

CENTRAL ELECTRICITY REGULATORY COMMISSION

NEW DELHI

Petition No. SM/353/2013 (Suo-motu)

Coram: Shri Gireesh B. Pradhan, Chairperson  
Shri V.S. Verma, Member  
Shri M. Deena Dayalan, Member  
Shri A.K.Singhal, Member

Date of Order: 7<sup>th</sup> January, 2014

**IN THE MATTER OF**

Determination of Benchmark Capital Cost Norm for Solar PV power projects and Solar Thermal power projects applicable during FY 2014-15

**ORDER**

1. The Commission notified the Central Electricity Regulatory Commission (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2012 (hereinafter "the RE Tariff Regulations") on February 6, 2012.
2. The Benchmark Capital Cost Norms as stipulated under Regulation 57(1) for Solar PV power project and under Regulation 61(1) for Solar thermal power project are applicable for solar power projects for the year FY2012-13.
3. The first proviso of the Regulation 5 of the RE Tariff Regulations provides that the Commission may annually review the benchmark capital cost norm for Solar PV and Solar thermal power projects.
4. In exercise of the power under Regulation 5 of RE Tariff Regulations, the Commission vide Order dated 28th February, 2013, determined the Benchmark Capital Cost Norm for Solar

PV power projects and Solar thermal power projects for the year 2013-14 (Petition No. 242/SM/2012 - Suo-Motu) at ₹ 800 Lakh/MW and ₹ 1200 Lakh/MW.

4. The Commission, in due discharge of the mandate under Regulation 5 of RE Tariff Regulations, proposes to determine the benchmark Capital Cost Norm for Solar PV power projects and Solar Thermal power projects applicable during FY 2014-15. The proposal is enclosed as **Annexure- I**.

Comments /suggestions of the stakeholders on the above proposal are invited by 31<sup>st</sup> January, 2014.

Sd/-	Sd/-	Sd/-	Sd/-
[A.K.SINGHAL]	[M. DEENA DAYALAN]	[V.S.VERMA]	[GIREESH B. PRADHAN]
MEMBER	MEMBER	MEMBER	CHAIRPERSON

New Delhi

Dated the 7<sup>th</sup> January, 2014

**Benchmark Capital Cost norm for Solar PV and Solar Thermal technologies, for FY 2014-15**

The proposed benchmark Capital Cost norm for Solar PV and Solar Thermal project, for FY 2014-15 are discussed below:

**A. Solar PV Power Projects: Capital cost of Solar PV projects****1. Module Price**

1.1 PV Insights in its report dated 4/9/2013 on solar module spot price reveals that silicon module prices are being traded in the range of 0.55 US\$ to 0.99 US\$ with an average of around 0.709 US\$. The Table 1 below shows solar module spot prices in the month of August 2013.

Table 1: Solar Module spot price

Item	High USD / Watt	Low USD / Watt	Average USD / Watt
<b>Silicon Solar Module</b>	0.99	0.55	0.709
<b>Thin Film Solar Module</b>	0.94	0.49	0.606

Source: PV insight, Report dated 4/9/2013

1.4 The Table 2 below shows the China /Taiwan PV module average spot prices prevailed during the month of August, 2013 and changes in prices in percentage term with respect to previous month:

Table 2: China/Taiwan PV-Spot Price in US \$ (August 2013)

