirling receivers, direct-illumination receivers (DIR) and indirect receivers where intermediate heat-transfer fluid is being used. Directly-illuminated Stirling receivers adapt the heater tubes of the Stirling engine to absorb the concentrated solar flux. Because of the high heat transfer capability of high-velocity, high-pressure helium or hydrogen; direct-illumination receivers are capable of absorbing high levels of solar flux.

The engine employed in the dish system converts heat to mechanical power in a manner similar to conventional engines, that is by compressing a working fluid when it is cold, heating the compressed working fluid, and then expanding it through a turbine or with a piston to produce work. The mechanical power is converted to electrical power by an electric generator or alternator. A number of thermodynamic cycles and working fluids have been considered for dish/engine systems. These include Rankine cycles, using water or an organic working fluid; Brayton, both open and closed cycles; and Stirling cycles.

Dish systems with supplementary combustion of fossil fuels integrated into the receiver component are a better solution for Industries as solar energy is not available 24 hours a day, even with thermal storage. Such systems are currently under development and are expected to be available for first demonstration projects in the near-term run.

Dish/engine systems are characterized by high efficiency, modularity, autonomous operation, and an inherent hybrid capability (the ability to operate on either solar energy or a fossil fuel, or both). Of all solar technologies, dish/engine systems have demonstrated the highest solar-to-electric conversion efficiency. The modularity of dish/engine systems allows them to be deployed individually for remote applications, or grouped together for small-grid (village power) or end-of-line utility applications.

In January 2010, Stirling Energy Systems commissioned a 1.5-megawatt power plant using Stirling technology in Peoria, Arizona.

Comparison of various CSP technologies

	Parabolic trough	Solar Dish	Solar Tower	Linear Fresnel
Working Temp.	150- 600 °C	Upto 1000 °C	Upto 1000 °C	Upto 400 °C
Conversion Efficiency	Around 20 %	Around 30 %	Around 20-25 %	Around 15-20 %
Concentration ratio	10-100	1000-4000	600-1000	10-100
Storage	Possible	Not possible	Possible	Possible
Area required (Acre/MW)	7-8	7-10	8-12	4-5
Commercial status	Commercial	Some pilot projects in the country	Only prototypes under Demo	Pre-commercial
Thermodynamic power cycle	Rankine	Stirling, Brayton	Brayton, Rankine	Rankine
Tracking	Single axis	Double axis	Double axis	Single axis
Advantages	Long-term proven reliability and durability	High temperature allows high efficiency of power cycle	High temperature allows high efficiency of power cycle	Simplified plant design, lower investment and operational costs
	Storage options available	High tolerance of variation in land slope	Tolerates non-flat sites	Tolerance for slight slopes, modularity in system
	Direct steam generation proven	High Modularity	Possibility of combined power cycles	Direct steam generation proven
	Highest number of commercial installations	High efficiency	Ability to provide high-temperature steam, higher generation efficiencies	minimized structural costs, low wind loads, and lower maintenance costs
	Better R&D experience; hybridization and storage optional	Great modular system; hybridization is optional	High conversion efficiency; storage and hybridization option	Small operation experience; storage and hybridization option
Disadvantages	Limited temperature of heat transfer fluid hampering efficiency and effectiveness	Not commercially proven in India	High maintenance and equipment costs	Storage for direct steam generating systems (phase change material) in very early stage
	Complex structure, high precision required during construction	High complexity compared to stand-alone PV	High land requirements	Larger area requirement cannot be placed close to process setup.
	Requires flat land area			Low efficiency

The above sections provide insight about the salient features of the CSP technology required for generating power. It needs pertinent mentioning some of the components, sub-systems used in all the aforementioned technologies are common in nature and play an important role in the functioning of the systems. Some of the typical components of the CSP plant which have a common bearing with all the technologies are as follows:

CSP Plant			
Solar Block		Power Block	Balance of Plant (BOP)
Solar Field	Thermal Storage	• Steam Generator • Turbine • Power Generator • Condensers • Transformer • Cooling Tower	• Pipes • Electric cables • Pressure Vessels • Water tanks
• Receiver • Reflecting Panels (Heliostats, mirrors) • Tracking System • Heat transfer fluid (Water, oil, salt, air) • Hydraulic drive • Supporting structures • Civil Works	• Storage medium ✓ Molten salts ✓ Metals ✓ Ceramic/porcelain • Circulation pump • Storage tanks • Insulation		

Solar field is not particular to any project. Typically in all technologies solar field is made of:

- <u>Receiver</u>: Receivers are either made of evacuated tubes, normal steel pipes or special cavities. The receiver tube has the co-axial structure made of external glass tube and concentric steel tube where heat transfer fluid flows. Coating on the steel tube ensures maximum absorption of the solar light spectrum with maximum re-emission by the hot tube surface. Vacuum stability in the room between glass and the steel tube is guaranteed by getter material stratified on the glass surface.
- <u>Heliostats, mirrors and reflecting surfaces:</u> Parabolic troughs, Fresnel mirrors, heliostats or parabolic dishes all are mirror based. The mirrors are either curved or flat and either glass-silver or high-reflectivity aluminium surfaces. A heliostat usually uses a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky. In the heliostat reflective surface of the heliostat is kept perpendicular to the bisector of the angle between the directions of the sun and the target as seen from the mirror. In almost every case, the target is stationary relative to the heliostat, so the light is reflected in a fixed direction. Heliostats are essentially distinguished from solar trackers or sun-trackers that point directly at the sun in the sky. However, some older types of heliostat incorporate solar trackers, together with additional components to bisect the sun-mirror-target angle. A conventional design for the heliostat's reflective components utilizes a second surface mirror. The sandwich-like mirror structure generally consists of a steel structural support, an adhesive layer, a protective copper layer, a layer of reflective silver, and a top layer of tempered float glass. Conventional heliostat is often referred to as a glass/metal heliostat. Alternative designs incorporate recent adhesive, composite, and thin film research to bring about materials costs and weight reduction.
- <u>Tracking System:</u> A solar tracker is a kind of device that exhibits the property of orienting various payloads toward the sun. Payloads can be any type of optical devices. The primary benefit of a tracking system is to collect solar energy for the longest period of the day, and with the most accurate alignment as the Sun's position shifts with the seasons. In addition, the greater the level of concentration employed the more important accurate tracking becomes, because the proportion of energy derived from direct radiation is higher, and the region where that concentrated energy is focused becomes smaller. Generally the tracking system can be classified as the single axis tracking system and the double axis tracking system. Single axis trackers have one degree of freedom that acts as an axis of rotation. Single axis system can be aligned in any direction with advanced tracking algorithms. There are several common implementations of single axis trackers. These include horizontal single axis trackers (HSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT). Dual axis trackers have the flexibility for two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis. Dual axis systems are classified by the orientation of their primary

axes with respect to the ground. Two common implementations are tip-tilt dual axis trackers (TTDAT) and azimuth-altitude dual axis trackers (AADAT).

- Heat Transfer fluid: HTF are usually artificial oils with altered boiling and/or freezing points, water - deaerated – air, gases and molten salts – phase changing materials that become liquid when heated. Traditionally mineral oil is being used as the heat transfer fuel which is also inflammable and toxic in nature. This type of heat transfer fluid has low specific heat and temperature restrictions to operate which further limits the operating temperature of the plant. Molten salt as the heat transfer fluid is specially formulated for solar applications that demand the optimum purity and performance. It has superior heat transfer compared to other fluids in its class. It also exhibits high thermal stability but however it has high freezing point rendering it difficult to operate it at regions with high ambient temperature. Improved heat transfer efficiency reduces a system's total energy requirements, and increases system longevity. The more efficient the heat transfer system is, the less energy that is required to maintain the bulk operating temperature of the fluid.
- Hydraulic Drives: Collector units of the solar field has its own solar sensors and the hydraulic drives which enables the mirrors to track the position of the sun and also allows the collector unit to track the sun along with its changing path. The hydraulic drives can adjust the 150 meter long collector chains with a precision of up to a tenth of millimeter allowing them to follow the sun on its daily course from east to west along a single axis.

Thermal storage section constitutes the important section of the CSP based power projects. Storage system can allow the operation of the plants to take place on the continuous and regular basis. Moreover, it also helps in increasing the operational temperature of the plant and thereby contributing towards enhancement of operational efficiency of the power plant. Important constituents of the storage section are as follows:

- Heat storage systems/tanks: Thermal Energy Storage (TES) option can collect energy in order to shift its use to later times, or to smooth out the plant output during irregularly cloudy weather conditions. Hence, the functional operativeness of a solar thermal power plant can be extended beyond periods of no solar radiation without the need of burning fossil fuel. Periods of mismatch among energy supplied by the sun and energy demand can be reduced. Concrete based heat storage systems are the most effective heat storage systems in the operation.

