Discussion Paper

DISCUSSION PAPER ON DETERMINATION OF TARIFF FOR PROCUREMENT OF POWER BY DISTRIBUTION LICENSEES AND OTHERS FROM SOLAR ENERGY PROJECTS FOR THE STATE OF GUJARAT

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Executive Summary

In exercise of the powers conferred under Sections 3 (1), 61 (h), 62 (1) (a), and 86 (1) (e) of The Electricity Act, 2003 and guidelines of the National Electricity Policy, 2005 and Tariff Policy, 2006 and all other powers enabling it on this account, the Gujarat Electricity Regulatory Commission (GERC) presents this Discussion Paper for determination of tariff for procurement of power by Distribution Licensees and others from solar energy projects. The National Action Plan on Climate Change (NAPCC) launched by the Government of India in June 2008 is a comprehensive plan with eight Missions that target specific issues and address the urgent and critical concerns of the country through a directional shift in the development pathway; further, the NAPCC targets an increase in renewable energy purchase by 1% a year with a target to achieve 15% renewable in India's energy mix by 2020. Gujarat's Solar Power Policy-2009 was launched in January 2009 with a target of installing 500 MW of solar photovoltaic and solar thermal generating plants by 2014, while the Jawaharlal Nehru National Solar Mission (JNNSM) launched in January 2010 targets 20,000 MW of net installed solar generating capacity throughout India by 2022.

In December 2009, the Central Electricity Regulatory Commission (CERC) passed an Order determining tariffs for various renewable energy sources, wherein the levelized tariffs for solar photovoltaic and solar thermal projects were determined at ₹ 17.14 and 12.54 per kWh, respectively. Due to oversubscription at JNNSM, a reverse-bidding process was adopted wherein the solar photovoltaic projects selected had bids between ₹ 10.95 and 12.57 per kWh, while solar thermal projects selected had bids between ₹ 10.24 and 12.24 per kWh. Many States have directly adopted the CERC-determined tariff directly, while other states have determined solar energy tariffs independently.

GERC passed its Solar Tariff Order in January 2010 determining a levelized tariff for solar photovoltaic projects at ₹12.54 per kWh (distributed as ₹ 15 per kWh for the first 12 years, and ₹ 5 per kWh for the next 13 years) and for solar thermal projects at ₹ 9.29 per kWh (distributed as ₹ 11 per kWh for the first 12 years, and ₹ 4 per kWh for the next 13 years). GERC has further mandated a specific solar Renewable Purchase Obligation (RPO) at 0.25%, 0.5% and 1% for 2010-11, 2011-12 and 2012-13, respectively.

Since the Gujarat Solar Power Policy-2009, more than 80 national and international companies have signed Power Purchase Agreements (PPA) totalling a sizable net capacity of more than 965 MW. Out of these signed PPAs, a substantial fraction of plants are expected to be commissioned by 31 December, 2011. Additionally, the Government of Gujarat has also initiated projects such as the 500 MW Solar Park near Charanka Village, Patan District, and the pilot 5 MW Gandhinagar Photovoltaic Rooftop Programme.

Solar Photovoltaic Technology:

The solar photovoltaic technology, although evolving, is a robust technology along with its advantages such as simplicity, modularity and low maintenance. The cost of photovoltaic modules, which contributes to more than 50% of the cost of the photovoltaic power plant, is steadily declining along with inverter costs.

Based on the basic differences between implementation of megawatt-scale ground-mounted photovoltaic systems, and kilowatt-scale rooftop photovoltaic systems, all photovoltaic systems can be categorized basically into two types for tariff applicability:

Table: Photovoltaic system classification for tariff applicability.

System Size	System Type	Evacuation Specification	Applicable Tariff
1 kW – 5 kW	Rooftop	230 V, 1 ϕ, 50 Hz	**Kilowatt-scale Photovoltaic Tariff**
5 kW – 100 kW	Rooftop	415 V, 3 ϕ, 50 Hz	
100 kW – 1MW	Rooftop/ Ground-mounted	11 kV, 3 ϕ, 50 Hz	**Megawatt-scale Photovoltaic Tariff**
1 MW – 4 MW	Ground-mounted	11 kV, 3 ϕ, 50 Hz	
> 4 MW	Ground-mounted	66 kV, 3 ϕ, 50 Hz	

The Discussion Paper considers predominant technologies available and deployed globally for tariff determination. The various parameters considered for tariff determination of solar photovoltaic projects are presented as follows:

Table: Summary of parameters for photovoltaic power projects.

PARAMETER	VALUE		
Plant Cost			
Capital Cost	Rs.	1100	Lacs per MW for megawatt-scale system
	Rs.	1.3	Lacs per kW for kilowatt-scale system
O&M Cost		0.75%	of Capital Cost
Escalation in O&M Cost		5%	Annually
Inverter Replacement Year		13th	Year
Inverter Cost during Replacement		3.81%	of Capital Cost
Performance Parameters			
Capacity Utilization Factor		18.5%	
Performance Degradation		1%	Annually
Auxiliary Consumption		0.25%	of Energy Generation
Useful Life		25	Years
Financial Parameters			
Debt : Equity Ratio		70 : 30	
Loan Tenure		10	Years
Interest Rate on Loan		12.00%	
Insurance Cost		0.35%	Annually
Interest on Working Capital		11.25%	Annually
Working Capital	Sum of:	1	Month's O&M Expense
		1	Months' Energy Charges at normative CUF

Rate of Depreciation	6%	Annually for the first…
	10	Years
	2%	Annually for the next…
	15	Years
Minimum Alternate Tax Rate	20.008%	Annually for the first…
	10	Years
Corporate Tax Rate	32.445%	Annually
Return on Equity	14%	Annually

The levelized tariffs for solar photovoltaic plants for a period from 29 January, 2012 to 31 March, 2013 are calculated as follows. Further, the annual decline in these tariffs is considered at 7% decline for 1 April, 2013 to 31 March, 2014, and a further 7% decline for 1 April, 2014 to 31 March, 2015.

Table: Levelized tariff for megawatt-scale and kilowatt-scale photovoltaic systems, 29 January 2012 to 31 March, 2013.

For megawatt-scale projects			
	Levelized Tariff	**Phased Tariff**	**Period**
With accelerated depreciation benefit	₹ 10.27 per kWh for 25 years	₹ 11.50 per kWh	for the first 12 years
		₹ 6.30 per kWh	for the next 13 years
Without accelerated depreciation benefit	₹ 10.81 per kWh for 25 years	₹ 12.04 per kWh	for the first 12 years
		₹ 6.84 per kWh	for the next 13 years
For kilowatt-scale projects			
	Levelized Tariff	**Phased Tariff**	**Period**
With accelerated depreciation benefit	₹ 12.49 per kWh	(Not Applicable)	for 25 years
Without accelerated depreciation benefit	₹ 13.14 per kWh	(Not Applicable)	for 25 years

Solar Thermal Technology:

While there are many solar thermal technology options such as parabolic trough, linear Fresnel lens, central receiver and parabolic dish technologies, all except the parabolic trough technology are yet to be realized at a mature and commercial level. Predominant technologies are considered for determination of solar thermal tariff, and the various parameters are as follows:

Table: Summary of parameters for solar thermal power plants.

PARAMETER	VALUE		
Plant Cost			
Capital Cost	Rs.	1450	Lacs per megawatt
O&M Cost		1.5%	of Capital Cost
Escalation in O&M Cost		5%	Annually

Performance Parameters			
Capacity Utilization Factor		23%	
Performance Degradation		0.25%	Annually
Auxiliary Consumption		10%	of Energy Generation
Useful Life		25	Years
Financial Parameters			
Debt : Equity Ratio		70 : 30	
Loan Tenure		10	Years
Interest Rate on Loan		12.00%	
Insurance Cost		0.35%	Annually
Interest on Working Capital		11.25%	Annually
Working Capital	Sum of:	1	Month's O&M Expense
		1	Months' Energy Charges at normative CUF
Rate of Depreciation		6%	Annually for the first…
		10	Years
		2%	Annually for the next…
		15	Years
Minimum Alternate Tax Rate		20.008%	Annually for the first…
		10	Years
Corporate Tax Rate		32.445%	Annually
Return on Equity		14%	Annually

Based on these parameters, the levelized tariff is calculated at ₹ 12.32 per kWh for solar thermal projects availing accelerated depreciation benefit and ₹ 13.00 per kWh for such projects not availing accelerated depreciation benefit. This tariff can be further sub-divided into two phases as follows:

Table: Levelized tariff for solar thermal power plants, 29 January 2012 to 31 March, 2015.

	Levelized Tariff	Phased Tariff	Period
With accelerated depreciation benefit	₹ 12.32 per kWh for 25 years	₹ 14.00 per kWh	for the first 12 years
		₹ 7.00 per kWh	for the next 13 years
Without accelerated depreciation benefit	₹ 13.00 per kWh for 25 years	₹ 14.68 per kWh	for the first 12 years
		₹ 7.68 per kWh	for the next 13 years

Other Considerations:

- Solar Power Projects established with only new Plants and Machinery would be eligible for the benefit of tariff determined within the scope of this discussion paper.
- The start-up power and stand-by supply are already considered within the scope of the auxiliary power consumption of the respective solar energy technologies.
- The Commission proposes that STU/Distribution Licensee shall provide auxiliary power for the solar generator under kWh to kWh adjustment basis.

- The Reactive Power Charges as approved by the Commission in tariff orders for the Gujarat Energy Transmission Corporation Ltd. (GETCO) from time to time shall be applicable to such projects.

- Switchyard equipment, metering and protection arrangement and RTUs at generator end shall be provided by the owners of solar generators at their cost, while the transmission line from the switchyard of generator to the GETCO substation shall be laid by GETCO.

- Wheeling:
  - At 66 kV voltage level and above:
    - As per the scope of the current Discussion Paper, this clause will be applicable to solar plants of capacity greater than 4 MW.

    - For wheeling of power to consumption site at 66 kV voltage level and above, the wheeling of electricity generated from the Solar Power Generators to the desired location(s) within the State shall be allowed on payment of transmission charges and transmission losses applicable to normal Open-Access Consumer.

    - For wheeling of power to consumption site at a voltage below 66 KV, the wheeling of electricity generated from the solar power Generators to the desired location(s) within the State shall be allowed on payment of transmission charges as applicable to normal open-access customers and transmission and wheeling loss @ 7% of the energy fed into the grid. This loss shall be shared between the transmission and distribution licensees in the ratio of 4:3.

  - At 11 kV or above and below 66 kV:

    - As per the scope of the current Discussion Paper, this Clause will be applicable to ground-mounted or rooftop solar plant of capacity between 100 kW and 1 MW, and ground-mounted solar plants of capacity between 1 MW and 4 MW.

    - The wheeling of power generated by such generators to the desired location(s) within the area of same distribution licensee shall be allowed on payment (in kind) of distribution loss @ 3% of the energy fed in to the grid.

    - The wheeling of power generated by such generator to the desired location(s) within the State but in the area of a different distribution licensee shall be allowed on payment of transmission charges as applicable to normal Open-Access Customers and transmission and distribution loss @ 10% of the energy fed in to the grid. These losses shall be shared among the transmission licensee and two distribution licensees involved in the ratio of 4:3:3.

- AT 415 V or below:
  - As per the scope of the current Discussion Paper, this clause will be applicable to rooftop solar installations of capacity between 1 kW and 5 kW feeding at 220 V, 1ϕ; and rooftop solar installations of capacity between 5 kW and 100 kW feeding at 415 V, 3ϕ.

  - No wheeling charges shall apply for wheeling of power generated by such projects, to the desired locations(s), as such projects decrease the transmission and distribution losses for the utility, and increase the efficiency of the grid.