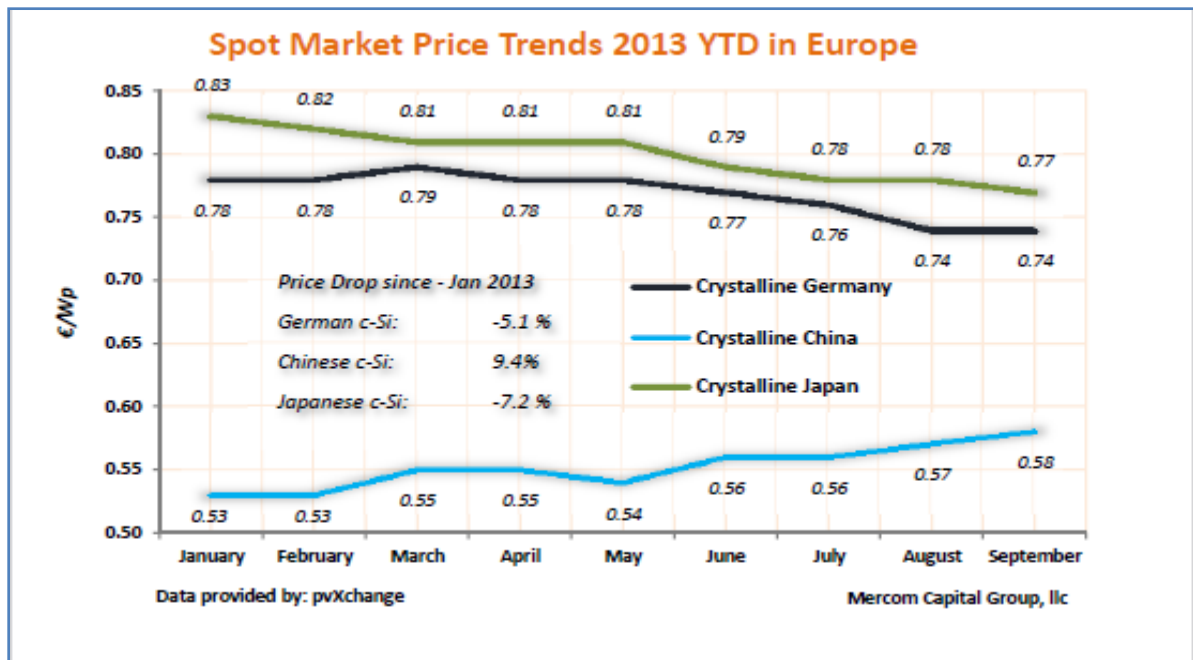
Particulars	Average	% Change
<b>Poly Price (per kg)</b>	17.43	5.89%
<b>Multi-Si wafer ( 156mm)</b>	0.86	-1.15%
<b>Cell Price (Per Watt)</b>	0.39	-2.50%
<b>Module Price (Per Watt)</b>	0.69	-1.43%
<b>Thin Film Price (Per Watt)</b>	0.62	No Change

Source: Mercom Capital Group, Digitimes, PVinsights, August 2013

The module price shown in the above Table 2 reveals that silicon module prices are being traded in the range of 0.69 US\$/Watt.

1.5 The reason for increase in the module price compared to last year, as per Mercom's Solar Market Intelligence Report (September, 2013), could be that the Chinese polysilicon makers have been raising their selling prices since the announcement of the Chinese polysilicon antidumping case. Under the new policy announced by Government of China, any imported polysilicon needs to provide a certificate of manufacturing origin and without the certificate the imported polysilicon will be imposed the highest antidumping rate at 57%. This new policy introduced in August, 2013 against the backdrop of EU launched anti-dumping and anti-subsidy investigations against China's PV products in 2012. Europe is the most important market for China's solar products, comprising 90 percent of total shipments. After several rounds of negotiations, the EU agreed to stop the investigations and insisted China to sign a "price undertaking" agreement. China, in turn, committed to a minimum price of 0.56 euro/ Watt and to limit the number of exports to the EU. Figure 1 below shows price trend in the spot market of Europe till September, 2013.

Figure 1: Spot Photovoltaic Module Price Trends in Europe



Source: Mercom's Solar Market Intelligence Report (September, 2013)

Above Figure 1 reveals that as compared to Chinese Module makers, Non-China Module prices fallen in Europe since January, 2013 as the demand impacted by European market shrinkage. Non-China module manufacturers could supply cells to EU customers at cheap price, without adding high anti-dumping tariffs cost.

1.6 However, based on the interaction with the various EPC contractors it is found that the prevailing module prices offered by the Chinese manufacturers in India are around 0.57/US\$. Since we are determining benchmark capital cost for the FY 2014-15, any future expected

reduction cannot be ignored. Therefore, the Commission has decided the average module cost of 0.54 US\$/Wp for determination of benchmark capital cost of Solar PV for FY 2014-15. Considering the Exchange Rate at ₹ 60.00/US\$ (average of daily exchange rate data available of RBI website of past six months), the Commission propose to consider the module cost at ₹ 324 Lakh/MW.