  Generally the Thermal Storage System is largely composed of two tanks, the cold tank that contains the storage medium at lower temperature and the hot tank that contains the storage medium at a higher temperature. Other components of the heat storage system are:
  - ✓ Storage medium inventory;
  - ✓ circulation pumps;
  - ✓ Piping.

  In presence of direct solar radiation the medium is pumped out from the cold tank to circulate in the solar field and is finally heated up to a higher temperature to be accumulated in the hot tank. When steam production is requested a medium flow is taken from the hot tank, circulated through the steam generator and finally re-collected in the cold tank.

- Storage medium: Storage of the heat on the short term basis can be provided by the fire-bricks, ceramic oxides, fused salts which melts at higher temperature Hitech, a fused salt mixture which is stable upto 540 °C is also identified as the promising energy storage medium. Current work is also carried by rocks, eutectic salts, and some synthetic organic materials of low pressure such as Gilotherm. For choosing a conventional storage material, its energy density, thermal conductivity, corrosion characteristics, cost and convenience to use as well as operating temperature of the fluid is diagnosed. The storage space must be also well insulated against heat losses.

Rationale for site selection for CSP projects

In order to select the optimal sites for the CSP demo projects, the Ministry of New and Renewable Energy (MNRE) sent invitations to states and asked for recommendations for the projects. The recommendations were based on meeting site requirements for two categories of CSP projects. The first category contained 3 of the 7 projects which had specific requirements which could be met only at specific sites, and the second category contained the remaining 4 of 7 projects which had no site specific requirements and could be located anywhere. The following table lists these two types of projects.

Site Specific Projects	Non-site Specific Projects
CSP project with storage (>= 10 hours)	CSP project with biomass support (Solar >= 60%)
CSP project with high operating temperature (>=500°C)	CSP project with gas support (Gas usage <= 30%)
CSP project with hybrid cooling (water <= 30%)	CSP project augmenting a coal fired power plant
	CSP project using Stirling Engines

MNRE laid out a detailed information template that had to be filled out for each recommended site. These requirements included parameters like status of land ownership, power evacuation facilities, water and road availability and geographical parameters like average ambient temperature, humidity, rainfall, endemic flora and fauna etc.

In response to MNRE's invitation of recommendations, 5 states – Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh and Karnataka - responded with potential locations along with the information described above. Based on this data, MNRE conducted a short-listing exercise to select the final candidate sites for the projects. This short listing was based on a quantitative scoring scale with specific points being assigned to specific site-attributes, as described below.

#	Site Attribute	Evaluation Criteria
1	Power evacuation	Not constructed = excluded; constructed/under construction = 5 points
2	GSS Type	no 110 KV or 132 KV GSS = excluded; otherwise: 5 points
3	Distance to the site	less than 1 km = 5 points <10 km = 4 points <20 km = 3 points and so forth with >50 km = 0 points

4	Water availability	Not available = excluded;
		with limitations = 2 points;
		no limitations = 5 points;

5	Acquired land	acquired = 5 points;
		under acquisition = 3 points;
		not acquired/to be acquired = 0 points

6	Area	less than 50 hectares = excluded; largest area: 5 points (all the rest proportionally scored)
7	Access to the site	no access = excluded; otherwise = 5 points
8	Populations nearby	< 1000 = 5 points; < 2000 = 4 points and so forth with < 50000 = 1 point
9	DNI	less than 5 KWh/m2 = excluded; highest DNI = 5 points (all the rest proportionally scored)
10	Solar Park	in existing/construction Solar Park = 5 points; in solar park being planned = 3 points

Based on this scoring metric, the following table shows the final candidate sites.

State	Proposed Location	Included	Reasons for exclusion
Rajasthan	Bhadla	Yes	Ok*
Rajasthan	Mathnia		no water
Rajasthan	Ramgarh		small size
Gujarat	Harshad		not ready
Gujarat	Charanka	Yes	Ok
Tamil Nadu	Kulathur		land issues
Tamil Nadu	Terkuveerapandiyapuram	Yes	Ok
AP	Gadwal		big boulders
AP	Ramagundam		not ready
AP	Nennal	Yes	Ok
AP	Gurajala		limestone slabs and river embankment
AP	Rajamundry		low DNI
Karnataka	Tulasigere		stone and rocky soil

* site has a GSS under construction, but will use a nearby existing GSS in the meantime

For each of the 4 selected sites, the respective state government is asked to provide a letter of comfort stating that:

- Land will be allotted
- Power evacuation will be available
- Water will be available
- Accesses will be made available, if required

These aspects along with the technical short-listing process described above will ensure that the sites selected for the demo projects are optimal choices.

Chapter 2: Technical Feasibility assessment

Project specific site details

Based on a quantitative scoring scale with specific points being assigned to specific site-attributes, and through field visits of the probable sites, the optimal sites selected for the demonstration projects were Bhadla (Rajasthan), Charanka (Gujarat), Terkuveerapandiyapuram (Tamil Nadu) and Nennala(Andhra Pradesh). Based on a careful consideration of physical and technical attributes like solar radiation level, availability of water, evacuation infrastructure, land area requirement etc., each of these four sites had to be selected for any of the following three proposed configurations:

Project configurations	Size of project (MW)	Maximum No. of Projects
CSP project with storage (>= 10 hours)	10-100	2
CSP project with high operating temperature (>=500°C)	20-100	1
CSP project with hybrid cooling (water <= 30%)	20-100	1

CSP is viable only in regions with high level of solar irradiance. CSP technologies, other than Stirling dish use Rankine cycle to convert heat energy to electricity through use of conventional steam generators. Water is consumed for steam production as well as for cooling/condensation. Thus water requirement is an important issue with CSP plants because areas with high DNI i.e. with higher sun intensity mostly correspond to places where there is scarcity of water. Considering the fact that water is the primary issue in Bhadla, hybrid cooling has been selected for this location. Hybrid cooling thus employed will reduce water consumption in the plant and the higher DNI will compensate for the reduced efficiency that hybrid cooling plants have compared to conventional wet cooling.

The size of the collector field for CSP plant, particularly one designed to provide heat-storage is high. The land requirement for a plant with thermal storage is almost 3 times and may go even higher than a plant without storage. Additionally there is some area requirement for storage equipments/mediums which may be as high as 15 % of the entire area. All the four sites have almost the same available land area with Nennala and Terkuveerapandiyapuram, having 160 hect. available area which is slightly more than 140 hect. available in Charanka. Also, the CUF is higher with plants with storage provisions as the hours of operation increase by the storage time and hence the water requirement increases drastically. Availability of water is thus a critical issue that needs to be addressed while considering storage for CSP plants. CSP plants require continual water supply for steam generation, cooling and cleaning solar mirrors. Considering these two factors, Nennala (Andhra Pradesh) and Terkuveerapandiyapuram (Tamil Nadu) were chosen for large storage configurations. Nennala benefits from a natural availability of water and is a green land bordered by agricultural lands.

Terkuveerapandiyapuram benefits from a natural availability of water and is a green land bordered by some patches of agricultural lands and several thermal power plants. The DNI is quite good and may provide a good source for power generation, on the other hand the ambient temperatures are high and a successful project under these conditions would show the possibility to deploy CSP with large storage in areas that are likely to be rich in DNI.

CSP technologies use direct sunlight, measured as Direct Normal Irradiation (DNI); which is the sunlight that is not diffused or deviated by clouds, fumes or dust in the atmosphere and which reaches the Earth's surface in parallel beams for concentration. All these four locations have DNI greater than 5 KWh/m² and hence high operating temperature configuration (>=500°C) can be assigned to any of the remaining sites. Charanka, the first solar park in India is already harbouring several PV projects; totalling nearly 300 MW out of the total park capacity is 590 MW. The masterplan of the solar park outlined a water body (man made lake) to be constructed at the site to prevent lack of water during canal unavailability. That lake is already constructed and so water is not a major issue at Charanka. Considering the fact that Gujarat is endowed with abundant solar intensity and

that high operating temperature requires high hourly DNI values it seems a natural choice that Charanka be the location for a high operating temperature project.