- As a promotional measure for solar power, which is still in its nascent stage, no cross-subsidy surcharges would be levied in case of third-party sale.

- The Intra-state ABT order will not be applicable to solar power generation projects.

- 100% of the gross proceeds on account of CDM benefit to be retained by the project Developer in the first year after the date of commercial operation of the generating station. In the second year, the share of the beneficiaries shall be 10% which shall be progressively increased by 10% every year till it reaches 50%, whereafter the proceeds shall be shared in equal proportion, by the generating company and the beneficiaries.

- The control period proposed for the solar energy tariff order is from 29th January, 2012 to 31st March, 2015.

- Considering the nature of solar energy, all solar energy power plants will be considered as 'must-run' facilities, and the power generated from such power plants will be kept out from the merit order dispatch principles.

:: End of Executive Summary ::

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Abbreviations

ABT	:	Availability-Based Tariff
AC	:	Alternating Current
AM	:	Air Mass
a-Si	:	Amorphous Silicon
BoS	:	Balance of System
CdS	:	Cadmium Sulphide
CdTe	:	Cadmium Telluride
CEA	:	Central Electricity Authority
CERC	:	Central Electricity Regulatory Commission
CIGS	:	Copper Indium Gallium Selenide
c-Si	:	(Single-) Crystalline Silicon
CSP	:	Concentrated Solar Power
CST	:	Concentrated Solar Thermal
CUF	:	Capacity Utilization Factor
DC	:	Direct Current
DNI	:	Direct Normal Insolation
EPD	:	Energy and Petrochemicals Department
GEDA	:	Gujarat Energy Development Agency
GERC	:	Gujarat Electricity Regulatory Commission
GETCO	:	Gujarat Energy Transmission Corporation Ltd.
GHI	:	Global Horizontal Insolation
GoG	:	Government of Gujarat
GoI	:	Government of India
GTI	:	Global Tilt Insolation
h	:	Hour
IC	:	Integrated Circuit
IEC	:	International Electrotechnical Commission
IMD	:	India Meteorological Department
JNNSM	:	Jawaharlal Nehru National Solar Mission
kWh	:	Kilowatt-hour (also known as a ‘Unit’)

L	:	Litre
Lac(s)	:	A unit in the Indian numbering system, which equals to 100,000. Also known as 'Lakh.'
LCOE	:	Levelized Cost of Electricity
MAT	:	Minimum Alternate Tax
mc-Si	:	Multi- (or Poly-) Crystalline Silicon
MNRE	:	Ministry of New and Renewable Energy
MPPT	:	Maximum Power Point Tracking
NAPCC	:	National Action Plant on Climate Change
NASA	:	National Aeronautics and Space Administration
NTPC	:	National Thermal Power Corporation Ltd.
NVVN	:	NTPC Vidyut Vyapar Nigam Ltd.
O&M	:	Operation and Maintenance
PPA	:	Power Purchase Agreement
PR	:	Performance Ratio
PV	:	Photovoltaic(s)
RBI	:	Reserve Bank of India
REC	:	Renewable Energy Certificate
RPO	:	Renewable Purchase Obligation
SBI	:	State Bank of India
SERC	:	State Electricity Regulatory Commission
sq.	:	Square
STC	:	Standard Testing Conditions
STU	:	State Transmission Utility
W	:	Watts
µc-Si	:	Micro-crystalline Silicon

1. Introduction

1.1 The Electricity Act, 2003

The following provisions of the Act provide the legal framework for the involvement of regulatory commissions in renewable energy:

1.1.1 Section 86.1 (e) of the Electricity Act 2003 mandates promotion of cogeneration and generation of electricity from renewable sources of energy:

“Promote cogeneration and generation of electricity from renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution license.”

1.1.2 Section 61 (h) of the Act provides that, while specifying the terms and conditions of determination of tariff, the Commission shall be guided by the objective of promotion of cogeneration and generation of electricity from renewable sources of energy.

“The promotion of cogeneration and generation of electricity from renewable sources of energy.”

1.1.3 Section 62 (1) (a) of the Act provides for determination of tariff for supply of electricity by a generating company to a distribution licensee.

“Supply of electricity by a generating company to a distribution licensee: Provided that the Appropriate Commission may, in case of shortage of supply of electricity, fix the minimum and maximum ceiling of tariff for sale or purchase of electricity in pursuance of an agreement, entered into between a generating company and a licensee or between licensees, for a period not exceeding one year to ensure reasonable prices of electricity.”

1.1.4 Section 3 (1) of the Electricity Act 2003 requires the Central Government to formulate, inter alia, the National Electricity Policy in consultation with the Central Electricity Authority (CEA) and State Governments. The provision is quoted below:

"The Central Government shall, from time to time, prepare the National Electricity Policy and tariff policy, in consultation with the State Governments and the Authority for development of the power system based on optimal utilization of resources such as coal, natural gas, nuclear substances or materials, hydro and renewable sources of energy."

1.2 National Electricity Policy, 2005

The National Electricity Policy, 2005 formulated in compliance with the above-stated Section 3 of the Electricity Act envisages:

"The Electricity Act 2003 provides that co-generation and generation of electricity from non-conventional sources would be promoted by the SERCs by providing suitable measures for connectivity with grid and sale of electricity to any person and also by specifying, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licensee. Such percentage for purchase of power from non-conventional sources should be made applicable for the tariffs to be determined by the SERCs at the earliest. Progressively the share of electricity from non-conventional sources would need to be increased as prescribed by State Electricity Regulatory Commissions. Such purchase by distribution companies shall be through competitive bidding process. Considering the fact that it will take some time before non-conventional technologies compete, in terms of cost, with conventional sources, the Commission may determine an appropriate differential in prices to promote these technologies."

1.3 Tariff Policy, 2006

The Tariff Policy, 2006 issued by the Ministry of Power, Government of India, also emphasizes on the importance of non-conventional sources of energy generation and states:

"Pursuant to provisions of section 86(1)(e) of the Act, the Appropriate Commission shall fix a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs. Such percentage for purchase of energy should be made applicable for the tariffs to be determined by the SERCs latest by April 1, 2006."

1.4 National Action Plan on Climate Change

The Prime Minister of India released the country's National Action Plan on Climate Change (NAPCC) on 30 June 2008. There are Eight National Missions which form the core of the National Action Plan. The NAPCC consists of several targets on climate change issues and addresses the urgent and critical concerns of the country through a directional shift in the development pathway. It outlines measures on climate change related adaptation and mitigation while simultaneously advancing development. The Missions form the core of the Plan, representing multi-pronged, long-term and integrated strategies for achieving goals in the context of climate change. NAPCC set the target of 5% renewable energy purchase for FY 2009-10. Further, NAPCC envisages that such target will increase by 1% annually for the next 10 years. This would mean NAPCC envisages renewable energy to constitute approx 15% of the energy mix of India.

The National Action Plan on Climate Change is the national strategy of India to achieve a sustainable development path that simultaneously advances economic and environmental objectives. The National Action Plan hinges on the development and use of new technologies. The National Solar

Mission is one of the eight national missions which form the core of the National Action Plan. Based on this vision a National Solar Mission was launched.

1.5 Gujarat Solar Power Policy-2009

The Gujarat Solar Power Policy was announced on 6 January, 2009, by the Energy and Petrochemicals Dept. (EPD), Government of Gujarat, with the following objectives:

- Promoting generation of green and clean power in the State using solar energy.
- To put in place an appropriate investment climate, that could leverage the Clean Development Mechanism (CDM).
- Productive use of the wastelands, thereby engendering a socio-economic transformation.
- Employment generation and skill enhancement of local youth.
- Promotion of R&D and facilitation of technology transfer.
- Establish core technical competence in professionals in the State to initiate and sustain use and effective management of newer applications.
- Promotion of local manufacturing facilities.
- Creation of environmental consciousness among citizens.

This Policy is effective up to 31 March, 2014, and targets a net installed solar generation capacity of 500 MW.

1.6 Jawaharlal Nehru National Solar Mission

The Jawaharlal Nehru National Solar Mission (JNNSM) was announced in 2009. JNNSM aims to promote the development of solar energy for grid connected and off-grid power generation. The ultimate objective is to make solar power competitive with fossil based applications by 2020-2022.

Table 1.1: Proposed Roadmap by the Jawaharlal Nehru National Solar Mission.

Application segment	Target for Phase 1 (2010-13)	Target for Phase 2 (2013-17)	Target for phase 3 (2017-22)
Solar Collectors	7 million sq. meters	15 million sq. meters	20 million sq. meters
Off-grid solar application	200 MW	1,000 MW	2,000 MW
Utility grid power including roof top	1,000-2000 MW	4,000-10,000 MW	20,000 MW

In order to encourage rapid scale-up, a scheme is introduced in cooperation with the Ministry of Power, National Thermal Power Corporation Ltd. (NTPC) and Central Electricity Authority (CEA) to off-take solar power and reduce the financial burden on the government. NTPC Vidyut Vyapar Nigam Ltd. (NVVN), a wholly owned subsidiary of NTPC, is chosen as the nodal agency for entering into Power Purchase Agreement (PPA) with solar power Developers.

State Governments are also encouraged to promote and establish solar generation parks with dedicated infrastructure for setting up utility scale plants to ensure ease of capacity creation.

Government commitments through JNNSM for development of long-term solar projects have attracted a large number of investors towards this sector in a short time frame. About 37.66[1] MW of projects have been commissioned in India during the last two years with the support of the semiconductor policy, solar SEZ, separate RPO for solar, feed-in-tariff, etc.

The JNNSM document also indicates that the Tariff Policy 2006 would be modified to mandate that State Electricity Regulators would fix a percentage for purchase of solar power. Further, the Mission document states that the solar power purchase obligation for States may start with 0.25% in Phase I (by 2013) and go up to 3% by 2022. This could be complemented by solar-specific Renewable Energy Certificate (REC) mechanism to allow utilities and solar power generation companies to buy and sell certificates to meet their solar power purchase obligations.

1.7 GERC Solar Tariff Order, 2010

Gujarat Electricity Regulatory Commission (GERC), in its Order No. 2 of 2010 dated 29 January, 2010 determined the tariff for procurement of power by the Distribution Licensees and others from solar energy projects for the state of Gujarat. In fact, GERC was the first State Electricity Regulatory Commission (SERC) in the country to issue a comprehensive Tariff Order on solar energy.

GERC unveiled attractive tariffs at ₹ 15 per kWh for the first 12 years and ₹ 5 per kWh for the next 13 years for photovoltaic power projects, and ₹ 11 per kWh for the first 12 years and ₹ 4 for the next 13 years for solar thermal power projects.

This tariff is a single-part, generic levelized tariff determined on a cost plus basis. Further, this tariff is applicable only to projects commissioned or to be commissioned up to 28 January, 2012.

1.8 Solar Tariff Orders in Other States

Regulatory Commissions of many states of India including Andhra Pradesh, Assam, Bihar, Haryana, Jammu and Kashmir, Punjab, and Uttar Pradesh have directly adopted the applicable solar tariff as the levelized tariff (for 25 years) as determined by Central Electricity Regulatory Commission (CERC) including the annual tariff determined from time to time for such projects. States including Chhattisgarh, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, West Bengal, Karnataka and Tamil Nadu have independently determined their solar tariffs. Further, West Bengal Electricity Regulatory Commission, in its Notification No. 47/WBERC dated 10 August 2010, accommodates kilowatt-scale photovoltaic systems of capacity as low as 100 kW (up to 2 MW), it also permits grid-connected rooftop photovoltaic systems of capacity as low as 2 kW for selected types of organizations.

[1] "Achieving 12% Green Electricity by 2017," a report prepared by World Institute of Sustainable Energy (WISE), Pune, June 2011.