In addition to the above proposed module cost, the Commission also proposes to consider an additional 0.5 % of the modules cost (i.e. 5 kW of module per MW) every year after 4th year to 25th year of operation on notional basis considering module degradation as allowed in the past based on the study carried out by the Commission. Accordingly, the Commission proposes to consider the total module cost at ₹ 334 Lakh/MW.

## **2. Non-Module Cost Component:**

The non-module cost components comprise cost towards land, civil & general works, ground mounting structures, power conditioning unit, cabling & transformer/ switchgears and preliminary/pre-operating expenses & financing costs. Each component of above referred non-module cost of Solar PV based power plant is estimated as under for the determination of benchmark capital cost of Solar PV projects for FY2014-15.

### **2.1 Land Cost**

The land requirement for Solar PV based power project depends upon the technology employed i.e. Crystalline or Thin film, conversion efficiency and solar radiation incident in respective area. The Commission, while determining the benchmark capital cost for Solar PV projects for the year 2013-14, had considered land requirement of 5 Acre/MW for crystalline PV project and its cost was considered as ₹ 16.8 Lakh / MW. The Commission also considered that the land acquired for setting up solar power projects is mostly arid/barren or of no commercial use. Therefore, the Commission proposes to escalate the normative land cost of FY2013-14 at 5% and proposes the land cost at ₹ 18 Lakh/ MW for the determination of benchmark capital cost of Solar PV projects for FY2014-15.

### **2.2 Power Conditioning Unit (Inverter)**

Power conditioning equipment is an important component of the balance-of-system. Power conditioners process the DC power produced by a photovoltaic system to AC power and match the same with utility's power. Based on the interaction with various solar PV project EPC service provider it is found that currently in the country various prominent Inverter suppliers are

supplying inverters for MW scale projects in the range of ₹ 40 Lakhs to ₹ 70 Lakhs /MW depending on the type and brand of the inverter. Some of the inverter manufacturers such as AEG, ABB and Schneider are already manufacturing solar inverters in India. The Commission proposes to consider normative inverter cost at ₹ 50 Lakhs/MW.

### **2.3 Civil and General Works:**

The cost associated with civil works includes testing of soil, preparation of soil/ground with all necessary works like earthmoving, digging holes for the foundations/pilings and leveling, fencing of the land, development of approach road, cable trenches, water supply arrangement in solar farm, control room etc. The General works include security of solar farm, setting up of power back-up generator; yard lighting, Earthling Kits, etc. Based on the interaction with the project developers, the Commission proposes to consider the cost for Civil and General work as ₹ 40.00 lakh/MW, for determination of benchmark capital cost of Solar PV projects for FY2014-15.

### **2.4 Ground Mounting Structures:**

This expenditure includes cost associated with manufacturing, delivery, installation and calibration of hot galvanized steel structures including all necessary material, works and installation on prepared foundations/pilings. Based on the interaction with the project developers, the Commission proposes to consider ₹ 50.00 Lakh/MW towards the cost for Ground Mounting Structures for benchmark capital cost of Solar PV projects for FY2014-15.

### **2.5 Cables and Transformers**

This expenditure includes EPC cost towards DC cabling between Solar PV panels & Inverters including junction boxes, AC cabling between Inverter & sub-station, Earthling arrangements and Transformer. The transformer cost includes the EPC cost of a step up outdoor type transformer, breaker, Current Transformers, Potential Transformers, Isolators, LAs, protection relay and TOD meter. The Commission, based on the interaction with the various project developers proposes to consider ₹ 60 Lakhs/MW as expenditure towards cables and transformers for solar PV projects for the determination of benchmark capital cost of Solar PV projects for FY2014-15.

## 2.6 Preliminary/Pre-operating expenses and Financing Costs

The preliminary/pre-operating expenses include transportation of equipment, storage of equipment at site, insurance, contingency, taxes and duties, IDC and finance charges etc. Detailed breakup of Preliminary and Pre-operative expenses and financing cost, lump sum in percentage of total capital cost is proposed as under:

- i. Insurance Cost: 0.5%
- ii. Contingency: 0.5%
- iii. Interest during Construction (IDC): 5%
- iv. Financing cost: 1%
- v. Project management cost: 1%
- vi. Pre-operative Cost: 1.0%

Preliminary/Pre-operating expenses and Financing Cost contribute to around 10% of total capital cost on average basis. Accordingly, Rs. 60.00 Lakh/MW is proposed to be considered as preliminary /Pre-operating expenses and Financing cost.