The following information was collected on the Terkuveerapandiyapuram site:

State	**Tamil Nadu**
Location	Terkuveerapandiyapuram Village, Otapidaram Taluk, Thoothukudi District, Tamilnadu
Qualification	Waste dry land. Coal is available nearby. Very near to 4 coal thermal power plants and a copper factory
Nearest city (name and distance in km)	Thoothukudi
- At least state two GPS coordinates at the borders	8.8 N, 78.14 E
Area (hectares)	160
Ownership of the land	State SIPCOT is developing a solar park
- Options: acquired by the state or private or to be acquired	not acquired
- If to be acquired, please state the necessary time	3 months
Power evacuation facilities	Constructed
Type of sub-station (voltages)	230/110KV SS(MEELAVITTAN)
Distance of the sub-station to site	5KM
Soil analysis	Very flat land. Very good soil. Soil is of soft clay, with tree and shrubs. Levelling requirements are minimum
- If completed, name of company that did the soil analysis	
Water availability	Bay of Bengal
- Quantity (cusec -cubic meter per second)	
- If Ground water at what depth?	
- If canal, what is the distance to the land?	5 km
- Any other source	
- Any restrictions in the use of the water	no limitations
Access roads	Existing
- Name of the road, if exists	Madurai-Thoothukudi Expressway
- Type of road – width	very good accesses
- Type of road - pavement type	Asphalt
- Connection from and to (in km)	Thoothukudi to Therkuveerapandiapuram (5km)
Solar radiation - DNI - Direct Normal irradiation	5693.9
Solar radiation - GHI - Global Horizontal irradiation	6052.9
Solar radiation - Diffuse irradiation	1880.5
Ambient temperature	
- Options: ground measured data, no ground measured data	Minimum 27.7°C Maximum 28.8°C

Humidity	
- Options: ground measured data, no ground measured data	Annual avg =76.7% (22Years)
Wind speed	
- Options: ground measured data, no ground measured data	Annual avg =4.99 m/s (10Years)
Wind direction	
- Options: ground measured data, no ground measured data	Annual avg =191.9º (10Years)
Rainfall	
- Options: ground measured data, no ground measured data	
Populations nearby?	
- State the number of people and the distance to the land up to a 5 km radius of the land	< 1000
- Main ocupation	Agriculture, Fishing
Endemic fauna in the site	Environmental assessment undertaken, Chapter 5
Endemic flora in the site	Environmental assessment undertaken, Chapter 5

The summary of the evaluation data is given below:

Power evacuation	Constructed
Type	230/110KV SS(MEELAVITTAN)
Distance to the site	5KM
Water availability	Bay of Bengal
water limitations	no limitations
Acquired land	not acquired
Area	160
Access to the site	Existing
Populations nearby	< 1000
DNI (per day)	5.69
Solar Park	Yes

Technology Configuration

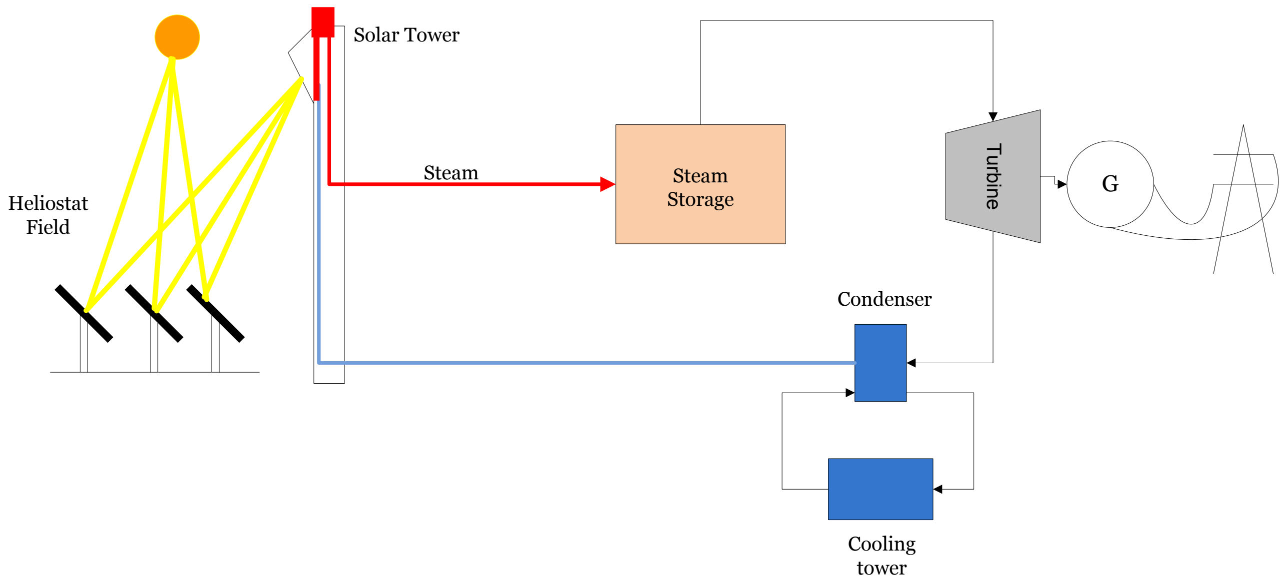
A primary benefit of the CSP technology is that it is grid-friendly and provides power during peak hours. Thermal storage allows CSP plant to overcome the problem of grid intermittency and to inject power into the grid during night, making them even more attractive to utilities when compared to other renewable technologies that lack this advantage. Thermal storage can be integrated with Parabolic trough, Linear Fresnel and Central Receivers (Solar Towers) to enhance dispatchability, allowing the solar plant to produce electricity in non-sunny hours to meet the power demand. With favourable conditions like clear weather and good solar irradiation, plants with thermal storage can operate at nearly 100% capacity factor, similar to conventional power plants (fossil fuel based). Also, from the economic sense; thermal storage will avoid the loss of time which would otherwise occur after occasional shutdown due to lack of solar irradiation.

Another benefit of storage is that it can adapt the profile of power produced throughout the day to demand and the total power output of the plant with given maximum turbine capacity can be increased. Various methods of storage include:

- Storage using concrete, ceramics etc.

- Storage through molten salts
- Storage in phase-change medium.

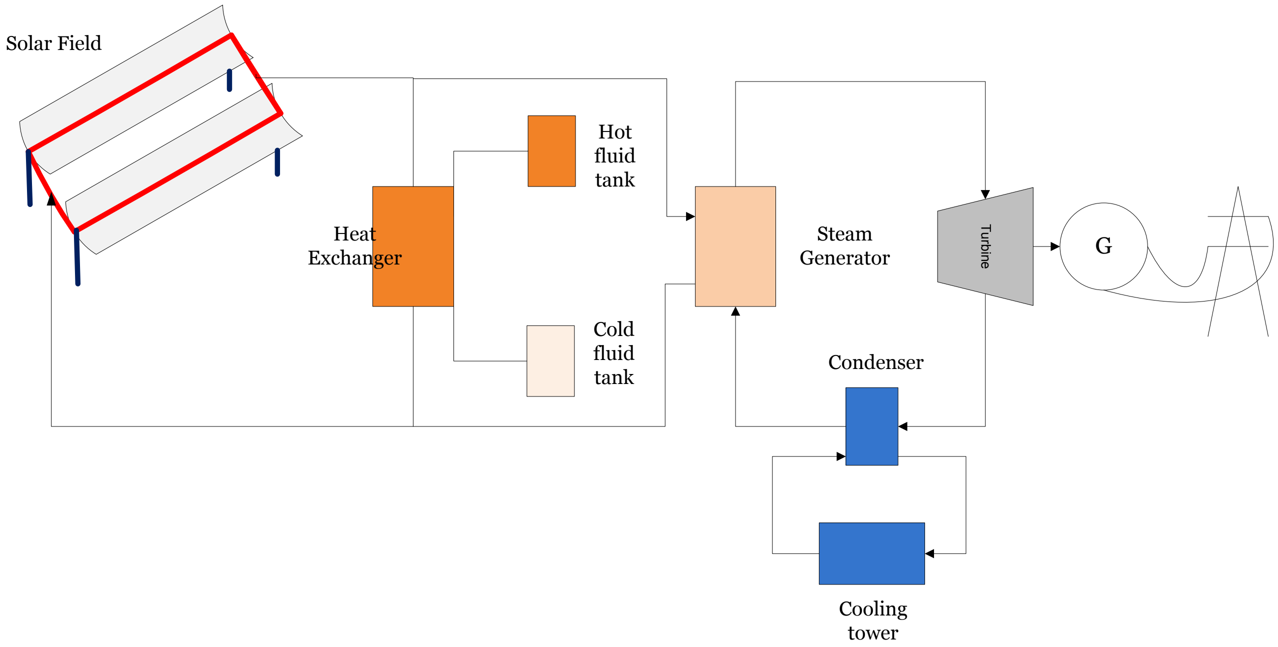
Various factors that determine the choice of storage medium are Energy density, Thermal conductivity, corrosion characteristics, cost, convenience of use, operating temperature of working fluid etc. With high temperature steam as the working fluid, the excess steam is utilised for heat storage within the storage medium, which is thermally insulated. Pressurised vessels provide limited capacity for storage as the cost is high and the additional operational time provided through storage is very less. Direct operation on steam i.e. coupling the receiver directly with the turbine has its disadvantages as the turbine drops offline as soon as an obstruction like a cloud comes by. The layout with steam storage is shown below:



Another evolving thermal storage technique is using concrete to store heat. Concrete offers very low thermal conductivity and is used for storing the heat of the operating fluid operates, even at temperatures higher than 500°C. Concrete storage is modular and scalable and is less expensive than molten salt storage.