It must also be noted that while the capped tariff under the Phase 1 of National Solar Mission is higher than the solar tariffs for many states, during the reverse bidding process for selection of Developers discounts up to ₹ 4 per kWh were offered by Developers.

1.9 Gujarat's Renewable Purchase Obligation

GERC, in its regulations titled 'Procurement of Energy from Renewable Sources' (Notification No. 3 of 2010) dated 17 April, 2010 has revised its earlier regulations and mandated to obligatory entities for minimum purchase of electricity (in kWh) from renewable energy sources.

Table 1.2: Renewable Purchase Obligation for Gujarat, 2010-2013.

Year	Minimum quantum of purchase from renewable energy sources (% of total energy in kWh)			
	Total	Wind	Solar	Biomass, Bagasse and others
2010-11	5%	4.5%	0.25%	0.25%
2011-12	6%	5.0%	0.5%	0.5%
2012-13	7%	5.5%	1.0%	0.5%

This Renewable Purchase Obligation (RPO) applies to:

- Distribution Licensees, and
- Any other Captive and Open-Access Users consuming electricity (i) generated from conventional Captive Generating Plant having capacity of 5 MW and above for his own use and/ or (ii) procured from conventional generation through open access and third party sale.

Further, this regulation recognizes the Certificates issued within the scope of Central Electricity Regulatory Commission's (CERC) Notification No. L-1/12/2010-CERC dated 14 January, 2010 as the valid instruments for the discharge of the mandatory obligations set out in these Regulations for the obligated entities to purchase electricity from renewable energy sources.

1.10 Developments in Gujarat

Since Gujarat's Solar Power Policy-2009, more than 80 national and international companies have signed power purchase agreements in two phases, totalling a sizable capacity of more than 965 MW.

The megawatt-scale solar photovoltaic plants of 46 MW capacity have been commissioned in Gujarat so far. Further, there have been estimates from various agencies of approximately 250 MW of solar photovoltaic power plants to be commissioned by 31 December, 2011.

In order to overcome the obstacles of acquiring large amount of land for solar power projects as experienced by private Developers, the Government of Gujarat has undertaken the development of Asia's largest solar park with a capacity of 500 MW near village Charanka of Patan District in Gujarat. This park will host both solar photovoltaic and solar thermal power projects from various Developers.

To promote kilowatt-scale distributed rooftop systems within the State, the Government of Gujarat is promoting the 5 MW Gandhinagar Photovoltaic Rooftop Programme, which targets numerous kilowatt-scale photovoltaic installations aggregating to a net capacity of 5 MW throughout Gandhinagar. The greater goal of this Programme is to:

- Establish a practice/ philosophy of distributed solar and other energy generation.
- Bring a level of comfort to all stakeholders for further scale-up.
- Encourage public participation.

Now, as GERC's existing Order for determination of tariff for procurement of power by the Distribution Licensee and others from solar energy projects, Order No. 2 of 2010 dated 29 January, 2010 is approaching the end of its control period, GERC presents this Discussion Paper to invite comments from potential stakeholders for the tariff order to take effect beyond the existing control period. All the values of parameters and the proposed tariffs are indicative and will be finalised with the tariff order.

:: End of Chapter 1 ::

2. Solar Photovoltaic Power

2.1 Solar Cell and Module Technologies

Photovoltaics (also called 'PV') is the direct method of converting sunlight into electricity through a device known as the 'Solar Cell.' When semiconductors such as silicon are exposed to sunlight, they produce small amounts of electric charge (electrons and holes). A well-designed solar cell separates this charge to form a positive and negative terminal. Hence, these terminals produce a voltage, and when connected to an external circuit, cause a flow of current. In this way, a solar cell in the Sun works just like a battery.

Many different solar cell technologies are available in the market today. Further, substantial R&D efforts are also underway globally for enhancing efficiencies and reducing costs of these solar cells, as well as developing novel cell technologies.

'First-Generation' solar cells are derived from the knowledge of the Semiconductor IC industry, where high-purity and expensive mono-crystalline silicon ingots are sliced into wafers, which are then processed into solar cells. This technology has now evolved into utilizing slightly lower grade poly-crystalline silicon also known as solar-grade silicon, where the efficiency of cells made from solar-grade silicon is slightly lower compared to that of semiconductor-grade silicon, but offers a substantial cost advantage. Both mono- and poly-crystalline silicon solar cells are bulk-silicon technologies, wherein the typical thickness of the wafer is around 170 µm (1 µm or '1 micrometer' is one thousandths of a millimetre).

As the required thickness for a solar cell is substantially less than the current thicknesses of bulk-silicon solar cells and the silicon contributes to approximately one third the cost of a photovoltaic module, current efforts are underway to reduce the thickness of the solar cells without inducing excessive breakage during manufacturing. Research is also carried out to optimize the device designs and obtain higher efficiencies. While typical efficiencies for bulk-silicon solar cells are around 14-18%, some companies have developed novel designs to achieve commercial efficiencies around 22-23%. The current bulk-silicon solar cell technology has a global market share of around 85-90%.

The 'Second-Generation' photovoltaic technology, also known as 'Thin-Film Technology' targets reducing the cost of photovoltaics by utilizing very thin layers of semiconductors. This technology utilizes only 1-2 µm of semiconductor absorber material, which is directly deposited on a supporting substrate such as glass, metal sheet or polymer. Amorphous silicon (a-Si) has historically been widely-used semiconductor for thin-film solar cells, while novel semiconductor structures like microcrystalline silicon (µc-Si), Cadmium Telluride (CdTe) and Copper Indium Gallium Selenide (CIGS), and their combinations are widely gaining popularity as thin-film alternatives.

How are the rating of a photovoltaic cell or module, and its efficiency determined?

The photovoltaic cell and module efficiencies are very common parameters when selecting photovoltaic modules for a power project. The cell and module efficiencies indicate the ratio of the output electrical power to the input solar radiation power. Similar to electric power, the input solar radiation power is also measured in 'Watts.'

Photovoltaic cell and module efficiencies are tested and certified at 'Standard Testing Conditions' (STC), which is an internationally accepted set of test conditions defined for the solar industry. STC specifies a temperature of 25°C and an irradiance of 1000 W/m^2 with an air mass 1.5 (AM1.5) spectrum. This condition approximately represents solar noon near the spring and autumn equinoxes in the continental United States with surface of the solar collector aimed directly at the Sun. STC conditions are achieved in a photovoltaic cell or manufacturing facility with the help of a Sun simulator. Every photovoltaic module is tested at STC after manufacturing, and the maximum power output from that module is known as its "rated" power.

Hence, for example, if a photovoltaic module is rated for 230 W output, it implies that the module will provide 230 W output at STC. Further, if the area of this module is 1.5m^2, then the efficiency of this module can be calculated as:

$$Efficiency = \frac{Output\ Power}{Input\ Power} = \frac{230\ W}{1000\,\frac{W}{m^2} \times 1.5\ m^2} = 15.33\%$$

In reality, the power output from this module would vary when it would be operating in a power plant due to the varying atmospheric conditions such as position of the Sun, clearness of the sky, ambient temperature, etc.

Moreover, it is obvious that photovoltaic modules of lower efficiency will require more area to achieve a particular net rating or capacity in terms of watts.

Figure 2.1: (a) A solar simulator for small solar cells, where the cell is placed under the simulator facing up (*courtesy of Spire Solar*), and (b) a large-area module tester, where the module is placed facing down (*courtesy of Newport Oriel Instruments*).

However, the efficiencies of thin-film solar cells are currently lower compared to their bulk-silicon counterparts at around 6-12% due to the lower crystalline quality and higher material defects. Moreover, large-area deposition of thin semiconductor films is a considerable technological challenge, and hence, the thin-film market growth has been slower than what was earlier speculated. Thin-film technologies are expected to perform better under diffused light than their crystalline-silicon counterparts. The thin-film technologies today have a combined photovoltaic market share of around 10-15%. Global research efforts are currently underway to improve efficiencies and develop commercial-scale large-area deposition technologies.

The 'Third-Generation' photovoltaic technology employs very specialized high-efficiency solar cells. These solar cells are expensive and typically used in space applications, but are now finding a place in terrestrial applications as the cost of these technologies are also declining. The effective cost of such solar cells is further reduced by concentrating large amount of light onto the cell using relatively inexpensive lens or mirrors. Such solar cell assemblies are designed to physically 'track' the Sun in order to focus the concentrated light at the solar cells and also increase the energy yield. Due to the high concentration of incident sunlight, this technology usually requires an active cooling mechanism such as forced air or water. Although a few such ground-mounted photovoltaic plants have been installed commercially in Europe and USA, the market share of this technology is negligible. However, this technology is attracting much attention as many experts believe that the key to cost-effective solar energy lies in such high-efficiency third-generation technologies. Substantial research is currently being carried out to develop high-efficiency solar cells, while companies are involved in designing cost effective mounting and tracking assemblies for such solar cells for commercialization.

Table 2.1: Photovoltaic technology efficiencies and market shares

Sr.	Technology	Typical Commercial Efficiency[2]	Record Laboratory Efficiency[3]	Market Share[4]
1.	Mono-Crystalline Silicon	14-18% Selected: 22-23%	25%	4%
2.	Poly-Crystalline Silicon	13-16%	20.4%	83%
3.	Amorphous Silicon	6-9%	10.5%	5%
4.	Amorphous/Microcrystalline Silicon		12.4%	
5.	Cadmium Telluride	9-11%	16.7%	6%
6.	Copper Indium Gallium Selenide	10-12%	19.6%	2%
7.	III-V Multi-junction	35%	43.5%	Negligible
8.	Organic Photovoltaics	<1%	8.3%	Negligible
9.	Dye-Sensitized Solar Cells	-	10.9%	Negligible

[2] Source: Martin A. Green et. al., "Solar Cell Efficiency Tables (Version 38)," Progress in Photovoltaics: Research and Applications, Vol. 19, Pg. 565, 2011.
[3] Solar cells are fabricated in laboratories through more sophisticated, accurate and controlled processing compared to commercially-manufactured cells and modules, and hence yield higher efficiencies. Further, efficiencies achieved in laboratories indicate the benchmark for manufacturing processes.
[4] Source: PV News, 2010.

In addition to the abovementioned photovoltaic technologies, many novel technologies such as organic, dye-sensitized and nano-structured solar cells are also heavily researched and carry a promise through lower cost and/or high-efficiency pathways. However, the current market share of all these technologies is negligible.

Usually, the solar cells are fragile, and the power output of a single solar cell is limited; for example, the typical power output of a single 6” x 6” poly-crystalline silicon solar cell is around 3.5-4 W at Standard Testing Conditions (STC). Therefore, they are connected in series and parallel, then encapsulated into a laminate to obtain a net higher power output and withstand harsh environmental conditions. Such a laminate is called a ‘Solar Module’ or a ‘Photovoltaic Module.’ Robust photovoltaic modules with different cell technologies are available in the market, and are sold based on their power output at STC, which is rated in watts.

The Ministry of New and Renewable Energy (MNRE) of the Government of India (GoI) has specified certain standards developed by the International Electrotechnical Commission (IEC) that qualify the photovoltaic modules for design as well as safety. Further, as per current industry practices, photovoltaic modules are warranted to exhibit more than 90% of their rated power during the first 10 years of operation, and more than 80% of their rated power during the subsequent 15 years. Such a standard 25 year warranty on the photovoltaic modules indicates the highly robust and

What is a solar photovoltaic module?

A Solar Photovoltaic Module is the basic building block of the photovoltaic system. A photovoltaic module converts sunlight directly into DC electricity using the numerous solar cells connected in series within it. These cells are encapsulated in laminates such as glass, ethyl vinyl acetate (EVA) and tedlar; they are sealed from the edges using silicone or other sealants and aluminium frames.

