1. Premise for development of Benchmark Norms

1.1. Background

In the exercise of powers conferred under section 61 read with section 178(2) (s) of the Electricity Act, 2003 (36 of 2003) the Central Electricity Regulatory Commission has notified the Terms and Conditions for Tariff Determination from Renewable Energy Sources, Regulation 2009. Subsequently, in December 2009, the Commission issued suo-motu tariff orders for the various renewable energy technologies including Solar Photovoltaic and Solar Thermal.

As per first proviso under Regulation 5 of the Central Electricity Regulatory Commission (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2009, the benchmark capital cost for Solar PV and Solar thermal power projects is to be reviewed annually. For FY 2009-10, the Commission has specified the normative capital cost for Solar PV and Solar Thermal Power Projects as Rs.1700Lakh/MW and Rs.1300Lakh/MW respectively. However, it has been observed that since the publication of the said Regulations, there has been significant change in the global market conditions for solar industry which is still evolving and certain developments in terms of policy at national level such as announcement of Jawaharlal Nehru National Solar Mission (JNNSM) has taken place; which would have bearing on industry structure, role of market participants and market models for harnessing of solar energy. In view of the above, it is essential to analyse the benchmark capital cost norm of installation for Solar PV and Solar Thermal Power Projects which are proposed to be commissioned beyond validity of current control period of FY 2009-10 (i.e. beyond March 31, 2010) .

1.2. Scope and Applicability of Revised Norms

As highlighted earlier, while the Control Period or review period under the RE Tariff Regulations, 2009 has been specified as three years, in case of Solar PV and Solar thermal power projects, the review of benchmark Capital Cost norms has been proposed to be undertaken on annual basis; in view of significant challenges entailed in specifying generic norm for the solar power projects with limited experience, diverse range of technological options and virtually no precedence of setting up such grid connected large size solar power projects within the country.

Accordingly, revised benchmark capital cost norm will have to be determined for solar power projects to be commissioned during FY 2010-11. Such revised capital cost norm for Solar PV based power projects to be commissioned during FY 2010-11 shall be finalised upon due regulatory process in the matter.

As regards determination of revised capital cost norm for Solar thermal power projects, it is observed that determination of revised capital cost norm for FY 2010-11 alone, may not be sufficient, as gestation period for solar thermal power projects is around 18-24 months. Based on present status of development of identified CSP projects, it is likely that no CSP installation would be commissioned during 2010-11. However, the advance actions (including placement of Work Orders for EPC work/ Equipment Supply) for implementation of the projects will have to be undertaken during 2010-11 to ensure commissioning during 2011-12. Thus, benchmark capital cost norm which represents completed capital cost (including interest during construction-IDC cost) shall correspond to CSP installations commissioned during 2011-12. In case, any CSP project is commissioned during 2010-11, it would enable such project to save cost component towards interest during construction (IDC) costs; which shall be retained by solar project developer which can act as an incentive to facilitate early commissioning of solar thermal power projects.

In this context it is observed that, while specifying the Control Period under the Regulations, the Commission has observed that gestation period of different RE technologies will have to be taken into consideration, as outlined under Clause 10.2 of the Statement of Reasons. The relevant extract of the same is reproduced below:

> *"10.2 In the explanatory note issued along with the draft Regulations, the rationale for considering the Control Period of 3 years has been elaborated. The Commission <u>considered gestation period of different RE technologies</u> for specifying the Control Period so that project conceptualised on the basis of these norms could receive the same tariff. <u>The Commission would like to further mention that these Regulations are being issued for the first time and</u>*

therefore, the aspects covered under these Regulations may need to be modified, considering experience of operationalisation of the Regulations. Therefore, short Control Period will enable the Commission to revisit the norms within short duration while ensuring certainty for reasonable duration." (Ref. Cl. 10.2 of Statement of Reasons)

In view of above, it is proposed that the revised benchmark capital cost norm for solar thermal power projects to be determined under this regulatory process shall be applicable for the solar thermal power projects to be commissioned during FY 2010-11 and FY 2011-12. However, revised benchmark capital cost norm for Solar PV power projects to be determined under this regulatory process shall be applicable for the solar PV power projects to be commissioned during FY 2010-11.

2. Benchmark Capital Cost for Solar PV Power Projects

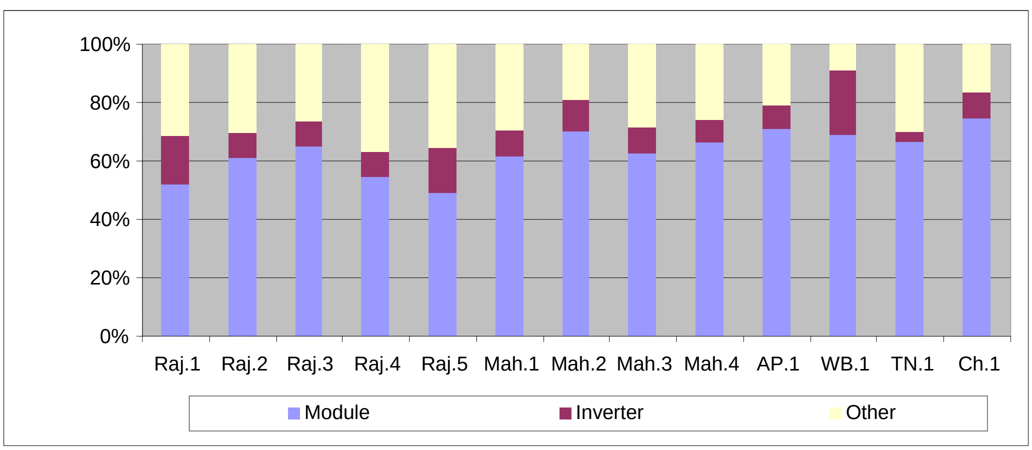
2.1. Introduction

The capital cost of the Solar PV power project can be broadly classified into two components, namely, (a) Solar PV Module component and (b) Non-Module component. The non-module component comprises following sub-components, viz. (i) Land and Site Development (ii) Civil and General Works (iii) Supporting structures (iv) Power conditioning units (v) cables and transformers including power evacuation facilities (vi) preliminary and pre-operative expenses including financing cost. Following paragraphs cover detailed analysis of various cost components and cost drivers for Solar PV based power projects in Indian context.

2.2. Solar PV development in India

The developer's interest in solar PV power development in India was triggered pursuant to announcement of generation based incentive scheme by MNRE for pilot/demonstration power projects. The capital cost information from the detailed project reports (DPR) or the petitions filed before regulatory commissions have been summarised in the following Chart.

Chart 2.1 : Module, Inverter and Other Cost by PV Project Developers



(Source: MNRE and ABPS Infra Research)

(Others include Expenditure towards Land, Civil and General Works, Structures, Cable and Transformers, Installation and Commissioning, Project Management, IDC and Financing Charges)

The information submitted by the various developers in their DPR suggests that solar PV module alone forms significant portion of the total capital cost and contribute to around 60% to 65% of the total capital cost. However, in fewer cases the cost towards solar module has found to be around 70% to 75% of the entire capital cost requirement for setting up solar PV power project. Thus, PV module cost forms significant component of the overall capital cost of the Solar PV based power plant.

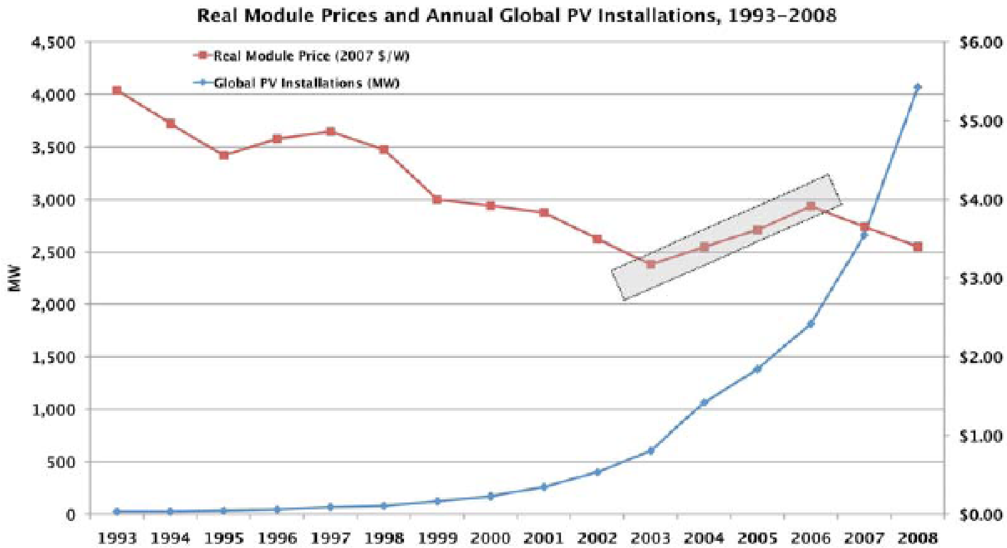
In this context, it is observed that few of the developers have quoted the expenditure towards Solar Modules to be in the range of $2.5/W (equiv. Rs 11.43 Cr/MW) or even less than $2/W (equiv. Rs 9.14 Cr/MW) (in fewer cases). It has also been observed that the feasibility report in such projects have been prepared by the developers in early 2009. However, the budgetary estimates could have been based on prices prevalent in earlier period.