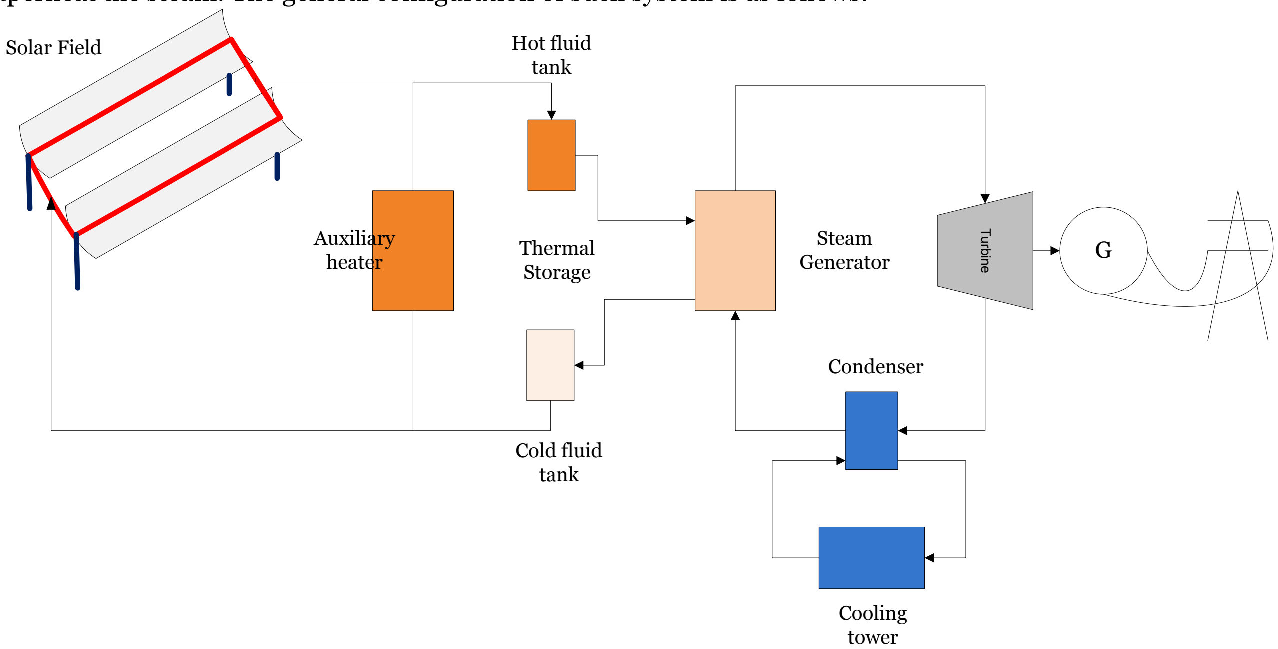
Another technology that is being developed for thermal storage is Indirect storage in a phase-changing medium. This method uses the melting/freezing points of salts such as sodium or potassium nitrates to store and deliver heat for condensation and evaporation of steam in direct steam plants. In this system, hot heat transfer fluid flows through a manifold embedded in the phase-changing materials, transferring its heat to the storage material. Various combinations of phase change materials include $LiNO3 – NaNO3$, $KNO3 – NaNO3$ etc. The main advantage of this technology is its volumetric density and the low cost of the storage materials. There are some developmental challenges of this method that need to be overcome before it becomes a commercially-viable solution.

Salt storage is the most prevalent storage technique in CSP power plants. The cool salt is passed through a heat exchanger with the oil that is heated by the concentrator, and then stored in the hot tank for later use. Alternatively, salt can be used as the heat transfer fluid and maybe stored in the storage tanks for future use. Various storage solutions in this category include Metal oxides (eg. MgO), Molten salts, Metals (Mercury, Lithium, Sodium etc.). A few molten salts are Nitrate salts ($NaNO_3$ + KNO3), Hitec ($NaNO_2$ + NaNO3+KNO_3). Molten salt has a low viscosity and has corrosive properties and hence careful consideration has to be given for storage and transportation through use of suitable pumps, valves, pipes, and gasket materials that will work with molten salt. A typical layout of a CSP plant with storage is shown below:



The thermal storage may be done using a single tank (thermocline) or using a dual tank configuration, with one tank hot and the other one cold. In single tank system, the hot storage fluid is taken from the top of the storage tank and the cold fluid is taken back to the receivers, thus maintaining thermal stability in the tank. Using only one tank reduces the cost of this system relative to two-tank systems.

Sometimes, the same fluid is used as a storage medium as well as the thermal fluid. Such fluid must have low thermal conductivity and high thermal heat capacity and heat may be extracted from the fluid using heat exchangers. In a dual tank storage, hot fluid is kept in one tank and the cold fluid in another. During day time, the cold fluid is heated and shifted to the hot tank and the heat is extracted from the hot tank whenever required. Moreover, an auxiliary medium may be used to provide additional heat to the working fluid of to superheat the steam. The general configuration of such system is as follows:



The working fluid may or may not be the same as the heat transfer fluid. When the same fluid, after getting heated through the solar collector or receiver flows to the high-temperature tank for storage and then through a

heat exchanger to generate steam; it is called a two tank direct system. Most of the existing Parabolic trough plants use mineral oil as the heat-transfer and storage fluid while molten salt is finding use in most of the plants based on Central receiver technology.

In an indirect system, different fluids are used for heat-transfer and for storage. The working is almost the same as a direct system but with an additional heat exchanger where the HTF transfers the heat to the storage fluid which in turn is used for storage and for generating steam. Indirect system is used mostly when the HTF is not suited for storage or when cost of HTF is high.

Solar thermal storage in Andasol Plants

The Andasol Plan was built in southern Spain with 624 Parabolic Trough collectors, arranged in 168 parallel loops. The Andasol 1 was commissioned in 2008, followed by Andasol 2 and 3 and collectively have a gross electricity output of around 180 GWh a year and a collector surface area of over 510,000 m^2. Each power plant has an electricity output of 50 megawatts and operates with Dual tank, indirect thermal storage. The plant is designed to optimise heat exchange between the heat transfer fluid circulating in the solar field and the molten salt storage medium and the water/steam cycle. With a full thermal reservoir the turbines can run for about 7.5 hours at full-load, even if it rains or long after the sun has set. The heat reservoirs are two tanks 14 metres in height and 36 metres in diameter, and contain liquid salt. Each provides 28,500 tons of storage medium. Andasol 1 will supply up to 200,000 people with electricity and save about 149,000 tons of CO_2 a year compared with a modern coal-fired power plant.

The cost of electricity generated from CSP plants is coming down. The cost of generation is almost comparable to Diesel generators and it will soon be cost-competitive with thermal generation from mid-sized gas plants. The factors affecting the cost of CSP electricity are the solar resource, grid connection and local infrastructure and project development costs. Energy storage is very important for the success of solar power tower technology, and molten salt is believed to be the key to cost effective energy storage. Cost efficiency would increase due to research and development advances, effects of large scale deployment, increased market competition, construction efficiency improvements and scaling up of current capacities.

Simulation with potential technology

The configuration specifics for this site have described in the previous section. Number of hours of storage required is higher than 10 hours with a minimum CUF of 40%. The idea is to test dispatchability in a higher scale that impacts the power generation substantially. There is no upper limit on the hours of storage and base load configurations are welcomed. In technological terms it is expected that a larger solar field will be installed as part of this demonstration project and commercial or off-the-shelf solutions are expected, thus special considerations have been incorporated in the specific technical evaluation criteria.