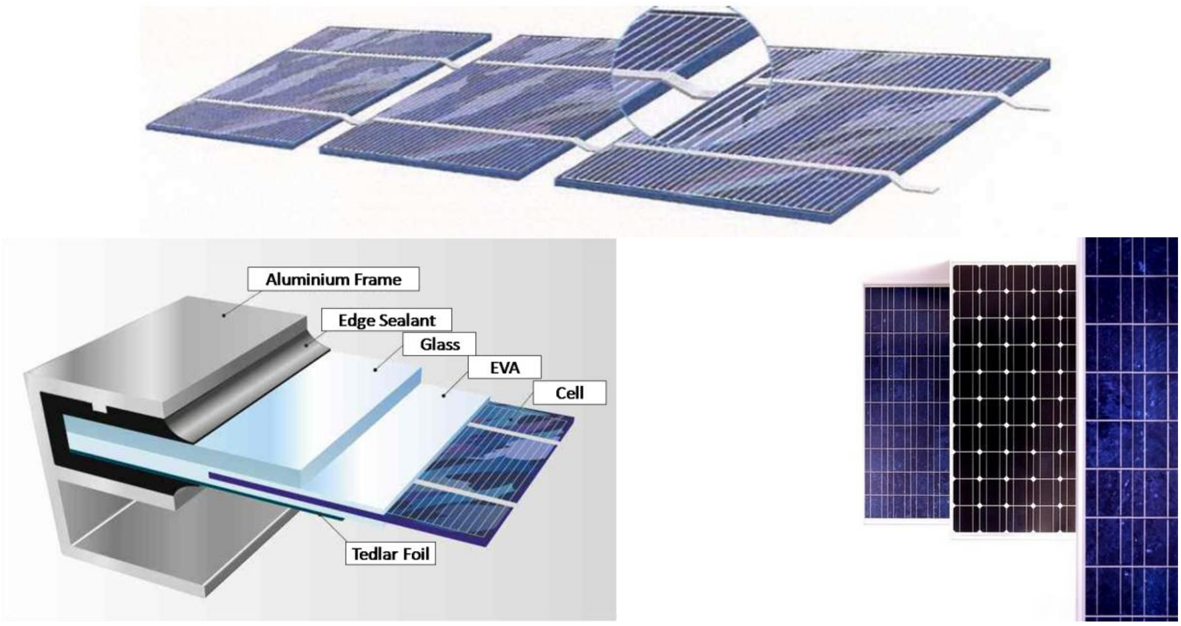

Figure 2.2: Construction of mono/ poly-crystalline silicon photovoltaic modules.

reliable nature of the photovoltaic technology. It should be mentioned at this point that even though many thin film technologies offer 25 year performance warranties, there is no long-term performance data available for such technologies and hence there is a need within the market to develop confidence on the long-term performance in the harsh Indian and Gujarat weather conditions.

Table 2.2: Module certifications accepted in India.

Certification	Description
IEC 61215	Crystalline and Multi-Crystalline Silicon Terrestrial PV Module: Design qualification and type approval.
IEC 61646	Thin-Film Terrestrial PV Module: Design qualification and type approval.
IEC 62108	Concentrated Photovoltaic Modules & Assemblies: Design qualification and type approval.
IEC 61730	Photovoltaic Module: Safety Qualification

2.2 Cost of Photovoltaic Systems

2.2.1 Cost of Photovoltaic Modules

The cost of the photovoltaic modules account for more than half the cost of the entire photovoltaic power plant, and hence, have a substantial impact on the resultant Levelized Cost of Electricity (LCOE). However, the photovoltaic module prices, irrespective of module technology, have been steadily declining owing to research and development, industry adaptation and economies of scale. The module prices have declined by more than half over the last decade, and are expected to drop at the same rate in the near future.

Table 2.3: Indicative prices of photovoltaic modules of various origins and short-term historic trends.[5]

Sr.	Module Type (Origin)	Price, July 2011 (€/W)	[← Trend (%) ←]	Price, July 2010 (€/W)	[← Trend (%) ←]	Price, July 2009 (€/W)
1.	Crystalline Silicon (Germany)	1.60	[-14%]	1.86	[-22%]	2.39
2.	Crystalline Silicon (Japan)	1.38	[-25%]	1.85	[-16%]	2.21
3.	Crystalline Silicon (China)	1.12	[-31%]	1.62	[-16%]	1.92
4.	Thin-film Amorphous/ Microcrystalline	1.00	[-24%]	1.31	[-24%]	1.73
5.	Thin-film CdTe/ CdS	1.03	[-36%]	1.61	[4%]	1.55

5 pvXchange GmbH online portal: http://www.pvxchange.com/

The short-term historic trends indicate a significant drop in crystalline silicon module costs over the last one year ranging from 14% to 31% depending on its origin. The Jawaharlal Nehru National Solar Mission mandates the use India-made modules in case of crystalline and poly-crystalline silicon modules, the costs for which are closer to their Chinese-made counterparts. Recent quotations for such modules obtained from domestic and international suppliers have indicated a price range of ₹60-65 per watt. Thin-film cadmium telluride modules have also seen a price reduction of 36% over the last one year, and have become an attractive proposition for many solar Developers.

2.2.2 Balance of System

All components of a photovoltaic power plant except the photovoltaic modules are collectively termed as the Balance of System or 'BoS.' With the reducing costs of the photovoltaic modules, the cost of balance of system may surpass the cost of photovoltaic modules as early as 2012.

The balance of system includes components such as:

- Photovoltaic inverters,
- Transformers,
- Module mounting structures,
- Combiner/ junction boxes,
- DC and AC power cables, communication cables,
- Engineering, civil works and labour.

As all commercial photovoltaic modules today generate only DC power, photovoltaic inverter become essential to convert this DC into AC power for either direct AC applications or feeding into the grid. Photovoltaic modules are usually connected in series and then in parallel, which are then connected to the photovoltaic inverter. The functionality of photovoltaic inverters includes: (i) maximizing the output power from the modules by maximum power point tracking (MPPT), (ii) converting the DC power into AC power, (iii) in case of grid-tied inverters, synchronizing the output voltage and frequency to match the grid parameters, and (iv) offer safety and protection to and from the photovoltaic system.

Photovoltaic inverters are rated for their power handling capacity, and inverters ranging from less than 1 kW and more than 1 MW capacity are commercially available. Inverters for photovoltaic power projects are classified based on their operational philosophy, which also has an implication on its capacity.

The price of the PV inverter is substantially governed by the capacity of the inverter, and accounts for 10-15% of the cost for a megawatt-scale photovoltaic power plant, and 15-20% for a kilowatt-scale photovoltaic power plant. Typical central inverter costs are in the range of € 0.20-0.24 per watt, while typical string and domestic inverters cost up to € 0.60 per watt depending upon the make and capacity. As the share of the inverter cost is lower compared to the overall project cost, Developers tend to be conservative in ensuring high quality inverters even if at a slightly higher cost.

As the solar photovoltaic market has been exhibiting strong growth, the demand for inverters began to outgrow the supply causing a bottleneck around 2009. As a result, the inverter prices did not see an aggressive reduction recently. However, with major inverter suppliers in Europe, USA, Taiwan, etc. increasing their capacities, the prices of inverters have started coming down at an annual rate of 10-15%. Further, with a surge of manufacturers from China as well as the push for manufacturing from India, the inverter prices are further expected to reduce considerably in the near future.

Table 2.4: Classification of photovoltaic inverters.

Type	Typical Capacity	Philosophy
Central Inverter	250 kW – 1.25 MW	○ Commonly used in megawatt-scale photovoltaic power plants in India and foreign countries. ○ A single inverter controls a large portion of the plant.
String Inverter	5 – 20 kW	○ Used in smaller photovoltaic installations including rooftop systems, and some megawatt-scale plants globally. ○ A single inverter controls a single or limited string of modules. ○ They offer multiple controls at a more basic level compared to central inverters, hence, reducing module mismatch losses and simplifying plant maintenance. ○ They are typically mounted outdoors, and have yet to prove their performance for harsh Indian weather conditions.
Domestic Inverter	1-5 kW	○ Typically used for domestic rooftop applications. ○ May be in a grid-tied or stand-alone mode.
Micro-Inverter	100 – 400 W	○ Novel technology with controls the output of each module individually converting it into AC. ○ Currently used in pilot small-scale installations only, but have a promising roadmap for wide applications.

Other balance of system components such as transformers, module mounting structures, DC and AC power cables and civil-related activities can be sourced from the domestic market. Moreover, the costs associated with project engineering, module mounting structures, and civil works are expected to decline with more industry learning in the coming few years.

2.2.3 Land Requirement

The land requirement for solar power projects primarily depends upon:

(i) Efficiency of the photovoltaic technology, and
(ii) Type of tracking used.

The land requirement for a particular technology will be inversely proportional to its photovoltaic module efficiency. It is an accepted rule of thumb that a 1 MW solar photovoltaic power plant with poly-crystalline silicon modules of 14% efficiency fixed at optimum inclination in Gujarat will utilize 4.5-5 acres of land. (This land requirement increases at higher latitudes, and decreases while moving towards the equator.) Similarly, a 1 MW photovoltaic power plant with 9% efficient thin-film modules will utilize 7-7.75 acres of land.

Various types of tracking mechanisms are used in order to maximize the capture of sunlight by the photovoltaic modules. The tracking can be single-axis based on daily motion of the modules from morning to evening, or it can be in a seasonal manner where the inclination of the modules is changed only a limited number of times during the year based on the season. Daily tracking has to be automated using motors and drives, while seasonal tracking can be automated or manual. Further, two-axis tracking is typically used for high-efficiency (third-generation) photovoltaic modules, which further increases the yield compared to single-axis tracking.

However, various tracking technologies also require additional land area to be able to incorporate the flexibility of photovoltaic module orientation without casting shadow on each other.

Table 2.5: Typical increase in yield and area requirement for various tracking philosophies for Gujarat.

Type of Tracking	Energy Yield...	Land Requirement...
Fixed at optimum tilt	Reference case	Reference case
Fixed horizontal	Decreases by 8-9%	Decreases by 50-70%
Single-axis seasonal	Increases by 3-5%	Increases by 20-30%
Single-axis daily	Increases by 20-25%	Increases by 20-40%
Two-axis	Increase by 25-30%	Increases by 80-120%

The land requirement for typical 1 MW poly-crystalline photovoltaic power plant at fixed optimum tilt is taken as 5 acres, and considered as a benchmark.

It is acknowledged that tracking technologies would require more area, but the cost of land is compensated through the increase in the plant's energy yield. Further, this benefit through increase in energy yield may be considered as an advantage by project Developers for implementing novel technologies.

2.2.4 Capital Cost of Megawatt-Scale Photovoltaic Plant

The current capital cost of a 5 MW photovoltaic power plant consisting of poly-crystalline silicon modules, and including land cost, is determined to be ₹ 55 Crores. Indicative costs of various components for such plants are shown in Table 2.6.

The capital cost of megawatt-scale photovoltaic power plants is determined taking a standard plant size of 5 MW. The cost is determined based on independent surveys of components, and feedback from private Developers, EPC contractors and government agencies. While the costs of individual heads indicated in Table 2.6 may vary slightly from case to case, no major deviation in the total (capital) cost of such plants is observed.

Hence, the capital cost per megawatt for a megawatt-scale photovoltaic power plant is taken as ₹ 11 Crores.

2.2.5 Capital Cost of Kilowatt-Scale Photovoltaic Plant

One of the major differences affecting the normalized cost of kilowatt-scale photovoltaic power plants compared to megawatt-scale plants is the cost of inverters, which are found to be as high as double in kilowatt-scale inverters compared to megawatt-scale inverters as indicated in Table 2.7.