The Table 3 below presents the breakup of benchmark capital cost norm for Solar PV projects for the FY 2014-15:

Table 3: Breakup for Capital cost projection

Sr. No.	Particulars	Capital Cost Norm for Solar PV project (Rs. Lakh/MW)	% of total cost
1	PV Modules	334.00	55%
2	Land Cost	018.00	3%
3	Civil and General Works	050.00	8%
4	Mounting Structures	040.00	7%
5	Power Conditioning Unit	050.00	8%
6	Evacuation Cost up to Inter-connection Point (Cables and Transformers)	060.00	10%
7	Preliminary and Pre-Operative Expenses including IDC and contingency	060.00	10%
8	Total Capital Cost	612.00	100%

### 3. Capital Cost of Solar Photovoltaic projects

The CERC has determined Solar PV Tariff for the Year 2013-14 at ₹ 8.75 (without AD benefit) and ₹ 7.87 (with AD benefit). The Solar photovoltaic projects are allocated, through competitive bidding, under JNNSM and as well as under the State specific Solar Policies at the tariff rate quite lower than the above referred CERC determined tariff . The lowest bids quoted under different solar programme are shown in Table 4 as under:

Table 4: Lowest Bid prices in various solar programme

Sr. No.	Solar Programme	Lowest bid
1	Batch II, Phase I	7.49
2	Karnataka Phase I	7.94
3	Madhya Pradesh	7.90
4	Tamil Nadu	5.97 with 5% escalation for first 10 years
5	Andhra Pradesh	6.49
6	Rajasthan	6.45
7	Punjab	7.67
8	Karnataka Phase II	5.51

Considering the above facts into consideration, the Commission proposes to consider total cost of Solar Photo voltaic power projects for the FY2014-15 as ₹ 612.00 Lakh/MW as benchmark project cost of Solar PV projects.

### B. DETERMINATION OF BENCHMARK CAPITAL COST FOR TYPICAL CSP (SOLAR THERMAL) PROJECTS FOR THE PERIOD 2014 – 15

#### SOLAR THERMAL OR CONCENTRATED SOLAR THERMAL (CST) TECHNOLOGIES

Under this section, technology specific parameters such as capital cost norm, capacity utilization factor, auxiliary consumption and O&M Expenses, for solar thermal projects have been discussed. Solar Thermal technologies use systems of mirrored concentrators to focus direct beam solar radiation to receivers that convert the energy to high temperatures for power generation. There are four commercially available CSP technologies:



1. Parabolic Trough
2. Central Receiver Tower
3. Dish Engine
4. Linear Fresnel

As per NREL Report the CSP projects of both parabolic trough and tower technology, as of 2011, have been deployed mostly in Spain and U.S. Some projects are also operational and under development in the Middle East and North Africa region (MENA). CSP projects that use linear Fresnel reflector and dish/Stirling Energy Systems are very few and still under developmental stage.

Parabolic Trough technology has achieved close to full commercial status while cost data for the power Tower, Fresnel and Dish Stirling technologies are in the process of being established. Therefore, available cost data of Parabolic Trough technology is considered for the determination of benchmark capital cost norm for solar thermal projects for the year 2012-13.

#### **CAPITAL COST AND CAPACITY UTILIZATION FACTOR (CUF)**

As per Regulation 5 of the RE Tariff Regulations-20010, the Commission needs to review the benchmark capital cost for Solar Thermal Power projects every year. Accordingly the Commission reviewed the same and fixed it at ₹ 1200 Lakh/MW for the FY 2013-14 (Order dated 28<sup>th</sup> February, 2013 in the Petition No. 242/SM/2012)

The Capital cost of solar thermal project is dependent on the solar irradiation level at a particular location. Variation of solar irradiation level at different locations result in variation in electricity output, CUF and capital costs. For solar thermal power projects, the electricity output is computed by the formula:

$$\text{=Annual average solar irradiation (KWh/m}^2\text{/year) x Plant Efficiency (\%)} \times \text{Solar Field size (m}^2\text{)}$$

Solar field size is the one of the most decisive factor in deciding the cost of the project. The solar field, comprising of mirrors, concentrates the incident solar irradiation onto heat absorber tubes which absorb the thermal energy and transfers it to a heat transfer fluid. Heat exchangers transfer thermal energy to generate steam that drives a conventional turbine.