In terms of the main areas in the project we have:

Solar field	Balance of Plant
- Heliostats, Mirrors or reflective surfaces - Receivers (evacuated tubes, steel pipes, cavities) - Collector Frames - Corrosion (applicable to any metallic structure) - Foundations - Tracking motors and algorithm - Electrical cables - HTF (water, oils, molten salts, air)	- Pressure vessels (Steam drum, expansion vessel, blow-down, deaerator) - Piping and pumps (pipes, pumps and feed heaters) - Electrical cables - Heat exchanger - Water Tanks or reservoirs (demineralization plant) - Heat storage tanks - Turbine (with alternator and step transformer) - Cooling tower

In terms of design and engineering no evaluation will be performed, since the whole nature of these projects is to allow innovative designs and engineering to be used, so all solar thermal technologies are allowed with an exception of Stirling engines which currently do not offer any storage solution. The area available for the project is 160 hectares which encompasses solar field plus Balance of Plant to fit in, which obviously limits the power plant rating and the consequent power generation. An exercise was done to design the maximum power plant

that would fit in such area obeying the CUF limitations and based on the radiation data supplied by the NREL/MNRE database that is available online. A privately developed model was used that uses an energy balance on an hourly basis, takes into consideration the solar field and the concentration factor, the optical and thermal losses of the solar field, the amount of energy necessary to vaporize water at the defined temperature, the amount of energy necessary to generate steam and based on the energy available from the solar field a certain amount of steam is generated and based on the efficiency of the turbine considered thus a power yield is obtained. Storage is considered and accounted for so that maximum and minimum number of hours of storage and thus average and peak CUF can be obtained. Additionally the heat exchanger efficiency as well as the IAM (Incident Angle Modifier) is also an input as well as the latitude of the place that adds some end losses on the collector (basically decreases the area available). Some differences apply to parabolic trough and Solar tower in terms of the way the solar field is emulated. The main outputs are the following and they were compared with the SAM model (in what can be compared):

Variables	Troughs (500°C)	Towers (350°C)	Towers (400°C)	Towers (500°C)
Total power rating	20.5 MW	24 MW	24 MW	23 MW
Total yearly generation	124.7 GWH	147.4 GWH	145.9 GWH	133.5 GWh
Average CUF	69%	70%	69%	66%
Peak CUF achieved (at least in one day)	98%	99%	99%	99%
Hours of storage	13.88	14.08	14.88	14.82
Total area of the power plant considering a 3x factor, that is the total size of the plant = 3 x solar field	147.7 hect	146.5 hect	146.5 hect	146.5 hect
Total area of the solar field (no spaces)	49.2 hect	48.8 hect	48.8 hect	48.8 hect
Average total efficiency	**16.3%**	**18.4%**	**19.2%**	**19.6%**

These results are not to be treated as benchmark for the project site as the purpose of the study was to get a better understanding of the system efficiency under available conditions. Hence, these results indicative, since the DNI was not locally measured and all the considerations used on the model were not specific to any technology but from benchmarks and known parameters of solar fields and Balance of Plant. A conservative view should be used and 10 to 15% less output is expected even if the DNI was exactly the same as the one used for the simulation.

Based on the site specific details and simulations with various technology configurations, Terkuveerapandiyapuram has been selected for pilot extended storage CSP plant with a minimum of 8 hours storage. This reduces the CUF from an estimated over 60 % to almost 45 %. This amongst other assumptions is used for the financial analysis below.

Chapter 3: Financial feasibility assessment

Project financing structure

The proposed CSP demo plants are designed to be one-of-kind, innovative pilot projects that will highlight the technical, commercial and economic viability of these technologies. Due to the highly experimental natural of these pilot plants, the Government of India is planning to make available specialized sources of funding for these projects. These funding sources are designed to facilitate CSP projects by offering longer term financing at extremely competitive rates, while only requiring the developer to contribute 20% of the total project cost as own equity.

While the exact quantum and terms of availability of these funds cannot be ascertained accurately at this stage, the following table highlights the potential project financing options that these CSP demo plants can be expected to employ for debt funding.

#	Funding Source	Cost of borrowing	Tenure	Clauses/Covenants
1	Asian Development Bank (ADB)	LIBOR plus 0.5% mark-up = ~1.45% + commitment charges. Assumed at 4% to include other spreads	5 years moratorium and 20 years repayment	ADB can only provide this loan to a sovereign Govt. Of India entity. Mechanisms to pass this on from GoI to private developers will have to be considered.
2	Clean Technology Fund	0.25% non-escalating	10 years moratorium and 30 years repayment	Only accessible through ADB. Needs to have a 1 is to 5 leverage ratio and must be for a demonstrable innovative use – CSP pilot projects fulfil this second criteria
3	Commercial loans	Risk weighted market rate = ~ 9-12%	1 year moratorium and 8 to 10 year repayment	Commercial lenders will perceive CSP demo projects to be highly risk, and will require some kind of collateral/assurance which is likely to raise cost of borrowing and/or limit availability

Based on these sources and characteristics of financing, the following funding mix has been assumed for the projects:

Mode of funding and its features	Interest rate	Repayment tenure (years)	Moratorium period (years)	Proportion of total capital cost
ADB and CTF blended loan	6.0%	20	5	40%
Developer's equity	Return on equity at 22.4% as per prevailing CERC norms			20%

In addition to the debt financing option listed above, the Government of India will also support the demo projects by offering a viability gap funding in the form of a grant. The amount of grant required by a project is fixed at 40% of the total project cost. The grant will be made available as three staggered payments each year since the start of the project construction (assumed to be 3 year). The grant will be paid out in unequal proportions:- 10% in the 1st year, and 45% each in the following two years.

The following presents the expected project (financial and economic) and equity returns for the project assuming a flat tariff of Rs. 5.82/kWh.

Project specific details

The following are the project specific financial and technical details that form the basis of our estimations. All other assumptions not mentioned below are assumed to be as per the prevailing CERC norms for solar thermal projects (please see appendix 1 for details). It is important to note that these details are merely representative and in no way suggest the likely configuration that might come up.

Project financing structure

#	Parameter	Value
1	Capital Cost	Rs. 250 million per MW
2	CUF	45%
3	Capacity	25 MW

VGF estimation

Allowed Tariff (INR/kWh)	**5.82**
Project IRR	5.87%
Equity IRR	9.57%
Economic IRR	9.03%
LCOE	5.46

Chapter 4: Social feasibility assessment

Social & Poverty Impact

Terkuveerapandiyapuram subproject is located in Otapidaram Taluk in Thoothukudi District of Tamilnadu. The proposed sub-project site is connected with access road and is situated in industrial area. It is about 5 km from the coastal area. There are two villages adjacent Terkuveerapandiyapuram CSP which are Therka Veera Pandya Puram which has approximately 150 households having a total of approximately 1,000 populations and the other village is Kumareddyapuram having a total population of approximately 600 populations from 100 households. This is a semi urban area with due access to other places through approach roads. Major occupation of the villager is daily wage earning from industry (industrial labour) and fishing. Water supply is managed through government pipe supply. The villages are electrified and they receive approximately 10 hours of electricity per day. People also have small shops in the village where the women are engaged. They have schools and hospitals in the village and college and bigger hospitals are away from the village which is in the district headquarter at a distance of approximately 20 kilometers. Drinking water is a problem.

The Project will contribute both directly and indirectly to poverty reduction through economic development. A Poverty and Social Analysis will be conducted to assess and identify ways in which the project might best address poverty reduction and social development issues. A social impact assessment report will be prepared. The poverty and social analysis will be undertaken addressing the key social issues in accordance with ADB's Guidelines for Incorporation of Social Dimensions in Bank Operations and ADB's Handbook on Poverty and Social Analysis The analysis will broadly cover various components such as (i) identifying the affected population and potential beneficiaries including minorities (indigenous people), (ii) assess the stage of development of different groups of the population, (iii) assess the gender impact of the Project, (iv) assess the needs of the affected population and their expectations from the Project, (v) assess the affected population's absorptive capacity to receive benefits from the Project, and potential to participate in implementing the Project. The methodology to be adopted in conducting poverty and social analysis will include both primary and secondary data. All available secondary socioeconomic data will be collected for the project areas through proper sources which will be reviewed and compiled. In addition to the secondary data, primary data will be collected through survey which will have both quantitative and qualitative methods. A sample socioeconomic survey will be conducted in the project area (CSP site) to collect the baseline information using a structured soco-economic questionnaire. The qualitative methodology will include but not limited to focused group discussions, key informant interviews and informal discussions with stakeholders. The survey will aim at collecting information pertaining to issues related to social, poverty, gender, indigenous people, and health issues especially HIV/AIDS, trafficking and labour etc. The findings of the social and poverty analysis will be presented as Summary Poverty Reduction and Social Strategy (SPRSS), in accordance with the ADB format.

Impact on Land Acquisition and Involuntary Resettlement

The site is situated on the government land. Approximately 600 Acres equivalent to 240 hectares of land is required which is government barren land. The land has been earmarked as part of overall industrial belt out of which 600 acres will be allotted for the CSP project. The land will be acquired by The State Industries Promotion Corporation of Tamil Nadu (SIPCOT). Detailed land survey will reveal whether the land is free from encroachment and squatters. No physical displacement is foreseen. Therefore, the sub project will be categorized as C as far as the resettlement issues are concerned. However, if any non titleholders (encroachers and squatters) are found during the detailed due diligence survey, necessary mitigation plan will be prepared as per ADB's Safeguard Policy Statement (SPS), 2009.