Hence, the capital cost per kilowatt for a kilowatt-scale photovoltaic power plant is taken as ₹ 1.3 Lacs.

Connection philosophy of a feed-in meter interconnection system.

Kilowatt-scale photovoltaic power plants, which are mounted on rooftops and directly feed electricity into the grid, are typically connected to the grid on one of the two following philosophies:

1. Feed-in metering (two-meter) philosophy, and

2. Net-metering philosophy.

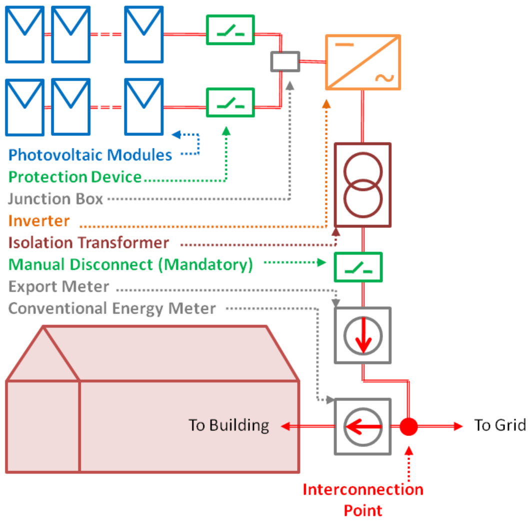

Figure 2.3: Feed-in metering interconnection schematic.

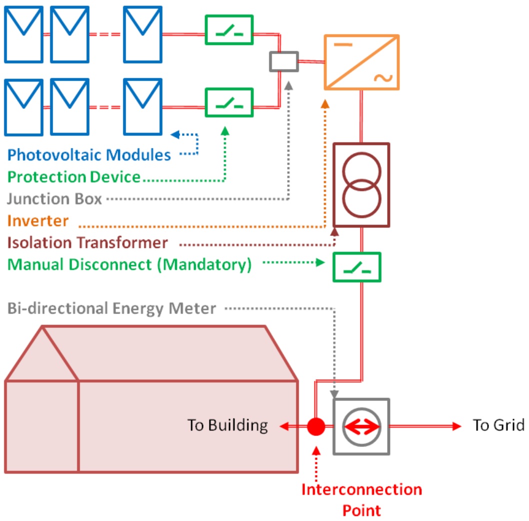

Figure 2.4: Net-metering interconnection schematic.

The two-metering interconnection scheme is applicable where a separate feed-in tariff is allowed for feeding of solar electricity into the grid, and hence, will be applicable in Gujarat. Energy is easily accounted for in this case through a dedicated feed-in meter. Such schemes are popular in several European countries including Germany.

The net-metering scheme is applicable where conventional electricity and solar electricity are traded at the same tariff. As the cost of solar electricity is higher compared to conventional electricity, such a net-metering scheme has to be supported with additional subsidies to the Developer. Such schemes are popular in several countries including USA and Japan.

Table 2.6: Typical cost heads for 5 MW ground-mounted grid-connected photovoltaic power plant.

Sr.	Head		Cost (Rs. Cr.)
1.	Photovoltaic Modules	:	30
2.	Inverters	:	6.5
3.	Module Mounting Structures	:	6
4.	Land, Building and Civil Works	:	4.5
5.	Evacuation Switchyard	:	3.5
6.	Wires and Electrical	:	2.5
7.	Engineering and Project Management	:	0.5
8.	Contingency (Approx. 3%)	:	1.5
	TOTAL:	**:**	**55**
	CAPITAL COST PER MEGAWATT	**:**	**11**
RUPEES ELEVEN CRORE ONLY PER MEGAWATT			

Table 2.7: Typical cost heads for 5 kW rooftop grid-connected photovoltaic power plant.

Sr.	Head		Cost (Rs. '000)
1.	Photovoltaic Modules	:	3,25
2.	Inverters	:	1,25
3.	Module Mounting Structures	:	50
4.	Building and Civil Works	:	50
5.	Isolation Transformer	:	30
6.	Wires and Electrical	:	5
7.	Engineering and Project Management	:	10
8.	Contingency (Approx. 10%)	:	55
	TOTAL:	**:**	**6,50**
	CAPITAL COST PER KILOWAT	**:**	**1,30**
RUPEES ONE LAC THIRTY THOUSAND ONLY PER KILOWATT			

2.2.6 Evacuation Cost

The Solar Power Policy, 2009 of the Government of Gujarat provides that the transmission line from the switchyard of the substation of the megawatt-scale solar power plant to the GETCO substation shall be laid by GETCO.

For smaller photovoltaic systems such as rooftop systems which are connected to the distribution grid at 11kV or below, the infrastructure typically exists as the solar power Generator is also the Consumer of the Distribution Utility. **However, in case the existing infrastructure is not sufficient for evacuation of solar power, such infrastructure should be developed or upgraded by the relevant distribution company.**

Hence, evacuation cost is not considered for calculation of solar tariff.

2.2.7 Operation and Maintenance Cost and its Escalation

Photovoltaic power plants are characterized by their simple and low-cost operation and maintenance (O&M). The operation and maintenance of a photovoltaic power plant mainly involves cleaning of the photovoltaic modules at a regular interval. The cleaning frequency of the modules of a commercial plant may be as high as once per week or as low as once per month.

In addition to cleaning staff, the photovoltaic power plants typically require security staff and site supervisors. Performance monitoring of such plants are typically done remotely, and an engineer is deployed onsite only during troubleshooting of issues.

Many earlier CERC and SERC tariff orders considered the operation and maintenance cost of 0.5% of the plant capital cost. However, the capital cost of the power plants have substantially reduced, while the cost of operation and maintenance has almost remained constant.

Hence, for the near term, the typical operation and maintenance cost of photovoltaic power plants is considered to be 0.75% of the capital cost of the plant. Further, as most of this cost is human resource-related, **the annual escalation of the operation and maintenance cost is considered to be 5%.**

2.2.8 Inverter Replacement

Photovoltaic inverters, central or string, come with a typical 5-year comprehensive warranty, with a provision for a 10-year extended warranty. However, an inverter replacement is envisioned typically around the 12th to 14th year of the operation of the plant. The cost of the inverter can be considered at 15% of the plant capital cost. Moreover, the costs of the photovoltaic inverters are also expected to decline at a steady rate of 10% annually.

Hence, an inverter replacement cost equivalent to 3.81% of the capital cost can be considered for the 13th year.

2.3 Performance Parameters of the Photovoltaic Power Plant

The energy output of a photovoltaic power plant primarily depends on two parameters: (i) Plant Performance Parameters, and (ii) Weather Parameters.

2.3.1 Plant Capacity

The capacity of a solar photovoltaic power plant can be defined as the cumulative rated capacity of the photovoltaic modules at Standard Testing Condition (STC) used in that power plant. Further, as it may not be practical to achieve the exactly desired plant capacity due to design constraints, a tolerance of $\pm$2% is allowed.

Additionally, during the supply of photovoltaic modules, the actual power output of the module at STC may be different from the rated module power due to the nature of its manufacturing. The net allowable module tolerance between the module rating and actual performance in a photovoltaic power plant is considered at ±3%.

2.3.2 Performance Ratio

The plant performance parameters are collectively represented through a single value known as the Plant Performance Ratio (PR). This performance ratio is a measure of the quality of a photovoltaic plant that is independent of the location and incident irradiation, and hence, often known as the 'Quality Factor.'

The performance ratio is expressed as a percentage value and indicates the fraction of nominal incident solar radiation energy incident on a plant array that is converted into useful electrical energy injected into the grid. The performance ratio takes into account energy losses within a photovoltaic power plant such as thermal losses, module mismatch losses, Ohmic (resistive) losses, inverter losses, etc. The procedure for determining the performance ratio of a photovoltaic power plant is prescribed in the Standard *IEC 61724: Photovoltaic System Performance Monitoring: Guidelines for Measurement, Data Exchange and Analysis*.

Based on independent surveys, analysis and feedback from private Developers, EPC contractors and government agencies it is determined that typical photovoltaic plants in Gujarat and India have recorded or quoted performance ratios between 70% and 80%, while 75% is an acceptable industry standard.

Table 2.8: Typical losses affecting the performance ratio of a photovoltaic power plant.

Loss Mechanism	Loss
Loss due to temperature	13%
Loss due to inverter efficiency	3%
PV module mismatch loss	2%
DC and AC wiring Ohmic (resistive) losses	2%
Soiling loss	3%
Transformer loss	1%
Other losses	1%
TOTAL LOSS	**25%**
NET PERFORMANCE RATIO	**75%**

2.3.3 Irradiance Data

As solar radiation is the primary fuel for the photovoltaic power plant, it is obvious that the energy output of the plant will be site specific; similar plants installed at different geographical locations will yield different energy outputs.

Radiation terminology explained…

Solar radiation is quantified in many ways depending on the aspect it is used for. Terms like radiation, irradiance, insolation, GHI, DNI, etc. refer to the solar resource, and are commonly confused or misused.

Radiation:

Radiation is a qualitative term, which indicates the process through which energy is emitted from a body. *Radiation* does not have any units associated with it.

Irradiance:

Solar *irradiance* indicates the amount of solar power incident on a fixed area. *Irradiance* is typically expressed in watts per square metre (W/m^2). *Irradiance* is measured through an instrument called 'pyranometer,' which displays the instantaneous power available from the Sun.

When the *irradiance* from the Sun is 1,000 W/m^2 (which also corresponds to Standard Testing Conditions – STC), this value is called "1 Sun." If the *radiation* from Sun is concentrated 10 times using a lens or a mirror assembly and the incident power increases to 10,000 W/m^2, then the *irradiance* is called "10 Suns."

Insolation:

Insolation is the amount of solar irradiance that is incident on a fixed area over a finite period of time, and hence corresponds to the physical unit of *energy*. I*nsolation* is typically expressed in kilowatt-hours per square metre per day ($kWh/m^2/day$) or ($kWh/m^2/year$) for a particular location, orientation and tilt of a surface.

Since 1,000 W/m^2 is 1 Sun, 1 hour of this ideal *irradiance* produces 1,000 watt-hours per square metre (1 kWh/m^2), which is also known as "1 Sun Hour." Colourful maps of solar potential display solar energy in $kWh/m^2/day$, which is equivalent to the number of full Sun Hours per day.

Types of Insolation: GHI,GTI, and DNI:

When discussing the solar resource, it is most common to consider the insolation received by a flat, horizontal collector. Such an insolation received by a stationary horizontal collector is called the **Global Horizontal Insolation (GHI)**.

For most fixed plate solar collectors, they are oriented at an inclination angle approximately equal to the latitude of its location and facing south if in the northern hemisphere (or facing north if in the southern hemisphere) to maximize the insolation received. The insolation received by such an oriented surface is called the **Global Tilt Insolation (GTI)**.

Many solar technologies prefer tracking the Sun so that the collector surface always faces the Sun in order to maximize the irradiance and insolation received. Further, tracking of the Sun becomes mandatory when higher concentrations are required in order to focus the light at the appropriate collector location. The insolation received by any such surface that is constantly facing the Sun, i.e. 'normal' to the Sun, is called **Direct Normal Insolation (DNI)**.

One should keep in mind that it is only the normal component, i.e. DNI, of solar radiation that is effectively concentrated, and hence, becomes the primary factor for determining potential for various concentrated solar photovoltaic and thermal technologies.

Gujarat is an attractive state for installation of solar energy systems due to the high levels of solar radiation that it receives. While irradiation and other weather data are available from the India Meteorological Department (IMD) and National Aeronautics and Space Administration (NASA) based on a limited number of observatories, many other private services are now available that claim to provide more site-specific and accurate weather data by interpolating existing long-term data with short-term measured data and advanced modelling.