Since the Capital Cost of the Solar PV based power projects shall be greatly influenced by the PV module prices and projections of demand/supply scenario of PV modules, a comparative analysis of various industry reports covering forecast of PV module demand-supply and prices thereof during 2010-11 has been carried out and presented in the following paragraphs.

2.3. Solar PV Modules

Photovoltaic modules are integral part of the entire value chain of Solar PV Projects. The story of Pholtovoltaic's (PV's) meteoric rise in recent years is by now well known. Having languished through the 1980s, it was resurrected during the mid-1990s as rising energy prices, growing concerns about the impacts of climate change and the depletion of fossil fuels drove governments around the world to promote the adoption of solar generation on a large scale. The results have been there for all to see. Fueled by aggressive policies and generous subsidies in Germany, Japan, the U.S. (especially California) and spain, worldwide demand for photovoltaics has grown at a remarkable pace over the last decade: global installations have increased from a mere 125 MW in 1999 to 4.5 GW in 2008, a CAGR of 47 percent for the last 10 years. The figure below presents the historic trend of PV module price and the global PV installations till 2008.

Chart 2.2 : Historical trend (1993-2008) of PV module prices & PV capacity



(Source: GTM Inc. and The Prometheus Institute)

As policy-led demand outstripped the ability of manufacturers to keep up, module prices reversed a decades-long trend of declining prices and increased from 2003-4 to 2006-7 by around 30%, manufacturing costs continued to fall steadily, driven by continuous technological innovation and process improvements, while profit margins increased dramatically for manufacturers. Not surprisingly, manufacturers both old and new announced Gigawatts in capacity expansion plans.

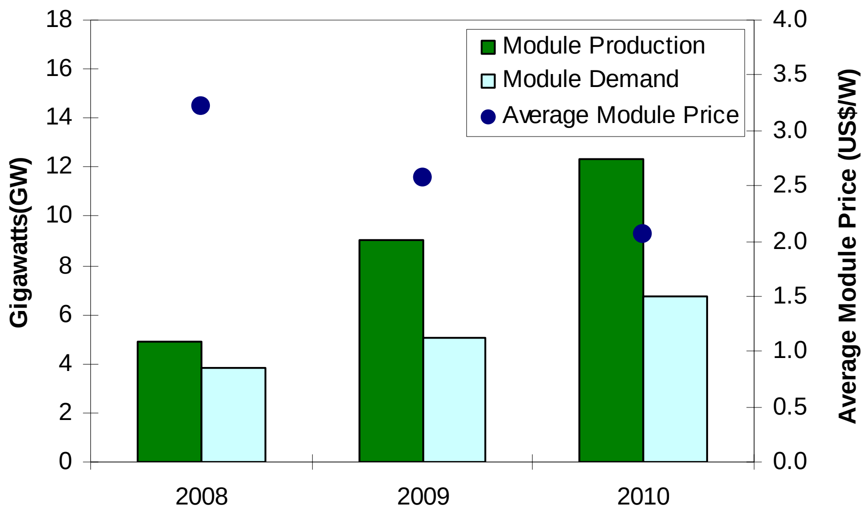
With this expansion in the manufacturing of PV modules, the industry now concerns that there is a clear possibility that silicon and module supply may continue to exceed global demand for PV, and that prices may therefore drop substantially to clear the market, ultimately resulting in thinner profit margins.

The PV industry analysts have divergent views of the near-term PV supply and demand scenario. However, analysts' project reductions in module prices starting in 2009 with continued growth in PV demand. The views of some of the industry experts are summarized in the following paragraphs.

2.3.1. Prometheus Institute For Sustainability Development

The Prometheus Institute has forecasted module supply, demand, and price, presented in the figure. It has projected that the module price of $3.6/W in 2007 may reduce by 11% in 2008, 18% in 2009, and 14% in 2010. It has been suggested by the Institute that the average price of module shall be approximately $2.5/W in 2009 with average prices reaching approximately $2.0/W in 2010. The Institute attributes this price reduction mainly to wide gap between module supply and demand. It has also projected that the gap between demand (5.1 GW) and supply (9.0 GW) of module in 2009 shall continue through at least 2010 with 12.4 GW module production vis a vis 6.8 GW of module demand).

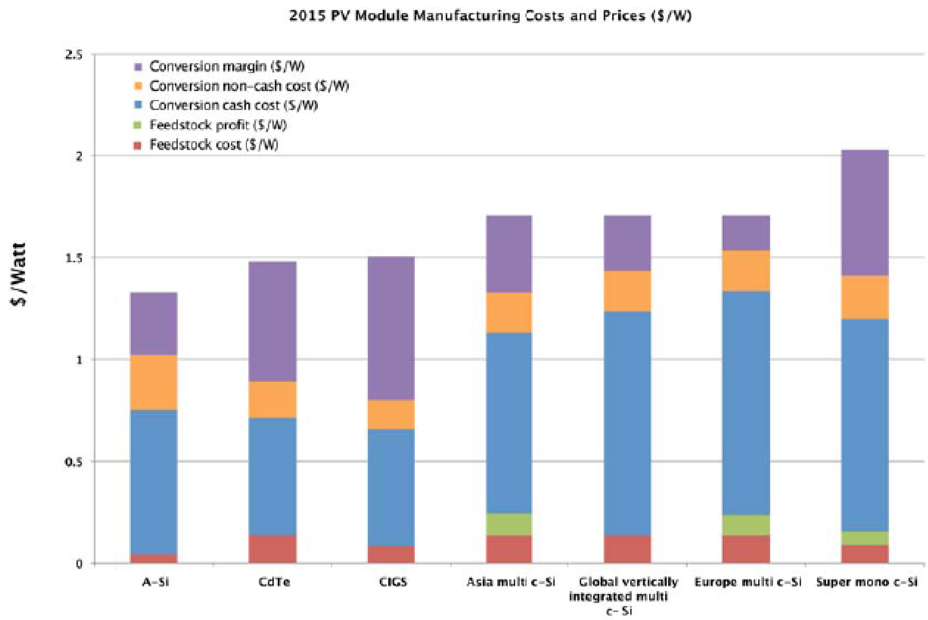
Chart 2.3 : Forecast of Demand-Supply and Module Price



(Source: Prometheus Institute, Global Photovoltaic Market Trend Analysis: Implications of the Financial Crisis, Ryan Wiser)

Further, it has been suggested that the manufacturing costs for PV modules shall continue to fall over the near term by 2015 and should be at or below $1.50/W for all major PV technologies by 2015. The Prometheus Institute and the Green Tech Media Inc has presented the expected cost of various modules by 2015 as shown in the figure below,

Chart 2.4 : Forecast of PV Module Prices (2015)



(Source: GTM Inc. and The Prometheus Institute)

2.3.2. Photon Consulting

According to the Photon Consulting, with poly-silicon prices dropping sharply, module overcapacity and weaker-than-expected demand, caused by the lack of capital and global economic recession, the solar industry is in a race to reduce costs and is becoming the first-choice alternative energy source.

Photon Consulting predicts that at the sector level, the 'true cost' of solar power has already seen a remarkable decline, averaging less than $2/W for c-Si modules and less than $4/W for systems.

Table 2.1: Module to System Price (Present and Forecast)

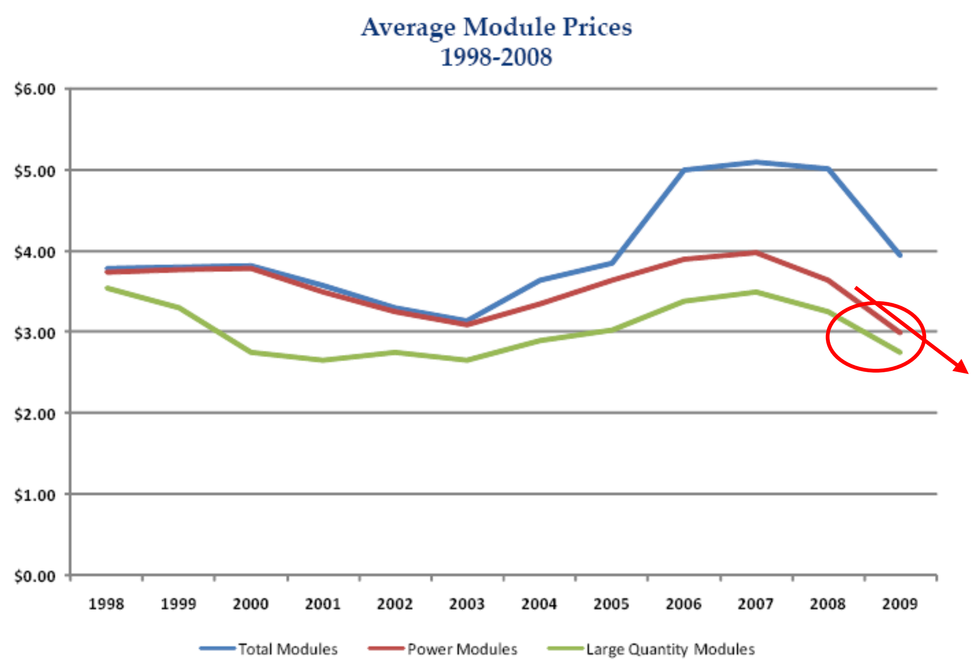
Silicon to c-Si Module	2007	2008	2009	2010	2011	2012
Sum of Average Cost (USD/W)	2.02	1.89	1.83	1.69	1.57	1.44
Sum of Best Practise Cost (USD/W)	1.48	1.38	1.25	1.13	1.03	0.95
Sum of Typical Cash Cost (USD/W)	1.42	1.33	1.29	1.19	1.10	1.01
Non Module c-Si						
Average all in Cost (USD/W)	2.99	2.67	2.40	2.21	2.12	2.01
Best Practise all in Cost (USD/W)	1.45	1.35	1.27	1.20	1.13	1.07
Typical Cash Cost (USD/W)	2.39	2.14	1.92	1.77	1.70	1.61
Total System (c-Si)						
Sum of Average Cost (USD/W)	5.01	4.56	4.23	3.90	3.69	3.45
Sum of Best Practise Cost (USD/W)	2.93	2.73	2.52	2.33	2.16	2.02
Sum of Typical Cash Cost (USD/W)	3.81	3.46	3.21	2.96	2.79	2.62