Impact on Indigenous People

The screening survey revealed that the sub project site is situated near to the industrial area which is almost a rural cum semi urban area. There are no such tribal populations found in the area which. There are no demarcated tribal areas found in the sub project area. No household or group belonging to scheduled tribes will lose housing, strip of land, or other fixed assets. Therefore, the IP issues are insignificant in the sub project area. Based on the assessment, the sub project can be categorized as C as far as the IP issues are concerned. However, necessary steps and mitigations will be taken during the detailed survey. If any IP is found during the detailed survey based on the final design, it will be addressed suitably as per ADB's Safeguard Policy Statement (SPS), 2009.

Impact on Gender

Women are largely responsible for household energy management, such as collecting, chopping and storing firewood. Therefore access to energy has a specific gender dimension. Renewable energy projects in India have demonstrated that renewable energy can directly contribute to poverty alleviation and gender benefits. Installing solar lights in homes enables children to study in the evenings and improve school performance. Solar lanterns have made the business of many women entrepreneurs profitable. Solar driers are a boon in remote areas for drying of fruit and vegetables. Even garment workers have been using solar energy to save electricity costs while running their sewing machines. Vocational trades involving the NGOs may be initiated for women to empower them by providing skills on tailoring, embroidery, food products etc. All these activities do have a direct link with the availability of energy. The EA will ensure that women are consulted and invited to participate in group based activities and where possible, women will be given the opportunity to learn new skills that may provide alternative forms of income generation and livelihood. Efforts will be made during the detailed assessment to assess the possible gender benefits of the project. If required, a gender action plan will be formulated to maximise project benefits for women through gender mainstreaming in the project and a gender responsive participation framework. Gender mainstreaming will include activities associated with empowerment, skills training, capacity building and gender sensitisation.

Other Social Issues (Labour and Health etc)

Temporary employment opportunities will be available for skilled and unskilled labour during project implementation and operation. Standard assurance on labour will be included in civil work contracts. Necessary health safety measures will be taken by the construction contractor to combat any disease like, HIV, STD due to the influx of migratory labour from outside.

Public Consultation and Stakeholders' Participation

Initial consultations have been carried out with the project authorities. Preliminary consultations were also carried out in the sub project sites. The Consultations will be continued involving all the stakeholders all through the project planning and implementation.

An initial Poverty and Social Analysis has been prepared as per ADB's format and presented below.

INITIAL POVERTY AND SOCIAL ANALYSIS (IPSA)

Country:	**India**	**Project Title:**	**Concentrating Solar Power Project (Terkuveerapandiyapuram)**

Lending/Financing Modality:	**XXX**	**Department /Division:**	**SARD/SAEN**

I.	**POVERTY ISSUES**
A.	**Links to the National Poverty Reduction Strategy and Country Partnership Strategy**

Achieving “poverty reduction and social development through faster and more inclusive growth” is a priority in India’s 11^{th} Five Year Plan (FYP) (2007-2012). The Planning Commission’s approach paper to the 11^{th} FYP identifies infrastructure bottlenecks and lack of adequate long-term funds for infrastructure as key binding constraints to realizing more equitable and sustainable growth and bridging the gender divide in the country. In addition, the Paper states that “good quality infrastructure is the most critical physical requirement for attaining faster growth in a competitive world and also for ensuring investment in backward regions”. ADB’s Country Partnership Strategy (CPS) for 2009 – 2012 aims to tackle poverty by supporting faster, more inclusive and gender equitable economic growth through job creation; improvement in the education, health and other social sectors; the provision of basic essential services to the poor; and bridging the divide between regions, sectors, and gender in the state.

India is bestowed with good solar irradiation across the country. In January 2010, the Government of India (GOI) launched Jawaharlal Nehru National Solar Mission (JNNSM). The targets of the JNNSM are, among others, to (i) create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022; (ii) ramp up capacity of grid-connected solar power generation to 1,000 MW within three years; and an additional 3,000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff; (iii) deploy 20 million solar lighting systems to rural areas by 2022; and (iv) create favorable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership. Availability of clean and reliable sources of energy is expected to catalyze economic growth in the service areas of future renewable energy projects and thereby create more economic opportunity for the population including the poor. The Project’s impact would be the development of long-term sustainable energy sources in a cost-effective manner in India.

The Project is aligned with the India Country Partnership Strategy (CPS) 2009-2012. One of the four strategy pillars of the CPS is the support for inclusive and environmentally sustainable growth, through the continued focus on infrastructure development and the enhanced focus on renewable energy. The Project will contribute to achieving the targeted capacity for solar power generation through 2012. The Project will contribute to the economic development of Tamilnadu through increased employment opportunities and increased tax revenues. Direct impact to local employment is expected during the construction and operation stage, while the tax revenues from the Project during operation stage can be used to fund social development projects that will benefit the poor and vulnerable and will have indirect impact

B. Targeting Classification

☒General Intervention ☐Individual or Household (TI-H) ☐Geographic (TI-G) ☐Non-Income MDGs (TI-M1, M2, etc.)

Explain the basis for the target classification: The Project is classified as General Intervention as power produced will be evacuated in the main grid where it will be available to the broad power users. The availability of electric power has an indirect but strong link with reducing poverty and encouraging economic growth.Though the Project will have a number of indirect benefits to end users in terms of investment and improvements to local public infrastructure, creation of economic potential and activity, greater wealth and opportunity in communities – all of which have a catalyst effect in directly improving peoples general well being and quality of life; despite this, power sector interventions are not considered as the single contributing factor to achieving more generalized and sustainable poverty reduction and alleviation. The classification therefore recognizes that while power itself will not implicitly decrease poverty, it is a critical stepping stone to attracting other means of economic investment and development that will provide the foundation for concrete poverty reduction strategies in the future.

C. Poverty Analysis

1. If the project is classified as TI-H, or if it is policy-based, what type of poverty impact analysis is needed? Not applicable.

2. What resources are allocated in the PPTA/due diligence? Social and gender analysis will be carried out by social development / safeguard specialist. Analysis will include the collection of baseline data (e.g., household surveys, including gender disaggregated data), assessment of primary and secondary data, and focus group discussions and public consultation with project affected peoples. Funds for social and gender analysis will be made available through the project PPTA.

3. If GI, is there any opportunity for pro-poor design (e.g., social inclusion subcomponents, cross subsidy, pro-poor governance, and pro-poor growth)? Not at present.

II. SOCIAL DEVELOPMENT ISSUES

A. Initial Social Analysis

Based on existing Information:

1. Who are the potential primary beneficiaries of the project? How do the poor and the socially excluded benefit from the project? The primary beneficiaries of the Project are - those who will receive clean renewable electricity from the project (these could be local, regional or even national and are therefore deemed as indirect beneficiaries); - those who will be temporarily be employed during construction and permanently employed for operations of the project; - and –women, who will benefit from: a) household electricity and street lighting, reduced time burdens from domestic chores and increased safety and security during night hours ;b) improved living standards and health condition.

2. What are the potential needs of beneficiaries in relation to the proposed project? The primary needs of poor and vulnerable stakeholders are jobs during construction and operation, access to markets in remote areas, and improved infrastructure and basic services like health, education and sanitation in the project area.

3. What are the potential constraints in accessing the proposed benefits and services, and how will the project address them? Remoteness of the project location.

B. Consultation and Participation

Indicate the potential initial stakeholders.

1. Primary stakeholders are peoples living in the direct area of influence of the project and its associated facilities. Other stakeholders include public & private sector shareholders and Government of Tamilnadu and Government of India.

2. What type of consultation and participation (C&P) is required during the PPTA or project processing (e.g., workshops, community mobilization, involvement of nongovernment organizations and community-based organizations, etc.)? Public consultations and focus group discussions will be carried out with project stakeholders during the project planning and implementation stages of development.

3. What level of participation is envisaged for project design?

☒ Information sharing ☒ Consultation ☐ Collaborative decision making ☒ Empowerment

4. Will a C&P plan be prepared during the project design for project implementation? ☐ Yes ☒ No

Consultations will be managed through a mix of formal and informal consultations with the affected communities – on an as needed basis. The nature and scale of impacts and the number of affected peoples is expected to be limited, thereby exempting the need for a structured and systematic process of engagement. Social assessment will nonetheless include gender sensitive and targeted consultation to ensure that women's needs are analyzed and opportunities considered.