2.3.4 Capacity Utilization Factor

The electrical energy output of a photovoltaic power plant can be calculated using the performance ratio and the global irradiance on the plane of the photovoltaic arrays, which are oriented at an optimum tilt angle. Further, the Capacity Utilization Factor (CUF) can be calculated based on the energy output of the plant.

Table 2.9: Global irradiance at select locations and their typical performance.

Location	Global Horizontal Insolation[6] ($kWh/m^2/year$)	Global Tilt Insolation ($kWh/m^2/year$)	Electricity Output from a Typical[7] 1MW PV Plant (MU)	Calculated CUF (%)
Ahmedabad	1,905	2,117	1.59	18.13
Charanka	1,883	2,066	1.55	17.69
Rajkot	1,945	2,157	1.62	18.47
Surat	1,905	2,095	1.57	17.94

The above table indicates that it is feasible to achieve CUF of 18.5% in Gujarat. The details given in the above table are based on data which are generalised in nature. Discussion with some of the developers revealed that, they are expecting CUF to the extent of 19% or even higher. Keeping these aspects in view, we considered a realistic figure of 18.5% for the Capacity Utilisation Factor for the purpose of determination of tariff.

2.3.5 Annual Degradation in Performance

A performance warranty for 25 years on photovoltaic modules is an industry standard today. Typical warranties guarantee a performance of more than 90% for the first 10 years, and a performance of more than 80% for the next 15 years, adding to a total of 25 years. This implies an annual degradation rate of 0.9% for the photovoltaic modules.

No substantial degradation is expected in the performance of the balance of system.

Hence, the acceptable annual degradation in the performance of the grid-connected photovoltaic system is 1%.

[6] Global Horizontal Insolation and Global Tilt Insolation are based on NASA's Surface Meteorology and Solar Energy data, which is derived using satellite observatories and averaged over 22 years of data. This data may be generalized and/ or interpolated for a specific location, and although substantial agreement with other weather datasets is observed, a certain level of uncertainty will always exist.

[7] A 'Typical' PV Power Plant is assumed to have a performance ratio of 75%.

2.3.6 Auxiliary Energy Consumption of Photovoltaic Power Plant

A photovoltaic power plant consumes minimal energy for auxiliary purposes. Auxiliary power may be required for air-conditioning in inverter and control rooms, cleaning water softening and pumping system, security night lighting and general office lights and fans.

The auxiliary consumption of the photovoltaic power plant can be estimated at 0.25% of the total energy generation.

2.3.7 Useful Life

The standard warranty of photovoltaic modules, which account for more than half of the cost of the entire plant, is for a period of 25 year. However, the photovoltaic power plant including the modules, is expected to last substantially beyond this period.

GERC, in its current Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has stipulated a solar power plant life of 25 years. Further, CERC, in Clause 2 (1) (y) of its Renewable Energy Regulation No. L-7/186(201)/2009-CERC dated 16 September, 2009 also defines the useful life of solar photovoltaic or a solar thermal power plant as 25 years.

Hence, the useful life of solar photovoltaic projects is taken as 25 years for calculation of the tariff.

2.4 Finance-Related Parameters of the Photovoltaic Power Plant

2.4.1 Debt-Equity Ratio

The GERC Multi Year Tariff Regulation, 2011, notified by the Commission provides a normative debt-equity ratio of 70:30 for Generating Companies/ Licensees. Further, Clause 5.3 (b) of the Tariff Policy, 2006, notified by the Ministry of Power, GOI, stipulates a debt –equity ratio of 70:30 for financing of power projects. Further, the GERC, in its current Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has stipulated the same debt-equity ratio.

Hence, the debt-equity ratio of 70:30 is considered for financing.

2.4.2 Loan Tenure

The GERC Multi Year Tariff Regulation, 2011, notified by the Commission provides for a loan tenure of 10 years. Further, GERC in its last Solar Tariff Order has stipulated the same loan tenure.

Hence, a loan tenure of 10 years is considered.

2.4.3 Interest Rate on Loan

The interest rates have increased substantially in the Indian financial market due to the continuously rising inflation rate; a strong evidence of volatility is that the leading bank in India (State Bank of India - SBI) has announced change in its base rate six times during the last 10 months. While all banks have their own base rates, project financing interest rates are typically indicated by their relation with the SBI base rate. A reasonably sound project usually gets funding at rate 100 to 200 basis points above the base rate.

While the inflation and monetary policy of the Reserve Bank of India (RBI) shall determine the interest rate for the next period, it is unlikely to have any significant decline in interest rates, at least during the next six months. However, as the control period of the tariff under discussion is well beyond one year and the term of loan is 10 years, it is advisable to consider the weighted average of interest rate in the recent past. CERC, in Clause 14 (2) of its Renewable Energy Regulation No. L-

7/186(201)/2009-CERC dated 16 September, 2009 has also taken this approach of taking the weighted average of interest rates of the past period to work out the interest cost.

Table 2.10: SBI base rates revised from 1 January, 2011 to 5 October, 2011.

Period				SBI Base Rate for Lending
1	1 January, 2011	to	2 January, 2011	7.60%
2	3 January, 2011	to	13 February, 2011	8.00%
3	14 February, 2011	to	24 April, 2011	8.25%
4	25 April, 2011	to	11 May, 2011	8.50%
5	12 May, 2011	to	10 July, 2011	9.25%
6	11 July, 2011	to	12 August, 2011	9.50%
7	13 August, 2011	to	5 October, 2011	10.00%
WEIGHTED AVERAGE:				**8.93%**

In the current scenario, the weighted average base rate of SBI for the period between 1 January, 2011 and 5 October, 2011 is 8.93%. A reasonable mark-up of 200 basis points on this weighted average would result in an effective interest rate of 10.93%, which could be used for tariff determination purpose in this discussion document.

While the above method seems logical, it may be noted that the Developers may not get the borrowings at this 10.93% as the latest SBI base rate has increased to 10%. Hence, the interest rate on loan to be considered for the current discussion paper is based on the current interest rate. The existing SBI base rate is 10%, which can be further marked up by 200 basis points for financing of solar power projects.

Hence, the interest rate on loan for tariff computation is determined to be 12%.

2.4.4 Insurance Cost

Insurance cost at the rate of 0.35% of the capital cost is considered annually. This insurance cost is as per GERC's last Solar Tariff Order, and is considered over and above the operation and maintenance cost.

2.4.5 Working Capital

GERC, in its last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has considered the following to be included as working capital, which is also considered here:

(i) One month's expense on operation and maintenance expenses, and

(ii) Receivables equivalent to one month's energy charges for sale of electricity calculated on a normative CUF.

2.4.6 Interest Rate on Working Capital

Interest rates on working capital are found to be lower than long-term interest rates for power project over the last ten years. This gap between the long-term loan and working capital loan rate is typically between 50 and 100 basis points. Accordingly, the interest rate on working capital is considered to be 75 basis points lower than that on the long-term loan.

Hence, the interest rate on working capital is considered to be 11.25%.

2.4.7 Rate of Depreciation

CERC, in Clause 15 of its Renewable Energy Regulation No. L-7/186(201)/2009-CERC dated 16 September, 2009 indicates that the value base for purpose of depreciation shall be based on the capital cost of the asset; salvage value of the asset shall be considered as 10% and depreciation shall be allowed up to maximum of 90% of the capital cost. Depreciation per annum shall be based on 'Differential Depreciation Approach' over loan tenure and the period beyond loan tenure over useful life computed on 'Straight Line Method'. Depreciation shall be chargeable from the first year of commercial operation. Provided that in case of commercial operation of the asset for part of the year, the depreciation shall be charged on *pro rata* basis.

GERC, in its last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has considered a high rate of depreciation as a promotional measure during the loan tenure, and then the remaining depreciation is spread over the remaining useful life.

Hence, depreciation of 6% per annum is considered for the first 10 years, and 2% for the next 15 years.

2.4.8 Return on Equity

The GERC Multi Year Tariff Regulation, 2011, notified by the Commission provides norms for the Return on Equity as 14% per annum. GERC has also allowed Income Tax at 20.008% (18.5% MAT + 5% Surcharge + 3% Education Cess) per annum for 10 years, and Corporate Tax at 32.445% per annum from 11th year onwards. Any further enhancement in the RoE will burden the consumers.

Hence, the return on equity considered is 14%.

2.5 Tariff for Photovoltaic Systems

2.5.1 System Classification

Based on the basic differences between implementation of megawatt-scale ground-mounted photovoltaic systems, and kilowatt-scale rooftop photovoltaic systems, all photovoltaic systems can be categorized basically into two types for tariff applicability:

Table 2.11: Photovoltaic system classification for tariff applicability.

System Size	System Type	Evacuation Specification	Applicable Tariff
1 kW – 5 kW	Rooftop	230 V, 1 ϕ, 50 Hz	**Kilowatt-scale Photovoltaic Tariff**
5 kW – 100 kW	Rooftop	415 V, 3 ϕ, 50 Hz	
100 kW – 1MW	Rooftop/ Ground-mounted	11 kV, 3 ϕ, 50 Hz	**Megawatt-scale Photovoltaic Tariff**
1 MW – 4 MW	Ground-mounted	11 kV, 3 ϕ, 50 Hz	
> 4 MW	Ground-mounted	66 kV, 3 ϕ, 50 Hz	

2.5.2 Levelized Tariff

The various parameters for determination of tariff for solar photovoltaic power projects can be summarized as below:

Table 2.12: Summary of parameters for photovoltaic power projects.

PARAMETER	VALUE		
Plant Cost			
Capital Cost	Rs.	1100	Lacs per MW for megawatt-scale system
	Rs.	1.3	Lacs per kW for kilowatt-scale system
O&M Cost		0.75%	of Capital Cost
Escalation in O&M Cost		5%	Annually
Inverter Replacement Year		13th	Year
Inverter Cost during Replacement		3.81%	of Capital Cost
Performance Parameters			
Capacity Utilization Factor		18.5%	
Performance Degradation		1%	Annually
Auxiliary Consumption		0.25%	of Energy Generation
Useful Life		25	Years
Financial Parameters			
Debt : Equity Ratio		70 : 30	
Loan Tenure		10	Years
Interest Rate on Loan		12.00%	
Insurance Cost		0.35%	Annually
Interest on Working Capital		11.25%	Annually
Working Capital	Sum of:	1	Month's O&M Expense
		1	Months' Energy Charges at normative CUF
Rate of Depreciation		6%	Annually for the first…
		10	Years
		2%	Annually for the next…
		15	Years
Minimum Alternate Tax Rate		20.008%	Annually for the first…
		10	Years
Corporate Tax Rate		32.445%	Annually
Return on Equity		14%	Annually

Based on the technical and financial inputs considered in this chapter, the levelized tariff including return on equity for megawatt-scale solar photovoltaic power projects availing the accelerated depreciation benefit using a discount rate of 10.74% is calculated to be **₹ 10.27 per kWh**, while the tariff for projects not availing the accelerated depreciation benefit is calculated to be **₹ 10.81 per kWh**.

Similarly, the levelized tariff including the return on equity for a kilowatt-scale solar photovoltaic power projects availing the accelerated depreciation benefit using a discount rate of 10.74% is calculated to be **₹ 12.49 per kWh**, while the tariff for projects not availing the accelerated depreciation benefit is calculated to be **₹ 13.14 per kWh**.

In GERC's last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010, the tariff was determined individually for two sub-periods, which is beneficial to the Developer from a financial standpoint. Similarly, the tariffs for megawatt-scale photovoltaic power plants commissioned between 29 January, 2012 and 31 March, 2013 are divided into two sub-periods as indicated in Table 2.13.