(Source: Photon Consulting)

2.3.3. Navigant Consulting

Navigant Consulting has also suggested that the average PV module price trend is reducing and was below $3/W during 2009 and shall follow further declining trend in the near term. The following graph presents the average prices of module,

Chart 2.5 : Historical trend of Average Module Prices

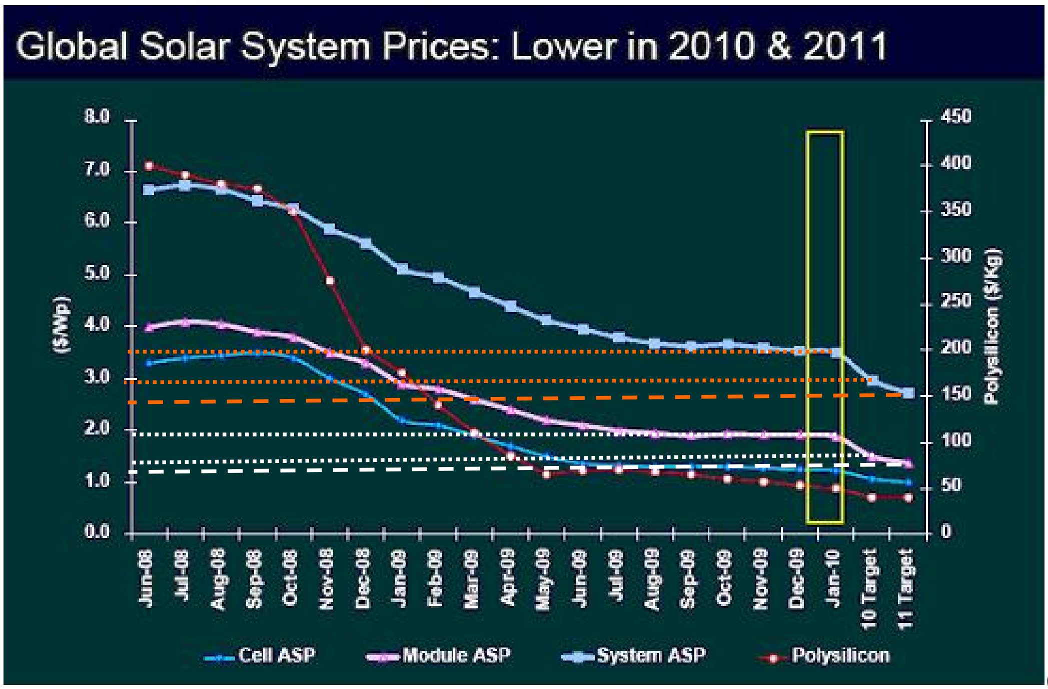


Navigant Consulting predicted that the drop in the Spanish market and the financial crisis would have significant impacts on the global PV market.

2.3.4. Morgan Stanley

Morgan Stanley also suggests that the prices of module in Jan, 2010 shall be just under \$2/W, after a continuous decline trend followed in 2008. It also suggests that by the end of 2010 the prices of module shall reduce significantly and may reach below \$1.25/W whereas by the end of 2011 the price of module shall be slightly above \$1/W. Further, it suggested that the entire system cost shall be around \$3.5/W (approximately Rs15.75Cr/MW) during the start of 2010 and shall reach below \$3/W (approximately Rs 13.5Cr/MW) by the end of 2010. It is also suggested that by the end of 2011 the cost of entire system shall be slightly above \$2.5/W (approximately Rs 11.25Cr/MW).

Chart 2.6 : Declining trend of Module and System prices

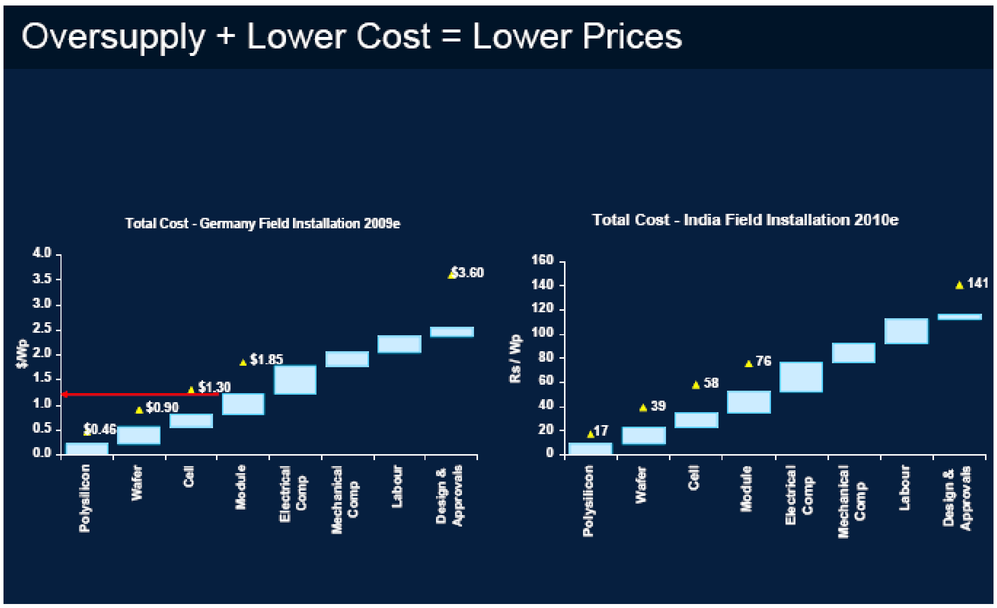


(Source: Morgan Stanley, Solar Energy Conclave)

Morgan Stanlay presented the breakup of entire capital cost requirement for setting up solar PV power project and suggested that the expenditure towards solar module was around \$1.3/W in 2009 whereas the expenditure of entire system in Germany was approximately \$3.6/W which translates to around Rs16Cr/MW.

Taking into consideration the trend, the Morgan Stanlay have estimated the capital cost requirement for setting up solar PV based power plant in India. It has been suggested that the installation cost in 2010 shall be around Rs14.1Cr/MW (approximately $3.15/W) where as the expenditure towards module shall be around Rs7.6Cr/MW or $1.69/W. This is also in line with the suggestions given by Photon Consulting which have projected that the prices of module shall be around $1.68/W for crystalline module. The comparative analysis of expenditure towards individual component for Germany (2009)) and India (2010) is presented in the figure below,

Chart 2.6 : Break-up of Installed Cost in Germany (2009) and India (2010)