C. Gender and Development: Proposed Gender Mainstreaming Category: Some Gender Benefits

1. What are the key gender issues in the sector/subsector that are likely to be relevant to this project/program? Opportunities to benefit and improve the quality of life and well being of women will be assessed during project appraisal. Where opportunity exists, these will be funded under a specific gender and community based technical assistance fund. The main (indirect) benefits expected to women will be in the form of access to new, improved or more reliable lighting in homes and villages. This will reduce women's time and burden on household and domestic activities; - improve their health and well being, as this will replace the need for more costly, less clean and efficient sources of energy(e.g., firewood, kerosene) for household heating and lighting. Opportunities may also focus on creating new or alternative forms of livelihoods, provision of skilled training and/or education.

2. Does the proposed project/program have the potential to promote gender equality and/or women's empowerment by improving women's access to and use of opportunities, services, resources, assets, and participation in decision making? ☒ Yes ☐ No

Please explain. The benefits to women will be felt and seen locally, within their family and community structures.

3. Could the proposed project have an adverse impact on women and/or girls or to widen gender inequality?

☐ Yes ☒ No Please explain Women are expected to benefit from the intended outcomes of the project.

III. SOCIAL SAFEGUARD ISSUES AND OTHER SOCIAL RISKS			
Issue	**Nature of Social Issue**	**Significant/Limited/ No Impact/Not Known**	**Plan or Other Action Required**
Involuntary Resettlement	Construction of CSP will require approximately 600 acres equivalent to 240 hectares of land which is primarily government owned barren land. Therefore no private land acquisition is foreseen.	**No Impact**	☐ Resettlement Plan ☐ Resettlement Framework ☒ Environmental and Social Management System Arrangement ☐ None ☐ Uncertain
Indigenous Peoples	The area where the project will be constructed is not owned/used/claimed by any IP or scheduled tribe.	**No Impact**	☐ Indigenous Peoples Plan ☐ Indigenous Peoples Planning Framework ☒ Environmental and Social Management System Arrangement ☐ None ☐ Uncertain
Labor ☒ Employment Opportunities ☐ Labor Retrenchment ☒ Core Labor Standards	Temporary employment opportunities will be available for skilled and unskilled labor during project implementation and operation. Standard assurance on labor will be included in civil work contracts.	**Limited Impacts**	☐ Plan ☐ Other Action ☒ No Action ☐ Uncertain
Affordability	Power will be sold directly to the grid. No affordability issue is expected. Power tariff will be determined by Competent authority.	**No Impact**	☐ Action ☒ No Action ☐ Uncertain
Other Risks and/or Vulnerabilities ☒ HIV/AIDS ☐ Human Trafficking ☐Others (conflict, political instability, etc.), please specify	• The project will minimize the risk of HIV/AIDS among the migratory and local workforce through awareness raising initiatives.	**Limited** This will be further assessed during the social due diligence under PPTA	☐ Plan ☐ Other Action ☐ No Action ☒ Uncertain

IV. PPTA/DUE DILIGENCE RESOURCE REQUIREMENT
1. Does the TOR for the PPTA (or other due diligence) include poverty, social and gender analysis and the relevant specialist/s? ☒ Yes ☐ No
2. Are resources (consultants, survey budget, and workshop) allocated for conducting poverty, social and/or

gender analysis, and C&P during the PPTA/due diligence? ☒ Yes ☐ No

Consulting requirements include the use of individual consultants which include international social development /safeguards specialist for more immediate due diligence tasks including necessary costs for carrying out the social surveys etc.

Chapter 5: Environmental feasibility assessment

Legal Regulatory Framework

It is important that the CSP projects that will emerge from the MNRE project are in tune with the legal framework in the country and state. The existing laws and regulations concerning environmental conservation may restrict certain developmental activities. It is important that the Environmental Management Framework prepared for the CSP project remains responsive to the changing legal framework. The following laws, regulations and policies have been reviewed in this chapter for their relevance to the CSP project context.

National Environmental Laws

The Environmental regulations, legislation, policy guidelines that may impact this project, are the responsibility of a variety of government agencies. The principal Environment Regulatory Agency in India is the Ministry of Environment and Forests (MoEF). MoEF formulates environmental policies and accords environmental clearances for different projects. The relevant environmental legislations in India are mentioned below

(i) The Water (Prevention and Control of Pollution) Act, 1974, amended 1988.
(ii) The Water (Prevention and Control of Pollution) Rules, 1975.
(iii) The Air (Prevention and Control of Pollution) Act 1981, amended 1987.
(iv) The Air (Prevention and Control of Pollution) Rules, 1982.
(v) The Environment (Protection) Act, 1986, amended 1991 and including the following Rules/Notification issued under this Act.
- The Environment (Protection) Rules, 1986, including amendments.
- The Municipal Solid Wastes (Management and Handling) Rules, 2000.
- The Hazardous Wastes (Management and Handling) Rules, 2003.
- The Hazardous Wastes (management, handling and transboundary movement) Rules 2009.
- The Bio-Medical Waste (Management and Handling) Rules, 1998.
- Noise Pollution (Regulation and Control) Rules, 2000.
- Wild Life (Protection) Amendment Act, 2002.
- Ozone Depleting Substances (Regulation & Control) Rules, 2000.
- The Biological Diversity Act, 2002.
- The Environment Impact Assessment Notification, 1994; amended up to 2009;
- Batteries (Management & Handling) Rules, 2001.
- The Environmental Clearance Notification, 1994.

(vi) Noise Pollution (Regulation and Control) Rules, 2000.
(vii) The Indian Wildlife (Protection) Act, 1972, amended 1993.
(viii) The Wildlife (Protection) Rules, 1995.
(ix) The Indian Forest Act, 1927.
(x) Forest (Conservation) Act, 1980, amended 1988 (National Forest Policy, 1988).
- Forest (Conservation) Rules, 1981 amended 1992 and 2003.
- Guidelines for diversion of forest lands for non-forest purpose under the Forest (Conservation) Act, 1980.

(xi) The National Environmental Appellate Authority Act, 1997.
(xii) The National Green Tribunal Act, 2010.

Other National Policy Acts

The Indian policy framework consists of following main regulations:

1. The Electricity Act, 2003.
2. National Resettlement & Rehabilitation Policy, 2007 (NRRP) (MoRD, DoLR).
3. Right of Way and Compensation under Electricity Laws.
4. Land Acquisition Act, 1894.
5. The Indian Telegraph Act (ITA), 1885.
6. Indian Treasure Trove Act, 1878 as amended in 1949.
7. Provisions of the Panchayats (Extension to the Scheduled Area) Act, 1996.

8. The Right to Information Act, 2005.
9. National Policy on HIV/AIDS and the World of Work, Ministry of Labour and Employment, GoI.
10. National Policy on Safety, Health and Environment at Work Place, Ministry of Labour and Employment, GoI.

Relevant TN State Government Laws and Regulations

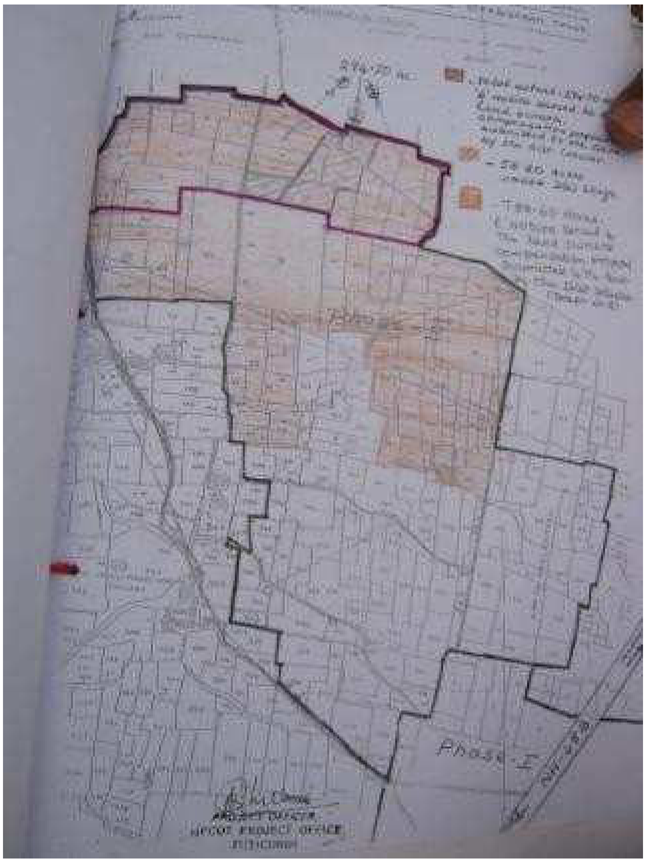
1. The Tamil Nadu Forest Act, 1882
2. Tamil Nadu Preservation of Private Forest Act 1949.
3. Tamil Nadu Hill Areas (Preservation of Trees) Act, 1955
4. Ban on felling of trees of spontaneous growth in forest areas as per directions of SC in W.P. 202/95 dated 12.12.96

Specific Provisions:

5. CRZ Regulations: The Central Government vide its notification number S.O.114 (E), dated the 19th February, 1991, has declared Coastal Regulation Zone and imposed certain restrictions on the setting up and expansion of industries, operations and processes in the said Zones. The Act prescribes several activities that are declared as prohibited activities within the CRZ such as setting up of new industries and expansion of existing industries. However this excludes facilities for generating power by non-conventional energy sources and setting up of desalination plants in the areas not classified as CRZ-I (i).