Table 2.13: Levelized tariff for megawatt-scale and kilowatt-scale photovoltaic systems commissioned between 29 January, 2012 and 31 March, 2013.

For megawatt-scale projects			
	Levelized Tariff	**Phased Tariff**	**Period**
With accelerated depreciation benefit	₹ 10.27 per kWh for 25 years	₹ 11.50 per kWh	for the first 12 years
		₹ 6.30 per kWh	for the next 13 years
Without accelerated depreciation benefit	₹ 10.81 per kWh for 25 years	₹ 12.04 per kWh	for the first 12 years
		₹ 6.84 per kWh	for the next 13 years
For kilowatt-scale projects			
	Levelized Tariff	**Phased Tariff**	**Period**
With accelerated depreciation benefit	₹ 12.49 per kWh	(Not Applicable)	for 25 years
Without accelerated depreciation benefit	₹ 13.14 per kWh	(Not Applicable)	for 25 years

2.5.3 Successive Revisions to Tariff

It is the intention of GERC to support the development of a long-term solar industry in Gujarat taking advantage of its enormous solar energy potential, which would accelerate the reduction in solar energy prices both in Gujarat as well as India. However, it may be inappropriate to commit the solar energy tariffs for the long term in view of the dynamically changing prices of solar energy technologies, and the potential economic burden on Consumers in case of deviation or reduction of actual solar energy prices from currently determined project prices.

The global trends in the photovoltaic industry indicate a continual drop in the price of photovoltaic modules of various technologies, and also a steady drop in the price of photovoltaic inverters. Further, the decrease in costs of photovoltaic systems is ensured through widespread industry learning and economies of scale. The Indian market has already seen a steep drop in the cost of solar projects. Based on the trends of various photovoltaic system components, it is expected that the price of solar systems will continue to drop by 7-8% annually in the near term.

Hence, a conservative annual decline in the photovoltaic tariff for both megawatt-scale and kilowatt-scale is considered at 7% decline for 1 April, 2013 to 31 March, 2014, and a further 7% decline for 1 April, 2014 to 31 March, 2015.

:: End of Chapter 2 ::

3. Solar Thermal Power

3.1 Solar Thermal Technologies[8]

Solar thermal technologies attain very high working temperatures by concentrating light through various mechanisms. Hence, solar thermal technologies have traditionally been known as Concentrated Solar Power (CSP). However, as the philosophy of concentrating light is also gaining popularity in solar photovoltaic technologies, it would be appropriate to term these solar thermal technologies used for generating power as Concentrated Solar Thermal (CST).

Sunlight incident on the surface of the earth comprises of two components: (i) direct component, which is seen coming directly from the sun, and (ii) diffused component, which is visible through scattering from the sky. The optics used for concentration of light can effectively concentrate only the direct component of the sunlight. Hence, the Direct Normal Irradiance (DNI) becomes the primary basis for conversion and ultimately output of the solar thermal plant.

The concentration is achieved typically through various reflection methodologies, which define these technologies. There are four primary solar thermal technologies, which in addition to different construction of reflectors, also differ based on reliability, maturity, and economics.

3.1.1 Parabolic Trough Technology

Parabolic trough power plants consist of many parabolic trough collectors, a Heat Transfer Fluid (HTF) system, a steam generation system, a Rankine steam turbine/ generator cycle and optional thermal storage and/or fossil-fired backup systems. The collector field is made up of a large number of single-axis-tracking parabolic trough solar collectors. The solar field is modular in nature and comprises many parallel rows of solar collectors, normally aligned on a north-south horizontal axis. Each solar collector has linear parabolic-shaped mirrors that focus the sun's direct beam radiation on a linear absorber pipe 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 absorber. A heat transfer fluid is heated up as it circulates through the absorber and returns to a steam generator of a conventional steam cycle.

Additionally, a parabolic trough solar thermal plant may also contain a thermal energy storage system and a back-up boiler, which usually working with natural gas. The back-up boiler tends to increase the capacity factor of the system, allowing the plant to operate even when there is not enough direct solar radiation, and sometimes to fit to a demand curve. Introducing one of these systems allows solar thermal power plants to deliver reliable, dispatchable, and stable electrical energy to the grid. Moreover, it improves the use and amortization of the power block.

[8] Natalia Kulichenko and Jens Wirth, "Regulatory and Financial Incentives for Scaling Up Concentrating Solar Power in Developing Countries," Energy and Mining Sector Board Discussion Paper, Paper No. 24, World Bank Group, June 2011.

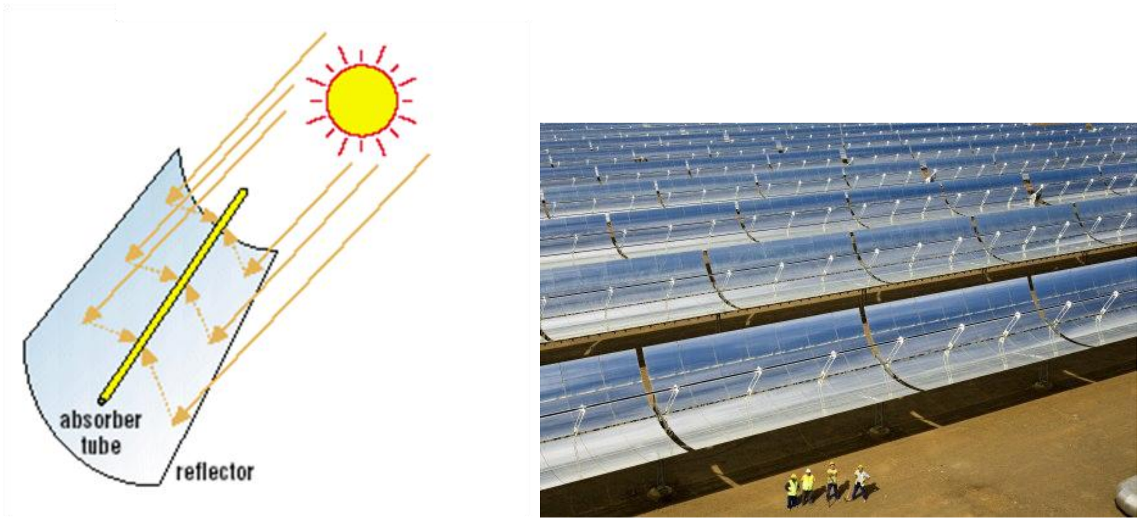

Figure 3.1: Solar parabolic trough (a) concept, and (b) 'Andasol-1,' Spain.

Typical parabolic trough reflectors can achieve a solar concentration of 70-80 Suns. The commercially proven technology is limited to a temperature of around 400°C, after which, in addition to degrading the fluid, thermal losses increase and the selective coatings also may be degraded. Therefore, there are several lines of R&D today directed at studying both working fluids and the rest of the components.

The fluid currently in use in commercial plants is synthetic oil. Synthetic oil's advantages include a much lower vapour pressure than water at the same given temperature, so pressures required in the system are much lower, which allows simpler facility and safety measures. Furthermore, current oils have responded very well to the current needs of commercial plants, as their maximum temperature coincides with the optimum collector operating temperature. Disadvantages include a high price, and a maximum working temperature below 400°C, which limits the power cycle temperature and, therefore, its electrical conversion efficiency.

Molten salt is another alternative HTF. The salt most commonly used in solar applications is nitrate salt with advantages including low corrosion effects on materials used for solar field piping, high thermal stability at high temperatures, low steam pressure making it possible to operate at relatively low pressures in its liquid state and its availability and low cost. The main disadvantage is the high freezing point of the salt, which may range from 120 to 200°C depending on the type used. The freeze-protection strategy is very important in this case, and several different techniques are necessary to maintain the fluid above a certain temperature: constant circulation of salt, auxiliary heating and heat tracing throughout the piping.

While parabolic trough solar thermal plants of capacities more than 50 MW are considered to be at a commercial scale, the optimal size for such plants are considered to be more than 150 MW. Compared to other solar thermal technologies, the parabolic trough technology is the most mature with currently over 1.2 GW of installed capacity worldwide.

3.1.2 Linear Fresnel Technology

Linear Fresnel power plants consist of many Linear Fresnel reflectors, an HTF system, a steam generation system (if not direct steam generating), a Rankine steam turbine/generator cycle and optional thermal storage and/or fossil-fired backup systems.

The main difference between the parabolic trough technology and the Fresnel technology is the reflector configuration. Similar to the parabolic trough, the Fresnel collector is designed as single-axis tracking. Therefore, the Linear Fresnel reflectors concentrate sunlight using long flat-plane mirror strips that are grouped in a mirror field close to the ground. The sunlight is focused onto a linear fixed absorber located above this mirror field and optionally equipped with an additional secondary reflector located above the absorber.

While the Linear Fresnel concept could use an oil heat transfer fluid, the configurations in development are mainly based on direct steam generation, that is, circulating water/steam in the receiver serves as a heat transfer medium. Hence, a separate steam generation system is not required in the case of direct steam generation. Those Fresnel trough systems are currently operating with saturated steam parameters of up to 55 bar/ 270°C, but in the medium and long term, superheated steam generation is proposed. Similar to the parabolic trough system, the Linear Fresnel system can also be operated with HTFs based on molten salt or synthetic oil.

The Linear Fresnel technology may be a lower cost alternative to parabolic trough technology for the production of solar steam for power production. The main advantages, compared to parabolic trough technology, are seen as:

- Inexpensive planar mirror and simple tracking system.
- Fixed absorber tubes with no need for flexible high pressure joints.
- No vacuum technology and no metal-to-glass sealing and thermal expansion bellows for absorber tubes for lower temperature configurations.
- Absorbers tubes similar to troughs likely for higher temperature designs.
- Because of the planarity of the reflector strips and the low construction above ground, wind loads and material usage are substantially reduced.

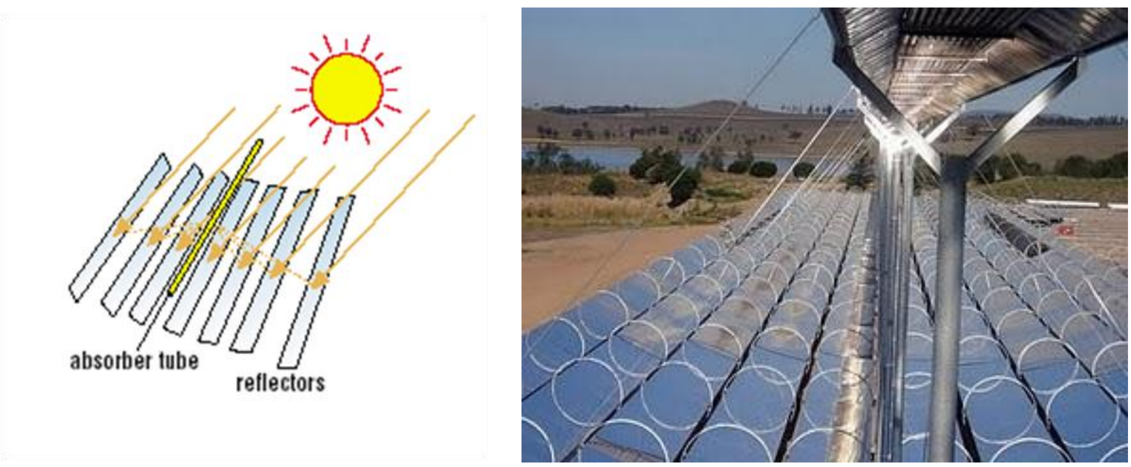

Figure 3.2: Linear Fresnel lens (a) concept, and (b) 'Kimberlina Solar Thermal Energy Plant,' USA.