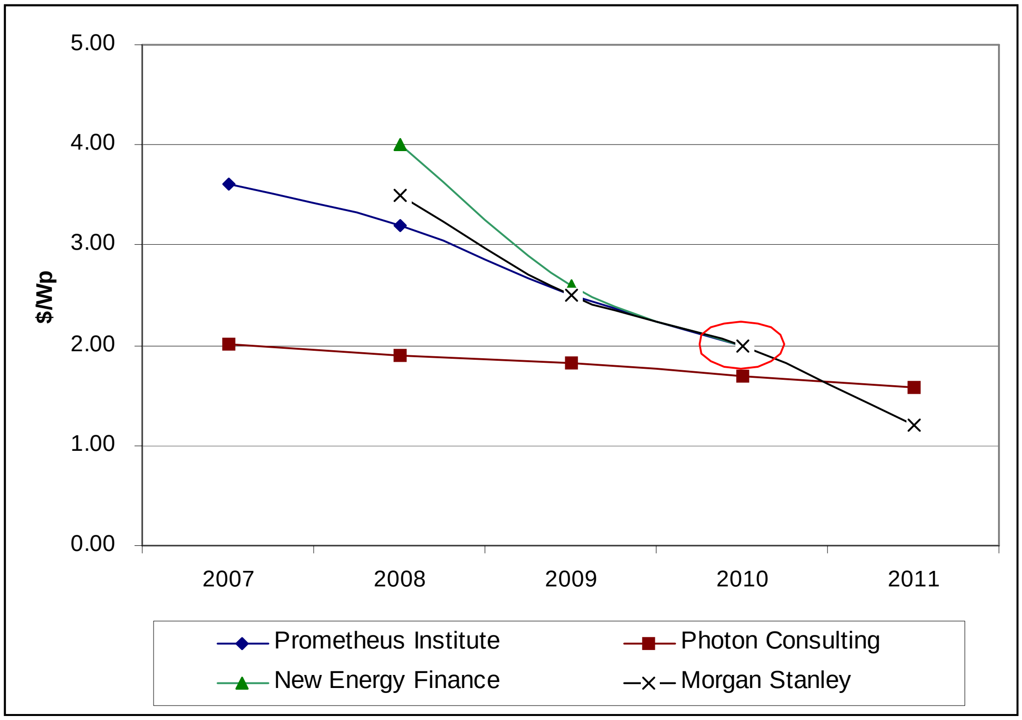


(Source: Morgan Stanley, Solar Energy Conclave)

2.3.5. Comparative analysis of Module price forecasts

The comparison of PV Module price forecasts by various industry reports is presented in the following chart. Most of the industry reports tend to suggest that the PV module prices would be approx. US$ 2/W or lower.

Chart 2.7 : Comparative analysis of forecasted Module Price (in 2010)



2.3.6. CEA Report : PV Module prices

Central Electricity Authority (CEA) in its recent report on Grid Integration Rooftop Solar PV has outlined the approximate manufacturing cost and market share of the various PV modules. It suggests that the cost of mono crystalline silicon to be around USD 2.4/Watt (equiv. Rs10.97Cr/MW) and poly crystalline silicon to be around $2.15/W (equiv. Rs 9.83 Cr/MW). Further, under thin film category the cost of Copper Indium Gallium de-selenide (CIGS) has been stated to be around $1.75/W (equiv. Rs 8Cr/MW) and of Cadmium Telluride around $1.15/W (equiv. Rs 5.25Cr/MW), as summarised under following Table. .

Table 2.2: CEA Report: Estimated Cost of PV Technologies

S No	Technology Type	Current Conversion Efficiency (%)	Manufacturing Cost ($ per Watt)	Market Share (%)	Manufacturing Cost (Rs Crore per MW)
A.	**Crystalline Silicon**			**92**	
A.1	Mono Crystalline	17-23	2.40		11.10
A-2	Poly Crystalline	15-18	2.15		9.94
B.	**Thin Film**			**8**	
B.1	Amorphous Silicon	6.0	1.35		6.24
B.2	Tandem Micro Crystalline	8.5	1.35		6.24
B.3	Cadmium Telluride	11.0	1.15		5.32
B.4	Copper Indium Gallium Diselenide	12.0	1.75		8.09

(Source: CEA, Power Line April, 2009)

It is noted that the premise for cost estimate under the CEA report is based on Power Line magazine published in early 2009. It is however observed that with the present declining trend of PV cell prices, the cost of module is further expected to reduce.

Hence, based on the observation of various analysts presented above and keeping into consideration the evolving market scenario, it is expected that the module price shall reduce significantly and hence the capital cost requirement of the solar PV power projects. Accordingly, the cost of Solar PV Module for projects to be commissioned during FY 2010-11 may be considered as $2/W equivalent to Rs 9.15Cr/MW.

2.4. Non-Module Cost Component

The non-module cost components comprise cost towards Land and Land Development, General works, MS Supporting Structures, Power Conditioning Units (Inverters), Cables and Transformers, and Preliminary and pre-operative expenses. Based on the project cost information compiled from project developers as summarised under Chart 2.1, it is observed that non module component together contributes to approximately 35% - 40% of the overall capital cost requirement of solar PV based power plant.

2.4.1. Land

The requirement of land for setting up solar power project largely depends upon the technology employed (i.e. crystalline technology or thin film) and the solar radiation incident in the respective area. It is observed that the solar to electricity conversion efficiency for thin film modules is less than crystalline silicon modules and hence may require large land per MW than latter. According to a Report published by US Dept of Energy and EPRI, approximately 2.5 Hectare of land area is required for setting up 1 MW Solar PV power project.

Table 2.3: Approximate Requirement of Land for PV project

Table 4. Resource requirements.

Indicator Name	Units	Base Year 1997	2000	2005	2010	2020	2030
Land	ha/MW	5	4	3	2.5	2.5	2.5
	ha	0.08	9.6	24	40	40	40
Critical elements (e.g., In, Se, Ga, Te)	MT/GW_p	NA	50	30	20	10	3
Water	m^3	nil	nil	nil	nil	nil	nil

Source : U.S. Department of Energy and EPRI : RE technology characterisation Topical Report

Various institutions involved in research and development of solar power also suggests that approximately 5 Acre/MW (~ 2.2 hectare/MW) of land shall be required for setting up solar power project in India. However, it has also been suggested that with the development in technology, the solar to electricity conversion efficiency shall improve which will eventually translate to reduction in requirement of land per MW of installation.

The land acquired for setting up solar power projects is mostly arid or of no commercial use. However, it has also been observed that the cost of the land for setting up power project varies from one state to another and contributes approximately less than a per cent to two per cent of the total capital cost requirement for setting up power project.

Barring few cases in which the developer proposes to set up solar power projects at its own land, in most the cases the allotment of land to the developers for setting up power projects in respective States is carried out at concessional rates subject to fulfilment of certain conditions. Keeping the aforesaid facts into consideration, the cost of land as Rs1Lakh/Acre or approximately Rs.5~6Lakh/MW (corresponding to 5 acres per MW) may be considered.

2.4.2. Civil and General Works

The civil works associated with setting up of Solar Power Projects essentially includes cost associated with testing of soil, levelling of land for setting up solar modules, fencing of land for protecting solar farm, development of approach roads, provisions of water supply in the solar farm, control room, development of foundation for solar arrays, trench for laying cables etc. Similarly, general works include security of the Solar Farm, setting up of power back-up generator, installing lighting arrestor and earthing kit, street lighting etc. It has been observed from analysing the reports submitted developers submitted that the expense towards civil and general works together comprises approximately 6% of the total capital cost requirement on an average basis which is equivalent to approximately Rs 0.90 Cr/MW may be considered for projects getting commissioned in FY 2010-11.

2.4.3. Civil and General Works

Further, the PV module support structures have significant role in power generation. In order to get the maximum power, PV modules need maximum exposure to direct sunlight for the longest time. Any shading shall reduce module output considerably. The material used to prepare the structure can be aluminium, angle iron, stainless steel etc. Further, in order to account for the seasonal changes in sun altitude and to increase the power generation, tracking system is installed with the help of which the module can tilt in single axis or double axis. It has been observed that MS Structure contributes to around 5% of the total capital cost requirement on average. Accordingly, expenditure towards Solar PV Module Structure for projects to be commissioned during FY 2010-11 may be considered as Rs 0.80 Cr/MW.

2.4.4. Power Conditioning Unit

It has been observed that the Power Conditioning Unit (PCU) contributes to approximately 11% to 12% of the total capital cost. The submission made by the developer suggests that the expenditure towards a power conditioning unit ranges from Rs1.6Cr/MW to Rs2.0Cr/MW. Accordingly it is proposed that expenditure towards Power Conditioning Unit may be considered as Rs 1.80 Cr/MW

The expenditure towards Cables and Transformers together constitute to around 6% of the total capital cost on average basis and accordingly it is proposed that Rs 0.85 Cr/MW may be considered as expenditure towards cables and transformers for solar PV projects getting commissioned in FY 2010-11.

2.4.5. Preliminary/Pre-operating Expenses and Financing Cost

Preliminary and pre-operative expenses contribute to approximately 11% to the total capital cost on an average basis. The preliminary and pre-operative expenses essentially include services related to installation related to installation and commissioning, project management, expenditure incurred in transportation of equipments, insurance, contingency, taxes and duties, IDC and finance charges etc. For the solar PV projects to be commissioned during FY 2010-11 Rs1.65 Cr/MW as Preliminary and Pre-operative expenses and financing cost may be considered.

Keeping the above facts into consideration, the expenditure towards Non-Module component together forms around Rs 6.05Cr/MW for Solar Photovoltaic Power Projects proposed to be commissioned in FY 2010-11.

The table below presents the break of the capital cost for Solar PV projects proposed to be commissioned during FY 2010-11

Table 2.4: Breakup of the Capital Cost Projection

S No	Particulars	Projected Cost (FY 2010-11) (Rs.Cr/MW)
1	Land	0.05
2	Civil and General Works	0.90
3	**PV Modules** (estimate @ US$ 2/Watt)	**9.15**
4	Module Structures	0.80
5	Power Conditioning Unit	1.80
6	Cables and Transformers	0.85
7	Preliminary & Pre-Operative Expenses	1.65
8	**Total**	**15.20**

2.5. Capital Cost of Solar PV Projects through Tender basis

It has also been found that few of the entities, namely, Maharashtra State Power Generation Company Limited, Karnataka Power Corporation Limited to name a few, have opted for global tendering process for award of turnkey contracts (EPC contract) for setting up solar PV power projects. It has been observed that more than

20 companies, domestic as well as international have participated in the tendering process. The table below summarises the details of the project along with the scope of work and the awarded price for EPC contract for setting up of Solar PV project.