Designing the 'right' size of solar field to generate sufficient thermal heat required to drive the turbine continually throughout its operation depends on the solar irradiation level which varies according to the 'time of day' (maximum in the afternoon, low in the mornings and evenings) and 'month of year' (lower during monsoon, higher during summer months).

A larger than necessary (or a smaller) solar field may result in excess (or deficient) solar energy required to drive the turbine thereby causing solar energy to be dumped. Based on the solar field efficiency, hourly incident irradiation and the thermal to electric plant efficiency, solar simulation software is used to compute the thermal heat of steam required by the system to drive the steam turbine for different solar field sizes, along with electric output, capital costs and CUF.

The CUF is dependent on solar field size and no. of hours of storage which are optimized for minimum LOCE. Project cost is dependent on the CUF projected and corresponding solar field size. Solar irradiation varies from location to location across the country. Therefore field size requirement and in turn the project cost would also vary for a particular CUF across the country.

Based on discussion with the experts working with different developers who were awarded CSP projects (parabolic trough technology) in Phase I of JNNSM, we have provided a brief assessment of capital cost with data and reasons considering following three factors:

- i. It is important to point that no solar thermal plant is fully operational in our country and therefore the performance data of actual working is not available. As the project commissioning date has been extended, it is unlikely that except one project, may be commissioned before March 2014 and one year performance data would be available by March 2015; therefore we have to rely on the estimations.

- ii. It is equally important to consider the depreciation of the Rupee versus foreign currencies. This aspect has been covered, bifurcating the major items of imports and local supply in determining the capital costs.
- iii. Thirdly, it is important to recollect that a recent bidding process for 2 x 50 MW CSP projects invited by Rajasthan Renewable Energy Corporation at a benchmark capital cost of Rs. 10.45 per KWh and a declared solar resource of 1,678 KWh/m<sup>2</sup>/year (based on ground measured data from the station installed and maintained by Ministry of New and Renewable Energy (MNRE) – Centre for Wind Energy Technology (CWET) under their Solar Radiation Resource Assessment (SRRA) project) failed to elicit any bids. Therefore in our view the above points and following data and analysis may be considered in determining capital costs for control period 2014 – 15, as per details attached.

### **SOLAR RESOURCE ESTIMATION**

The solar resource data of one of the CSP projects allocated in Phase I of JNNSM located in Western Rajasthan considered which was estimated based on sophisticated satellite modeling developed by Spanish R&D organization under Spanish Ministry of Science & Innovation (CIEMAT) and ground measured data received from one of the developers, which was quality checked, compared with other satellite estimated data, corrected the Linke Turbidity factor (a measure of the Aerosols and water vapour in the atmosphere). The solar resource from different sources, which are correlated and tabulated in Table 5 below:

Table 5: Solar resource from different sources

<b>Source</b>	<b>NREL</b>	<b>CIEMAT</b>	<b>Meteonorm</b>	<b>NASA</b>	<b>Ground</b>	<b>CWET</b>
<b>Annual DNI (Kwh/m<sup>2</sup>/year)</b>	2,084	1,847	1,794	2,044	1,893	1,678
<b>Comment</b>	2002 - 07 average	TMY	Average	22 year average	2011	2012

There is sufficient reason to believe that due to dynamic presence of aerosols (mainly due to dust coming from the Saudi peninsula) the DNI in Western Rajasthan has been lower than expectations. The same view can be applied even for Gujarat. Therefore, the DNI of 1,847/KWh/m<sup>2</sup>/year is considered a realistic estimation for CSP projects in determining the benchmark capital cost.