6. Office Memorandum No. J-11013/41/2006-IA.II(I) dated June 30, 2011 - Environmental clearance for setting up of Solar Thermal Power Plants under JNNSM-applicability of EIA Notification 2006
   It is clarified that Solar Thermal Power Projects do not fall under the EIA notification 2006. However, it should (i) seek consent to establish from SPCB under Air and Water Acts, forest clearance under FC Act, (ii) conform to CRZ notifications, (iii) restricted land use to Solar Thermal, and (iv) any other rules such as HSM Rules etc.

Physical Features of the Site



Toothikudhi Site

Village: Terkuveerapandiyapuram Village, Otapidaram Taluk, Thoothukudi District, Tamilnadu
Coordinates: (To be corrected)
It is about 5 km from the coastal area.

Land Requirement of CSP Project site: 600 acres

1,655 sq km Government land to be acquired by SIPCOT (The State Industries Promotion Corporation of Tamil Nadu) for development of solar park/industrial hub.

Master Plan studies: None

Lots of coal fired power generation plants in the area. Data regarding generation, power flow, stack emissions would be required to ascertain cumulative impact on dust settlement on solar panels.

Power Evacuation:
Power evacuation through Meelavittan 230/110 kV GSS (5 km away; already online).

Power evacuation line between Project and GSS required to be constructed.

Water:
Only water availability is the Bay of Bengal (5 km away) through pipeline.

There is no water body in the vicinity of the site and water for the project is to be procured from private water tankers. This practise is being followed by all IPPs in the area as there is no unsaline water available.

The water has to be brought in pipe line/tankers from Bay of Bengal and then de-salined using desalination plants. The highly saline waste from desalination plant cannot be put back to sea (CRZ regulations) or be left to flow over ground (Hazardous Waste Rules). Project planning to provide for evaporating the water and then disposing of the salts in specific Hazardous waste site would be required.

The above factors would increase the input plant costs as well as O&M costs.

Habitation:
500 people live on a 5 km radius who are mainly farmers and fishermen.

Other Industries:
Sterlite Chemical Industries 92 km).
IPP Thermal plants – 5 in numbers.
SPV plant about 5 km from site.

Tuticorin Port handles imported bulk coal that is used for power generation in the area.

Forest:
The area has generally high salinity and therefore lots of small trees and scrubs exist in the proposed land.

National park and Sanctuaries:
There is apparently no conservation area in the vicinity of the proposed project site. A detailed assessment will be conducted later on based on the available baseline data.

Data required

Specific phase-wise activities required for Environmental Impact Mitigation baseline development, mitigation and monitoring are given below:

Planning phase
- Assessment of all Environmental Impacts.
- Consent of Establishment (COE).
- No objections certificates from Wildlife department (sanctuary buffer zones, forest areas, etc.).
- State Pollution Control Board Approvals and Consultation.
- Permissions for any boreholes for water.
- Listing of trees from Forest Department.
- Technical layouts, power evacuation map (TRANSCO), associated facilities.
- Waste disposal planning – construction etc.
- Hazardous waste disposal planning – land fill site, batteries, panels, inorganic toxic waste, SF6, leakages and contingency plans.
- Baseline parameters measurements – water, air, noise, soil (150 ha -> 2 samples; 35 ha -> 1 sample).
- Soil levelling – soil displacement management plan.
- Health and safety planning.
- Power Grid in case of export of power.
- Load centre consumer base list.

Construction phase
- Availability of public amenities – water and sanitation.
- Availability of construction camp with electricity, water, toilets.
- Hazardous waste disposal implementation.
- Waste disposal implementation.
- Health and safety implementation.

Operation phase
- Compliance with statutory requirement of GOI and State, Support to inspection visits.
- Monitoring report.

Data required for Environmental safeguards
The impact will be assessed on assumptions derived from site visits and physical survey of the land. The land belongs to the government and/or forest therefore no resettlement issues are envisioned. However, unforeseen impacts may arise during construction for which provision for mitigation and compensation needs to be made. Consultations will be needed to be carried out with relevant stake holders about 5 km from the site. The impacts for CSP plant currently seem to be limited to cutting and lopping of non-forest or forest trees during the construction. The power evacuation lines would normally avoid any forest area, ecologically sensitive areas such as national parks and sanctuary/buffer zone as well any tribal areas.

Data required:
- Alternative analysis of CSP site.
- Contour/Topography report of the project site with drainage, waste disposal site etc.
- Map marked with project and all other project related facilities along with other environmental features using Auto-cad software using Survey of India toposheet (1:50,000 scale) and satellite maps as base map.
- Forest Diversion and Land acquisition case.
- Water availability and quality, environmental air, water, soil, and noise parameters for baseline development.
- Disposal of Hazardous and non-hazardous wastes given the site is pristine in nature.

ADB Specific Guidelines for Environmental Safeguards
The pilot CSP will require preparation of an environmental assessment and review framework (EARF), resettlement framework (RF) and indigenous people's planning (IPPF) framework. Furthermore, it will require initial environmental examination (IEE) and resettlement plan (RP). Because retroactive financing is envisaged, safeguard documents will be prepared before contract awards, necessary clauses will be included in contracts and the EA will be held responsible for implementation of EMP.

Environment Documents
The Environment Assessment and Review Framework (EARF) and Initial Environment Examination (IEE) document prepared for the CSP would normally contain:
- Project description, district data, project related maps and site details etc.
- Site Surveys and preparation, Site selection criteria,
- Environment Management Plan (EMP) and budget,
- Suitable Mitigation measures that are consistent with state Government and ADB policies,
- Environment Monitoring Plan with budget; and contractors requirements,
- Institutional arrangement and staffing requirements, and
- Forest diversion cases (if any).

Roles and Responsibilities
The Project will establish an organization to manage environmental, occupational health, and safety aspects during construction and commercial operation of the power plant. An Environmental and Social Unit at SECI or any Monitoring Agency will have to be established during the project implementation and monitoring period to ensure compliance with safeguards requirement of ADB, state government and GOI.

There will be various stages in the project preparation and implementation. Each stage will require specific activities to be completed for which appropriate institutional arrangements are to be in place. The major responsibilities for the planning and implementation of these activities will be with the project developer along with managing the environmental and social safeguards issues. Additionally, construction contractor will be responsible for mitigating environmental and social issues if found during the construction.

Appendix 1: Major Assumptions

Assumption Head	Sub-Head	Sub-Head (2)	Unit	Assumptions
Power Generation				
	Capacity			
		Installed Power Generation Capacity	MW	25
		Capacity Utilization Factor	%	45.0%
		Auxiliary Consumption Factor	%	10.0%
		Useful Life	Years	25
Project Cost				
	Capital Cost/MW	Power Plant Cost	Rs Lacs/MW	2500
Sources of Fund				
		Tariff Period	Years	25
	Debt: Equity			
		Debt	%	70%
		Equity	%	30%
	Debt Component			
		Moratorium Period	years	As per funding source
		Repayment Period(incld Moratorium)	years	
		Interest Rate	%	6% (ADB Loan for 50% of project cost) and 12 % (commercial bank loan for 20% of project cost)
	Equity			
		Return on Equity	% p.a	22.40%
		Discount Rate		9.2%
Financial				
	Fiscal			
		Income Tax	%	32.45%
		MAT Rate (for first 10 years)	%	19.00%
		80 IA benefits	Yes/No	Yes
	Depreciation			
		Depreciation Rate for first 12 years	%	5.83%
		Depreciation Rate 12th year onwards	%	1.54%
Working Capital				
	For Fixed Charges			
	O&M Charges		Months	1
	Maintenance Spare	(% of O&M expenses)		15%
	Receivables for Debtors		Months	2

	For Variable		
	Interest On Working Capital	%	12.80%
Operation & Maintenance			
	power plant (FY11-12)		1% of project cost
	Total O & M	%	5.72%