Table 2.5: Solar PV Projects awarded through Competitive Bidding Route

Particulars	MSPGCL	KPCL
Capacity (MW)	1	3
Location	Chandrapur	Yapalaniddi
Technology	a-Si Thin Film	Crystalline
Scope of Work	Supply, installation, Commissioning & Maintenance	EPC, Operation and Maintenance for 3 years after Commissioning
Expected Commissioning	Jan-10	Aug-10
Awarded Cost	12.50	42.00
Cost (Rs.Cr/MW)	**12.50**	**14.00**
Number of Bidders	20	24
Tendering Procedure	Global	Global
Awarded to	Moser Baer	BHEL

(Source: Press Releases, Sep 4, 2009 and Jan 7 2010, Business Line)

Thus, the competitively awarded PV power projects in the recent past have discovered EPC cost in the range of Rs 12.5 Cr/MW to Rs 14 Cr/MW. Further, it is observed that EPC costs comprising equipment supply, installation, erection, testing and commissioning constitute to around 85%-92% of the total capital cost. This, overall capital cost of the competitively awarded projects is estimated to be around Rs 13.60 Cr/MW to Rs 15.20 Cr/MW.

2.6. Summary

Based on detailed analysis of module costs and non-module cost components as well as comparison of cost discovered for PV projects through competitive tender route, it is proposed that the Benchmark Capital Cost Norm for Solar PV power projects to be commissioned during FY 2010-11 may be considered as Rs 1520 Lakh per MW.

3 Benchmark Capital Cost for Solar Thermal Power projects

3.1 Background

Internationally, the Solar thermal power plant development has gained momentum in the recent past with significant developer interest in the Concentrated Solar Power (CSP) technology. A recent report from CSP Today[1] has outlined that at present there are 679 MW of installed CSP capacity worldwide and more than 2000 MW of CSP capacity is under construction. The USA is the market leader in terms of installed capacity with 63% market share, followed by Spain with 32% of operating capacity. In terms of the technology employed, the market is dominated by Parabolic Trough technology, which accounts for 88% of operating plants and 97.5% of projects under construction.

In another Report by Greenpeace International, ESTELA and IEA SolarPACES, namely, *Concentrating Solar Power – Global Outlook 2009*, it is highlighted that the Parabolic trough technology forms the dominant share of solar thermal power plant installations and planned future capacity additions world over, followed by Solar Tower technology based installations, which are also growing rapidly, as summarised in the following Table.

Table-3.1 : Technology-wise CSP Installations

TECHNOLOGY TYPE	INSTALLED CAPACITY 2009 [MW]	ELECTRICITY PRODUCED UP TO 2009 [GWh]	APPROXIMATE CAPACITY UNDER CONSTRUCTION AND PROPOSED [MW]
Parabolic trough	500	>16,000	>10,000
Solar tower	40	80	3,000
Fresnel	5	8	500
Dish	0.5	3	1,000

Source: Report on Concentrating Solar Power – Global Outlook 2009 (Greenpeace Intl, ESTELA and IEA SolarPACES)

The solar field represents the largest share of the cost of any CSP plant. Depending on the technology this cost could vary from around 43% for Tower and Fresnel technology, to almost 60% for Parabolic Trough and Dish Stirling CSP plants. As per Industry Report by CSP Today, the most significant cost reductions are likely to

[1] Global Concentrated Solar Power Industry Report 2010-11 (CSP Today)

come about by innovations in solar field design, which could bring down the levelized cost of energy (LCOE) by 15 to 28% depending on the technology.

3.2 CSP development in India

The developer interest in solar thermal power development in India was triggered pursuant to announcement of generation based incentive scheme by MNRE for pilot/demonstration power projects. However, since the scheme envisaged the generation based incentive being offered for not more than 10 MW per State and not more than 5 MW per project developer, several project developers had initially prepared project scheme for 5 to 10 MW. The capital cost information from the detailed project reports (DPR) or the petitions filed before regulatory commissions have been summarised in the following Table, which essentially highlights the capacity limitation as selected by various project developers.

Table 3.2 : Summary of capital cost estimates by Project Developers

(all fig. in Rs Lakh / MW)

Particulars	Project (P1) Rajasthan	Project (P2) Rajasthan	Project (P3) Andhra Pradesh	Project (P4) Maharashtra	Project (P5) Gujarat	Project (P6) Chhattisgarh	Project (P7) Madhya Pradesh
Plant Capacity, (MW)	**10 MW**	**10 MW**	**5 MW**	**5 MW**	**5 MW**	**5 MW**	**5 MW**
Technology Option	**Solar Tower**	**Parabolic Trough**	**Parabolic Trough**	**Parabolic Trough**	**Parabolic Trough**	**Parabolic Trough**	**Parabolic Trough**
Land	0	0	50	50	50	50	50
Civil and Structural Works	64	129	46	46	46	46	46
Solar Field	976	2198	1290	1290	1290	1290	1290
Power Block	335	672					
Thermal Storage System	0	576	0	0	0	0	0
Preliminary/Pre-operative and Other Costs (incl. IDC & Contingency)	119	351	376	376	376	376	376
Total Capital Cost	**1494**	**3926**	**1763**	**1763**	**1763**	**1763**	**1763**

Source : MNRE & Petitions before SERCs

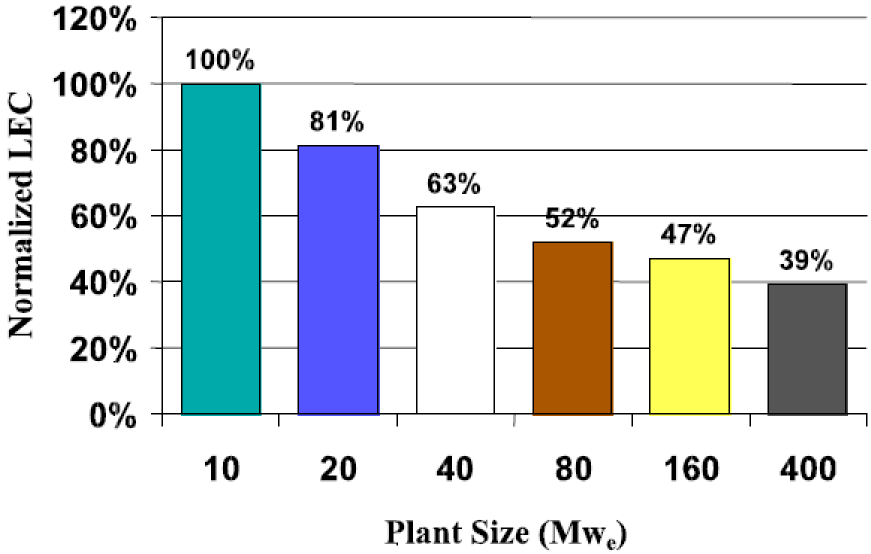
The capital cost as presented in the DPRs has varied from Rs 14.94 Cr/MW to Rs 17.63 Cr/MW (without thermal storage) and Rs 39.26 Cr/MW (with thermal storage). The capacity restriction to participate in GBI scheme may have influenced the selection of the capacity/project size; which may not necessarily represent optimal design and hence, capital cost benchmarks thereof may be sub-optimal.

As per Report[2] published by Office of Utility technologies, Energy Efficiency & Renewable Energy, U.S. Department of Energy and EPRI, increasing plant size is one of the easiest ways to reduce the cost of solar electricity from parabolic trough

[2] *Renewable Energy Technology Characterisation, Topical Report,* *(Dec 1997)*

power plants. Studies have shown that doubling the size reduces the capital cost by approximately 12-14% as presented in the following chart.

Chart 3.2 : Plant capacity and Levellised Cost



Source : U.S. Department of Energy and EPRI : RE technology characterisation Topical Report

It is envisaged that with the announcement of Jawaharlal Nehru National Solar Mission (JNNSM), selection of appropriate plant capacity/configuration would be guided by technical considerations. Thus, optimal design and cost structures for solar thermal power projects would emerge. While setting the Benchmark Capital Cost Norm for Solar thermal power projects in Indian context, it would be useful to analyse various cost components and cost drivers for Parabolic trough and Tower technology, since these technologies have been proposed to be deployed by various solar thermal power developers in Indian context.