### **YIELD ESTIMATION (ELECTRICITY GENERATION)**

Bankable yield estimation conducted for one of the CSP project developers using two methodologies and based on the design provided by the project owner. The results are tabulated below. One methodology used TRYNYSYS simulation software i.e. simulation conducted by global R&D leaders in CSP technologies Plataforma Solar de Almeria, CIEMAT's project demonstrating all CSP technologies (PSA), Almeria. The second methodology used System Analysis Modeling (SAM) software ( <https://www.nrel.gov/analysis/sam/>) for modeling and analysis has been developed by National Renewable Energy Labs, U.S. Department of Energy (NREL). SAM software is used extensively by project developers, policy makers and regulators in determining the project parameters (Electricity output, project cost, LCOE etc.) based on incident solar irradiation, standard solar component efficiencies and cost through the optimization of solar field size and no. of hours of thermal storage. NREL has also projected incident solar irradiation throughout India based on satellite modeling. ( [http://rredc.nrel.gov/solar/new\\_data/India/nearestcell.cgi](http://rredc.nrel.gov/solar/new_data/India/nearestcell.cgi))

Table 6: Yield estimation

<b>Yield (Electricity Output)</b>	<b>SAM</b>	<b>TRYNYSYS</b>
<b>Electricity Output (GWh)</b>	304.74	284.97
<b>CUF (%)</b>	32.51%	30.40%
<b><i>Plant</i></b>		
<b>Loops</b>	270	270
<b>Storage (hours)</b>	4	4
<b>Turbine nameplate capacity (MWe)</b>	116	116

Comparing the results it appears that modeling software SAM developed by NREL provides a reasonable and realistic estimation of the electricity output and the capacity utilization factor (CUF). Therefore, for the said project SAM estimated electricity generation was used. However, the said project design had a thermal storage component we have not considered it for the purpose of estimating the benchmark capital cost.

The data from another 50 MW CSP project based on parabolic trough technology (under JNNSM Phase-I), having part of the solar field (expressed in terms of “number of loops”) have already been installed and they are working well in the field. For the purpose of estimating the yield and capital cost, the same we have used the following parameters tabulated below.

Table 7: Yield Estimation

<b>Yield (Electricity Output)</b>	<b>CIEMAT data</b>
Electricity Output (GWh)	103.27
CUF (%)	23.60%
Loops	120
Storage (hours)	0
Turbine nameplate capacity (MWe)	55.55

It is important to point out that in CSP technology, unlike PV projects, the size of the solar field (expressed in terms of “number of loops”) determines the yield, project cost and capacity utilization factor (CUF). We have based the yield, costs and CUF based on an optimal design which is turn was based on the solar resource. In the RE Tariff regulations-2012, a CUF of 23% has been specified. The commission has therefore considered a capital cost for a 55.55 MW plant based on the solar field size of 392400 m<sup>2</sup> in determination of benchmark capital cost while maintaining CUF of 23%.

## PROJECT COST ESTIMATION

We have determined the optimal size of the solar field in estimating the capital cost, as shown in Table 8 below:

Table 8: Capital cost

Particulars	Unit	Rate	No.	Total	
Plant Capacity	MW	55.55			
Euro conversion (last 6 months avg.)	₹/Euro	76.55			
US \$ conversion (last 6 months avg.)	₹/\$	60.00			
Loops	\$/loop	5,50,000	120	loop	3,96,00,00,000
HTF System	\$/m2	70	392,400	m2	1,64,80,80,000
Interconnect piping	\$/m2	10	392,400	m2	23,54,40,000
Turbine	Euro/kW	120	55.55	MW	51,02,82,300
BOS	₹/MW	8,000,000	55.55	MW	44,44,00,000
Land	₹/Acre	200,000	350	Acre	7,00,00,000
Site development	₹/Acre	50,000	350	Acre	1,75,00,000
<b>TOTAL COST</b>					<b>6,88,57,02,300</b>
Cost / MW	₹ / MW				<b>12,39,55,037</b>
Cost / MW	₹ Crores/ MW				<b>12.39</b>

### SUMMARY

<b>The main results of our assessment are summarized DNI</b>	<i>kWh/m2/year</i>	1,847
<b>Yield (electricity production)</b>	<i>MWh per MW</i>	2.07
<b>CUF</b>	<i>%</i>	23.60%
<b>Capital cost</b>	<i>₹ (Crores) per MW</i>	12.39

Considering the above, the Commission proposes the benchmark Capital cost of Solar Thermal project at ₹ 12.0 Crore / MW.

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