Another critical aspect to be considered in case of Solar thermal power installation is gestation period for CSP projects which is around 18-24 months. Based on present status of development of identified CSP projects, it is likely that no CSP installation would be commissioned during 2010-11. However, the advance actions (including placement of Work Orders for EPC work/ Equipment Supply) for implementation of the projects will have to be undertaken during 2010-11 to ensure commissioning during 2011-12. Thus, benchmark capital cost norm which represents completed capital cost (including interest during construction-IDC cost) shall correspond to CSP installations commissioned during 2011-12. In case, any CSP project is commissioned during 2010-11, it would enable to save cost component towards interest during construction (IDC) costs; which shall be retained by solar project developer which can act as incentive to facilitate early commissioning of solar thermal power projects. Accordingly, it is proposed that the benchmark capital cost for solar thermal power project to be determined under this regulatory process shall be applicable for the solar thermal power projects to be commissioned during 2010-11 and 2011-12.

3.3 Overview of Cost Components & Cost Drivers for Solar Thermal Power Projects:

Following paragraphs cover analysis of various cost components and cost drivers for solar thermal power plants.

3.3.1 Parabolic Trough Technology:

Major cost components of the solar thermal power plants based on parabolic trough technology comprise solar collector system, thermal storage system (if applicable), structures, steam generator and heat transfer system and power block system. A typical schematic of parabolic trough based solar thermal power plant is presented below.

Fig 3.1 : Typical schematic of Parabolic Trough based power plant

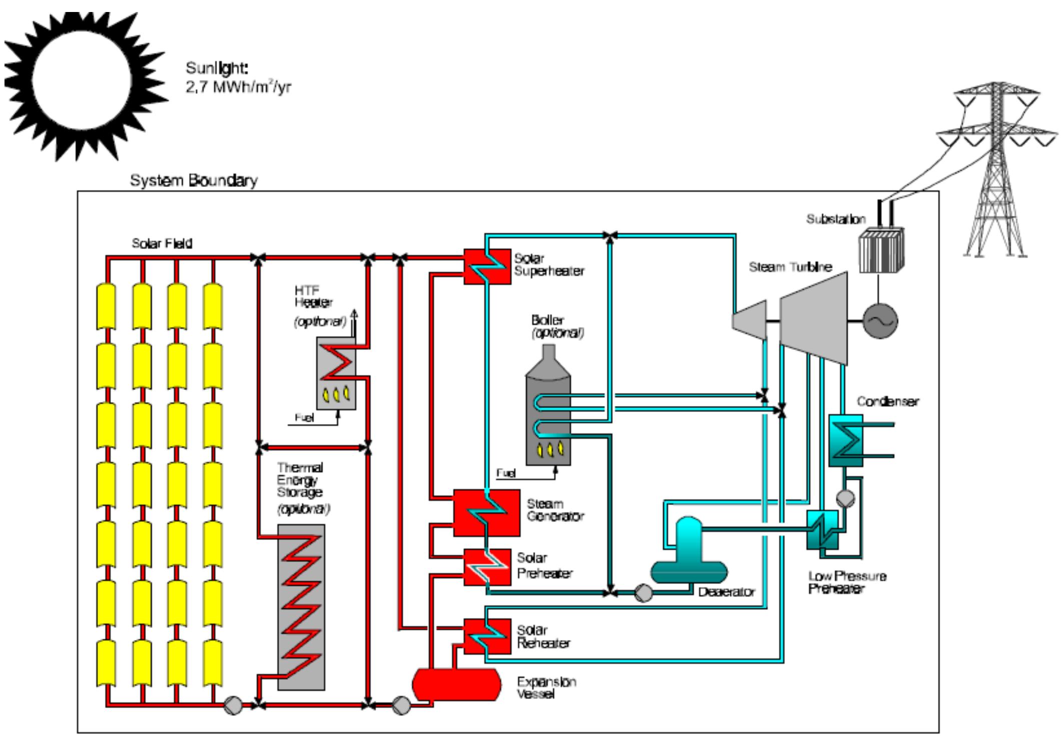
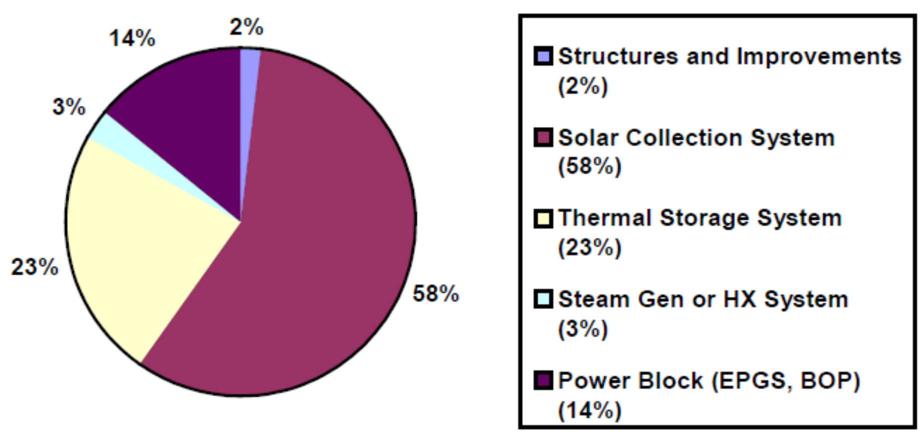


Figure 3.1 shows a process flow diagram that is representative of the majority of parabolic trough solar power plants in operation today. The collector field consists of a large field of single-axis tracking parabolic trough solar collectors. The solar field is modular in nature and is composed of many parallel rows of solar collectors aligned on a north-south horizontal axis. Each solar collector has a linear parabolic-shaped reflector that focuses the sun's direct beam radiation on a linear receiver located at the focus of the parabola.

The collectors track the sun from east to west during the day to ensure that the sun is continuously focused on the linear receiver. A heat transfer fluid (HTF) is heated as it circulates through the receiver and returns to a series of heat exchangers in the power block where the fluid is used to generate high-pressure superheated steam. The superheated steam is then fed to a conventional reheat steam turbine/generator to produce electricity. The spent steam from the turbine is condensed in a standard condenser and returned to the heat exchangers via condensate and feed water pumps to be transformed back into steam. Condenser cooling is provided by mechanical draft wet cooling towers. After passing through the HTF side of the solar heat exchangers, the cooled HTF is re-circulated through the solar field.

The composition of various cost components is presented in chart below.

Chart-3.3 : Major Cost Components of Parabolic Trough system (with storage)



Source: NREL Report on Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts, (Oct 2003)

National Renewable Energy Laboratory (NREL) has published a report[3] covering detailed assessment of Parabolic Trough and Solar tower technology cost and performance forecasts covering comparative analysis of independent studies undertaken by SunLab and Sargent & Lundy. Key findings and projections (near term, medium term and long term) for Parabolic Trough technology as outlined under said Report is summarised below.

Table 3.3 : NREL Report on Capital Cost Projection (2010) – Parabolic Trough

Capital Cost Projections for Solar Thermal Technology (Parabolic Trough Technology)								
Case	**Base Line**	**Sun Lab**			**Sargent & Lundy**			**Projects Cost Range in INR (Mid-Term) - 2010**
		Near Term	**Mid Term**	**Long Term**	**Near Term**	**Mid Term**	**Long Term**	
Project	**SEGS VI**	**Trough 50**	**Trough 150**	**Trough 400**	**Trough 50**	**Trough 150**	**Trough 400**	
In Service	**1989**	**2004**	**2010**	**2020**	**2004**	**2010**	**2020**	
Solar Collection System($/m2)	250	234	161	122	234	195	181	Rs 12.52 - 13.29 Cr/MW
Support Structure ($/m2)	67	61	54	46	67	56	52	
Heat Collection Element($/unit)	847	847	635	400	847	675	525	
Mirrors($/m2)	43	43	28	18	40	32	26	
Power Block ($/kWe)	527	367	293	197	306	270	198	Rs 1.23-1.34 Cr/MW
Thermal Storage ($/kWe)	NA	958	383	383	958	383	383	Rs 1.75 Cr/MW
Total Plant Cost ($/kWe)	**3008**	**4856**	**3416**	**2225**	**4816**	**3562**	**3220**	**Rs 15.61-16.27 Cr/MW**

Source *: NREL Report on Assessment of Parabolic Trough and Power Tower Solar Technology Cost andPerformance Forecasts, (Oct 2003)*

As per NREL report, total plant cost for parabolic trough based solar thermal power installations during 2010 have been projected to be in the range of US$ 3416/kW *(SunLab estimate)* – US$ 3562/kW*(S&L estimate)* (i.e. Rs 15.61 Cr/MW – Rs 16.27 Cr/MW). However, above cost projections include cost of thermal storage facilities but exclude other cost components such as land cost and financing costs.

Further, a Report published by US Dept. Of Energy and EPRI, provides detailed break-up of solar thermal plant cost components for SEGS (parabolic trough based Solar Electric Generating System-SEGS installations) over the period. The plant cost for various configurations of SEGS is stated to vary from US$ 3972/kW (equiv. Rs 18.15 Cr/MW) during 1997 (for 30 MW without thermal storage) to US$ 2999/kW (equiv. Rs 13.70 Cr/MW) during 2010 (for 320 MW with 10 hours thermal storage facilities), as summarised under following table.

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[3] *NREL Report on Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts, (Oct 2003)*

Table 3.4 : USDOE & EPRI Report Capital Cost Projections (2010)–parabolic trough

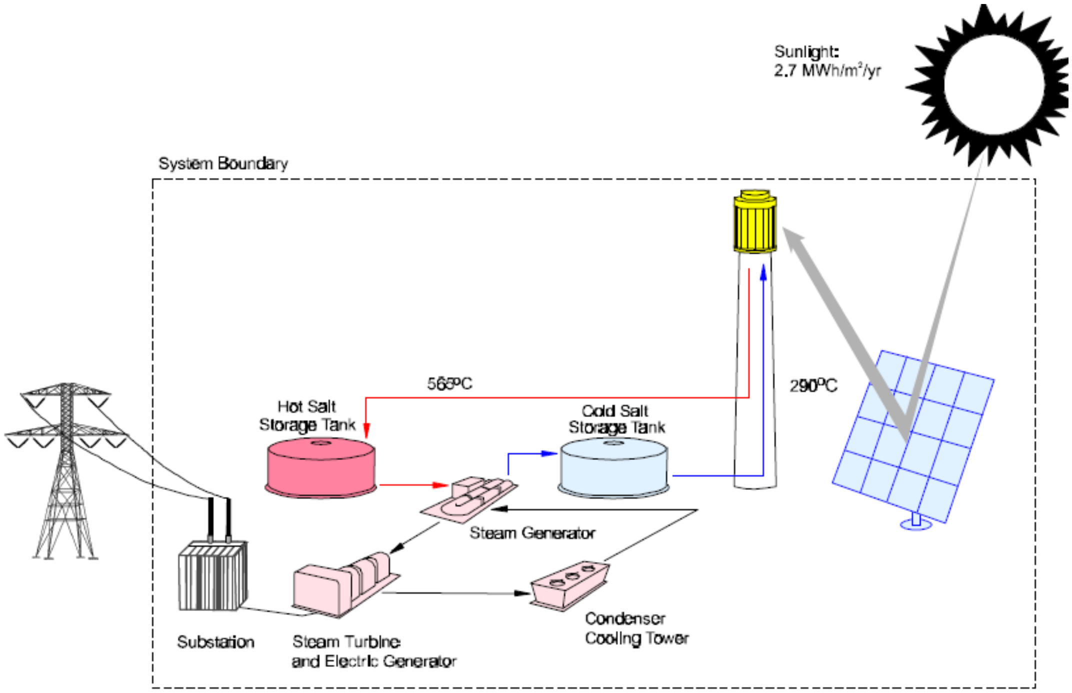
Particulars	UNITS	1997 SEGS VI Base Case	2000 SEGS LS-3 25% Fossil	2005 SEGS LS-3 with Storage	2010 SEGS LS-4 with Storage
Plant Design					
Plant Size	MW	30	80	161	320
Collector Type		LS-2	LS-3	LS-3	LS-4
Solar Field Area	m^2	188000	5,10,120	1.149,120	3.531,600
Thermal Storage	Hours	0	0	6	10
Performance Parameters					
Capacity Factor	%	34	34	40	50
Annual Energy Production	GWh/yr	89.4	238.3	564.1	1401.6
Capital Cost					
Structures/Collector Improvement	$/kW	54	79	66	62
Collector System	$/kW	3408	1138	1293	1327
Thermal Storage System	$/kW	0	0	392	528
Steam Gen or HX System	$/kW		109	90	81
Auxiliary Heater/ Boiler	$/kW	120	164	0	0
Electric Power Generation	$/kW		476	347	282
Balance of Plant	$/kW	750	202	147	120
Subtotal(A)	**$/kW**	**3972**	**2168**	**2336**	**2400**
Eng, Proj/Cost. Manag.	A*0.08		174	187	192
Subtotal(B)	**$/kW**	**3972**	**2342**	**2523**	**2592**
Project/Process Counting	B*0.15		351	378	389
Total Plant Cost	**$/kW**	**3972**	**2693**	**2901**	**2981**
Land@$4,942/ha			11	15	18
Toatal Capital Requirement	**$/kW**	**3972**	**2704**	**2916**	**2999**

Source : Renewable Energy Technology Characterisation, Topical Report,
Published by Office of Utility technologies, Energy Efficiency & Renewable Energy, U.S. Department of Energy and EPRI, (Dec 1997)

3.3.2 Solar Tower Technology:

Major cost components of the solar thermal power plants based on tower technology comprise Heliostat field, receiver system, tower and piping system, thermal storage system (if applicable), structures, steam generator, master control, and power block system. A typical schematic of solar tower power plant is presented below.

Fig 3.2 : Typical schematic of Solar Tower based power plant

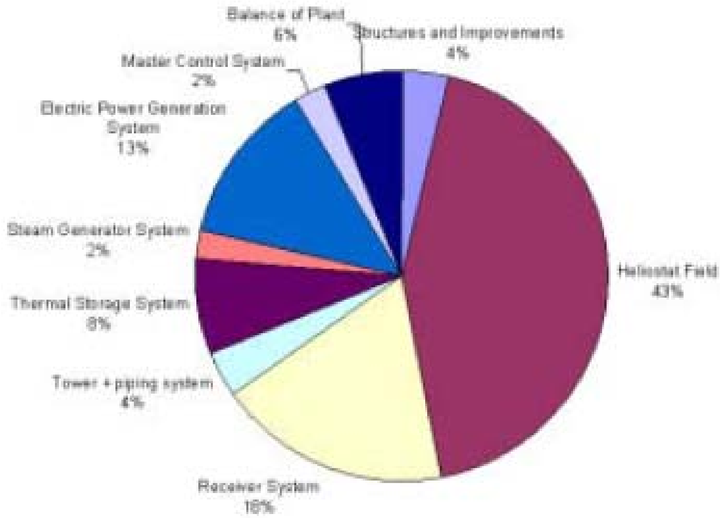


Solar power towers generate electric power from sunlight by focusing concentrated solar radiation on a tower-mounted heat exchanger (receiver). The system uses hundreds to thousands of sun-tracking mirrors called heliostats to reflect the incident sunlight onto the receiver.

In a molten-salt solar power tower, liquid salt at 290ºC (554ºF) is pumped from a 'cold' storage tank through the receiver where it is heated to 565ºC (1,049ºF) and then on to a 'hot' tank for storage. When power is needed from the plant, hot salt is pumped to a steam generating system that produces superheated steam for a conventional Rankine cycle turbine/generator system. From the steam generator, the salt is returned to the cold tank where it is stored and eventually reheated in the receiver. Figure 1 is a schematic diagram of the primary flow paths in a molten-salt solar power plant. Determining the optimum storage size to meet power-dispatch requirements is an important part of the system design process. Storage tanks can be designed with sufficient capacity to power a turbine at full output for up to 13 hours.

The composition of various cost components is presented in chart below.

Chart-3.4: Major Cost Components of Solar Tower system (with storage)



Source: NREL Report on Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts, (Oct 2003)

The solar field, electric power block, and receiver encompass approximately 74% of the total direct costs as shown above Chart. The major cost component is the heliostat field, which encompasses 43% of total costs. The next three categories are electric power block, 13%; receiver, 18%; and balance-of-plant, 6%.

National Renewable Energy Laboratory (NREL) has published a report[4] covering detailed assessment of Parabolic Trough and Solar tower technology cost and performance forecasts covering comparative analysis of independent studies undertaken by SunLab and Sargent & Lundy. Key findings and projections (near term, medium term and long term) for Solar Tower technology as outlined under said Report is summarised below.

[4] *NREL Report on Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts, (Oct 2003)*

Table 3.5 : NREL Report on Capital Cost Projection (2010) – Solar Tower

Capital Cost Projections for Solar Thermal Technology (Solar TowerTechnology)							
Case	**Sun Lab**			**Sargent & Lundy**			**Projected Cost Range in INR (Mid-Term) - 2010**
	Near Term	**Mid Term**	**Long Term**	**Near Term**	**Mid Term**	**Long Term**	
Project	**Solar Tres**	**Solar 100**	**Solar 220**	**Solar Tres**	**Solar 100**	**Solar 220**	
In Service	**2004**	**2010**	**2020**	**2004**	**2010**	**2020**	
Structures and Improvements,$/m2 field	12.3	4	2.7	11.6	3.9	2.7	Rs 9.98 - 12.35 Cr/MW
Heliostat Field, $/m2	145	107	76	160	134	117	
Receiver, $/m2 recv	50	27	21	57.143	30.631	23.834	
Tower and Piping, $/m2 field	12.1	9.1	9.2	11.6	8.7	9.1	
Thermal Storage, $/kWt	49	41	40	49	41	40	
Steam Generator, $/kWt	14	8	7	14	8	7	
Electric Power,$/kWe	733	400	380	557	306	231	Rs 1.40 -1.83 Cr/MW
Balance of Plant, $/kWe	532	116	7	733	367	169	Rs 0.53-1.68 Cr/MW
Sub-total Plant Cost, $/kWe	**5700**	**2700**	**1900**	**6424**	**3375**	**2684**	**Rs 12.34 - 15.42 Cr/MW**
Indirect Cost, $/kWe	440	241	183	1134	629	524	Rs 1.10-2.87 Cr/MW
Contigency,$/kWe	453	202	152	890	604	383	Rs 0.92-2.76 Cr/MW
Risk Pool, $/kWe	580	0	0	642	0	0	
Total Cosr,$/kWe	**7110**	**3143**	**2270**	**9090**	**4608**	**3591**	**Rs 14.36-21.06 Cr/MW**

Source *: NREL Report on Assessment of Parabolic Trough and Power Tower Solar Technology Cost andPerformance Forecasts, (Oct 2003)*

As per NREL report, total plant cost for tower based solar thermal power installations during 2010 have been projected to be in the range of US$ 3143/kW *(SunLab estimate)* – US$ 4608/kW *(S&L estimate)* (i.e. Rs 14.36 Cr/MW – Rs 21.06Cr/MW). However, above cost projections include cost of thermal storage facilities. While the base plant cost estimate by SunLab and S&L is in the range of US$2700/kW to US$ 3375/kW, significant difference in estimate of indirect costs and contingencies may have resulted into wide variation in cost estimates for tower based solar thermal power plants.

Further, a Report published by US Dept. Of Energy and EPRI, provides detailed break-up of solar thermal plant cost components for Solar tower based installation over the period. The plant cost for various configurations of Solar Tower plant is stated to vary from US$ 4365/kW (equiv. Rs 19.94 Cr/M) during 2000 (for 30 MW with 7 hours of thermal storage facilities) to US$ 2605/kW (equiv. Rs 11.90 Cr/MW) during 2010 (for 200 MW with 13 hours thermal storage facilities), as summarised under following table.

Table 3.6 : USDOE & EPRI Report – Capital Cost Projections (2010) - Solar tower

Particulars	UNITS	Small Hybrid Booster 2000	Large Hybrid Booster 2005	Solar Only 2010
Plant Design				
Plant Size	MW	30	100	200
Heliostat Size	m^2	95	150	150
Solar Field Area	m^2	275000	883000	24,77,000
Thermal Storage	Hours	7	6	13
Performance				
Capacity Factor	%	43	44	65
Annual Energy Production	GWh/yr	113	385.4	1138.8
Capital Cost				
Structures & Improvements	$/kW	116	60	50
Heliostat System	$/kW	1666	870	930
Tower/Receiver System	$/kW	600	260	250
Thermal Storage	$/kW	420	240	300
Steam Gen.system	$/kW	177	110	85
EPGS/ Balance of Plant	$/kW	417	270	400
Master Control System	$/kW	33	10	15
Directs Sub Total (A)	**$/kW**	**3429**	**1820**	**2030**
Indirect Engineering/Other	A*0.1	343	182	203
Sub total (B)	**$/kW**	**3772**	**2002**	**2233**
Project/Process Contigency	B*0.15	566	300	335
Total Plant Cost	**$/kW**	**4338**	**2302**	**2568**
Land @ $4.942/hectare		27	27	37
Total Capital Requirement	**$/kW**	**4365**	**2329**	**2605**

Source : Renewable Energy Technology Characterisation, Topical Report,
Published by Office of Utility technologies, Energy Efficiency & Renewable Energy, U.S. Department of Energy and EPRI, (Dec 1997

However, it is noted that above International Study Reports are slightly dated (Oct 2003) and mid-term projections for 2010 can only be considered as guidance, particularly in view of significant development in solar thermal technology applications and proliferation of such installations world over in the recent past.

3.3.3 Summary of Capital Cost for CSP installations (Operating & Planned):

While above reports provide insight into break-up of various cost components for solar thermal installation and its trajectory thereof, it is still based on estimate of project cost rather than actual cost for installation. Following table presents a summary of capital cost and key project parameters for the solar thermal projects already commissioned or at advanced stage of construction/financial closure. The list of the project covers solar thermal power installations in US and Spain comprising all types of technological options such as parabolic trough, solar tower & heliostats, compact linear Fresnel etc.

Table 3.7 : Capital Cost Summary of CSP Installations (Operating and Planned)

Particulars	CSP Projects : Information about Cost & Project Parameters							
	US				Spain			
	Nevada SolarOne	Carrizo	Ivanpah	Solana	Extresol-1	Solnova-1	Andasol-2	PS-10
Status	Commissioned (2007)	Announced	Announced	Announced	Financed	Financed	Financed	Commissioned (2006)
Owner	Acciona	Ausra	Brightsource Energy	Abengoa	ACS Cobra	Abengoa/ Solucar	ACS Cobra / Solar Millennium	Abengoa/ Solucar
Technology	Parabolic trough	Compact Linear Fresnel	Tower & Heliostat	Parabolic trough	Parabolic trough	Parabolic trough	Parabolic trough	Tower & Heliostat
Capacity, MW	64	177	400	280	50	50	50	11
Thermal storage	Steam-30 min	No	No	Molten salt - 6 hours	Molten salt - 7 hours	no	Molten salt - 7.5 hours	Steam-30 min
Gas back-up	2% or less	No	No	No	No	12-15%	No	No
Load factor	26%	25%	28%	40% (est.)	40%	26%	41%	25%
Land, hectare/MW	2.52	1.46	3.44	2.7	4.5	2.3	4	6.8
Cost/MW built	US$ 4.15 Mn per MW	US$ 3.1 Mn per MW	US$ 3.3 Mn per MW	US$ 3.6 Mn per MW	Euro 8.2 Mn per MW	Euro 5.5 Mn per MW	Euro 6.0 Mn per MW	Euro 3.9 Mn per MW
Cost/MW built, US$ /kW	4150	3100	3300	3600	11789	7907	8626	5607
Cost/MW built, Rs Cr/MW	18.97	14.17	15.08	16.45	53.87	36.14	39.42	25.62

Source : http://www.claverton-energy.com/wp-content/uploads/2009/01/mwsnap015.jpg

It is evident from above table that, the solar thermal power installations in US are predominantly without thermal storage or very limited gas back-up whereas solar thermal power installations in Spain are with thermal storage or gas back-up with high plant load factor (except PS-10). Hence, comparison of cost for solar thermal power installations in US (without thermal storage and gas back-up) would be more relevant while devising generic capital cost norm. Besides, these installations in US are also stated to be commissioned over 2010. For example, as per Report published by Greenpeace International, ESTELA and IEA SolarPACES[5], the Carrizo solar power is stated to be commissioned during 2010 and Ivanpah solar power is stated to be commissioned in stages from 2010 (Ivanpah-1 : 100 MW) to 2012/13 (Ivanpah: 300 MW).

It is also evident from above table that the capital cost of installations already commissioned and operational was higher at US $ 4150/kW (for Nevada Solar One in 2007) (equiv. Rs 18.97 Cr/MW for Nevada SolarOne) and US $ 5607/kW (equiv. Rs 25.62 Cr/MW for PS-10 in 2006) whereas the capital cost of solar thermal power installations proposed to be commissioned over 2010 is lower at US $ 3100/kW (equiv. Rs 14.17Cr/MW) (for Carrizo) and US $ 3300/kW (equiv. Rs 15.08 Cr/MW) (for Ivanpah) without thermal storage. The capital cost for CSP project with thermal storage facilities is US$ 3600/kW (equiv. Rs 16.45 Cr/MW).

[5] *Concentrating Solar Power – Global Outlook 2009*

3.3.4 Determination of Benchmark Capital Cost for Solar thermal in India:

The capital cost projections (2010) for CSP installations from various reports as well as for CSP installations planned for commissioning over the period from 2010 to 2012 have been summarised in the following table.

Table 3.8 : Summary of Capital Cost Projections for CSP (2010)

Item Description	**Parabolic trough based solar thermal power installation**		**Tower based solar thermal power installation**	
	US $/kW	**Equiv. (Rs Cr/MW)**	**US $/kW**	**Equiv. (Rs Cr/MW)**
NREL Report projections (2010)	3416-3562	15.61-16.27	3143 – 4608	14.36-21.08
US Dept. Of Energy & EPRI Report projections (2010)	2999 (with storage)	13.70	2605	11.90
Actual Project Information (Planned Capacity addition in 2010)	3600 (with storage)	16.45	3300 (without storage)	15.08

Forum for Advancement of Technology (FAST) has presented during recent Solar Energy Conclave that capital cost for solar thermal power plants during Phase-1 of JNNSM may be considered as US$ 3500/kW (Rs 16.00 Cr/MW). However, it is noted from Table-3.7 & Table-3.8 that the capital cost for the solar thermal power plants (without thermal storage facilities) to be commissioned during 2010 to 2012 has been reported to be in the range of US$ 3100/kW (equiv. Rs 14.20 Cr/MW) to US$ 3300/kW (equiv. Rs 15.08 Cr/MW).

Further, it is observed that, there exists significant scope for indigenisation in solar thermal technology particularly in power block and other balance of plant/system components albeit feasibility for extent of indigenisation for initial few projects could be limited.

Keeping the above facts into consideration, it is proposed to consider benchmark capital cost norm for Solar Thermal Power Projects to be commissioned during 2010-11 or 2011-12 as Rs 14.20 Cr/MW (equiv. US $ 3100/kW).

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