- Because of direct steam generation within the absorber tubes, no separate steam generator is necessary.
- Efficient use of land.
- Lower maintenance requirements are postulated.

However, there is also a significant drawback related to the LFR technology. LFR systems suffer from a performance drawback because of higher intrinsic optical losses (fixed absorber) compared to parabolic trough systems. Different studies evaluated a reduction in optical efficiency of around 30–40 percent compared to parabolic trough technology, which then must be compensated for by lower total investment costs.

Fresnel technology is still at an early development level compared to other CST technologies like parabolic trough.

3.1.3 Central Receiver

In Central Receiver (Power Tower) power plants, a field of heliostats (large two-axis tracking individual mirrors) is used to concentrate sunlight onto a central receiver mounted at the top of a tower.

Because of the high concentration ratios, high temperatures and hence higher efficiencies can be reached with central receiver systems. Within the receiver, the heat transfer fluid absorbs the highly concentrated radiation reflected by the heliostats and converts it into thermal energy to be used in a conventional power cycle. The central receiver concept can be incorporated with either a Rankine steam turbine cycle or a Brayton gas turbine cycle, depending on the applied HTF and the receiver concept, respectively.

Major investigations during the last 25 years have focused mainly on four plant configurations depending on the applied technology and heat transfer fluid system:

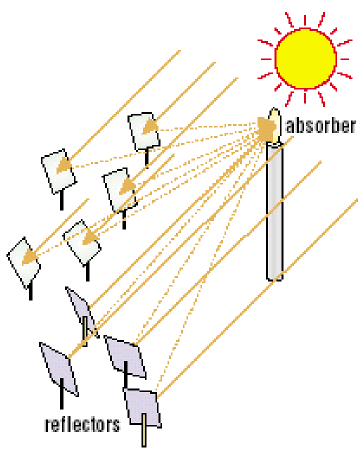

Figure 3.3: Central receiver technology (a) concept, and (b) 'PS20 Tower,' Spain.

- Water/steam solar tower (Rankine cycle)
- Molten salt solar tower (Rankine cycle)
- Atmospheric air solar tower (Rankine cycle)
- Pressurized air solar tower (Brayton cycle)

Water/steam offers the benefit that it can be directly used in a Rankine cycle without further heat exchange. The production of superheated steam in a solar receiver yields higher efficiencies and has been demonstrated in several prototype projects. However, the operational experience has shown some problems related to the control of zones with dissimilar heat transfer coefficients, like evaporators and super-heaters. Difficult to handle were also the start-up and transient operation of the system, leading to local changes of the cooling conditions in the receiver tubes, in particular in the receiver's superheating section.

Molten salt mixtures combine the benefits of being both an excellent heat transfer and a good high temperature energy storage fluid. Because of a very good heat transfer, the applied heat flux at the receiver surface can be higher compared to other central receiver designs, yielding higher receiver efficiencies. As the molten salt can be stored directly at high temperatures, the specific storage costs are the lowest under all CST technologies. This means that molten salt power tower technology, when proven, will be the preferred choice for applications that require a storage component.

Depending on the specific composition, the molten salt liquefies at a temperature between 120°C and 240°C (in the current state of the technology this is the upper end) and can be used in conjunction with metal tubes for temperatures up to 600°C without imposing severe corrosion problems. As discussed earlier with regard to parabolic trough systems, the challenge is to avoid freezing of the salt in any of the valves and piping of the receiver, storage and steam generation system at any time. The operating range of the state-of-the-art molten nitrate salt, a mixture of 60 percent sodium nitrate and 40 percent potassium nitrate, matches the operating temperatures of modern Rankine cycles.

In a molten salt power tower plant, the cold salt (290°C) is pumped from the cold tank to the receiver, where the salt is heated up to 565°C by the concentrated sunlight. This hot salt is then pumped through a steam generator to generate superheated steam that powers a conventional Rankine cycle steam turbine. The solar field is generally sized to collect more power than demanded by the steam generator system and the excess energy can be accumulated in the hot storage tank. With this type of storage system, solar tower power plants can be built with annual capacity factors of up to 70 percent.

Although power towers are commercially less mature than parabolic trough systems, a number of component and experimental systems have been field tested around the world in the last few years, demonstrating the technical feasibility and economic potential of different power tower concepts. Furthermore, the already operating power tower plants have proven their feasibility on an entry-commercial scale at small plant capacities.

3.1.4 Parabolic Dish Technology

The Parabolic Dish Technology, which uses a dish-engine, is unique among the solar thermal systems indirectly heating the working fluid of the power unit rather than an intermediate fluid to produce electricity. Dish-engine systems consist of a mirrored dish that collects and concentrates sunlight onto a receiver mounted at the focal point of the dish. The receiver is integrated into a high-efficiency engine (the Stirling engine is the most commonly used heat engines because of high efficiency). Solar Parabolic Dish-engine systems include two main parts: (i) a large Parabolic Dish, and (ii) a power conversion unit.

The power conversion unit is held at the focal point of the concentrator dish and includes a receiver, as well as a heat engine and generator assembly for converting the collected thermal energy to electricity. Typically, a high-efficiency Stirling engine is used. Individual units range in size from 3 to 25 kW and are self-contained and air-cooled, thus eliminating a cooling water requirement, which is a significant advantage of Dish Stirling systems. At the same time, an inherent issue with these systems is that electrical production ceases immediately upon loss of sun. In that respect, they are similar to solar photovoltaic plants. Currently, no concept for commercial thermal storage has been demonstrated and implemented for dish engine systems.

Compared to the other CST technologies, the main advantages of dish-engine systems are as follows:

- Water usage is limited to operational and maintenance activities (such as mirror washing).
- It has attained efficiencies as high as 30 percent in the testing facility at the Sandia Laboratories.
- Its modularity allows for a range of system sizes, from several megawatts to hundreds of megawatts.
- Central or decentralized operations are possible with the scale between 3 kW and several 100 MW.
- High energy density, lower land use.
- Short construction times.

The main disadvantages of dish-engine systems are higher investment costs, lack of existing storage and hybridization solutions, and a concern about higher operation and maintenance costs because of the large number of the kW-scale engines in a multi-MW installation.

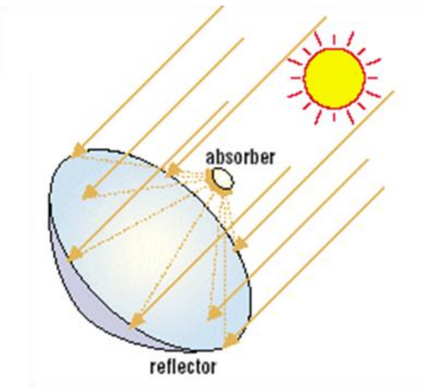

Figure 3.4: Parabolic dish technology (a) concept, and (b) 'Miricopa Solar Plant,' USA.

Table 3.1: Summary of solar thermal power technologies.[9,10]

Parameter	Parabolic Trough	Fresnel Trough	Central Receiver	Parabolic Dish
Plant Size, Envisaged	50-300 MW	30-200 MW	10-200 MW	10 kW-850 MW
Plant Size, Realized	50 MW with 7.5 h storage 80 MW without storage	5 MW	20 MW	1.5 MW
Peak Efficiency	22-25%	16-18%	18-22%	31%
Net Annual Efficiency	12-16%	8-10%	14-16% 20-30% (concepts)	20-30%
Capacity Utilization Factor	25-28% (without storage) 40-43% (7 h storage)	22-24% (without storage)	55% (10 h storage) Larger CUF possible	25-28%
Concentration of Sunlight	70-80 Suns	60 Suns	> 1,000 Suns	> 1,300 Suns
Operating Temperature	150-400°C	150-400°C	300-1,200°C	300-1,500°C
Receiver/ Absorber	Absorber is fixed to tracing collector, complex design	Absorber is fixed	External tube receiver	Multi-receiver system
Storage System	Indirect molten salt storage (380°C)	Short-time pressurized steam storage (<10 min)	Direct molten salt storage (550°C)	No storage currently realized
Hybridization	Yes, indirect	Yes, direct	Yes	Not planned
Power Cycles	Steam Rankine, Organic Rankine	Steam Rankine, Organic Rankine	Steam Rankine, Brayton (gas turbine)	Stirling Engine, Steam Rankine, Brayton (gas turbine)

9 Natalia Kulichenko and Jens Wirth, "Regulatory and Financial Incentives for Scaling Up Concentrating Solar Power in Developing Countries," Energy and Mining Sector Board Discussion Paper, Paper No. 24, World Bank Group, June 2011.

10 "Concentrating Solar Power in India," a report commissioned by the Australian Government and prepared by IT Power, 2011.

Grid Stability	Medium (High can be achieved through hybridization)	Medium	High	Low
Land Requirements (/MW)	6-6.5 acres (without storage) 10-10.5 acres (7 h storage)	4-5 acres (without storage)	12-15 acres (10-12 h storage)	6-7.5 acres (without storage)
Water Requirement	3 L/kWh (wet cooling) 0.3 L/kWh (dry cooling)	3 L/kWh (wet cooling) 0.2 L/kWh (dry cooling)	2.5-3 L/kWh (wet cooling) 0.25 L/kWh (dry cooling)	0.05-0/1 L/kWh (only for mirror washing)
Maturity	Proven	Under demonstration, on verge of commercial viability	Under demonstration, on verge of commercial viability	Under demonstration, on verge of commercial viability
Total Installed Capacity by Q4 of 2010	~1,000 MW	7 MW	10 MW (molten salt) 10 MW (superheated steam) 30 MW (saturated steam)	1.7 MW
Estimated Total Installed Capacity by 2013	3,000-4,000 MW	200-300 MW	600-900 MW	500-1,000 MW
Number of Technology Providers	High (>10)	Medium (3-4)	Medium (2-5)	Medium (4-5)
Technology Development Risk	Low	Medium	Medium	Medium

At the moment, dish-engine systems for large scale applications are considered commercially less mature than other solar power generation systems. A number of component and pilot systems have been field tested around the world in the last 25 years, demonstrating the technical feasibility and the economic potential of the parabolic dish collector for small-scale applications and/ or remote locations.

3.1.5 Hybridization of Technologies

Several hybridization options are available combining solar thermal technologies with conventional fossil fuel systems.

A simple option is to couple fossil-fuel based boilers in parallel to the solar thermal field consisting of parabolic troughs or linear Fresnel assembly. Alternatively, solar thermal-based preheating assembly can be added as a supplement to a big fossil fuel-based power plant to reduce their fuel consumption and gases emission; the annual contribution of solar energy to the net output of the hybrid power plant is typically less than 5%.

3.2 Cost of Solar Thermal Technology

Taking into account the maturity and already commissioned capacity of the parabolic trough technology, most parameters of this technology will be considered for the present Discussion Paper.

3.2.1 Capital Cost

The CERC, in its order dated 26th February, 2010 in suo motu Petition No. 53 of 2010 on *Terms and Conditions for Tariff determination from Renewable Energy Sources* has considered a capital cost of Solar Thermal Technologies at ₹ 15.3 Crores per megawatt. GERC, in its last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has considered a capital cost of ₹ 13 Crores per megawatt. However, these capital costs have been low for Developers considering the large scale, technological uncertainties and hence, perceived risks. Further, there have been a wide range of reports on the capital costs of various solar thermal technologies.

Upon reviewing the current state of technology and associated costs, and in order to support the development of solar thermal technology, a capital cost of ₹ 14.5 Crores per megawatt is considered.

3.2.2 Cost of Land

Taking into account the high capital cost of the solar thermal technology, and a substantially low fraction as the cost of land, the cost of land is considered as a part of the capital cost.

3.2.3 Evacuation Cost

The Solar Power Policy, 2009 of the Government of Gujarat provides that the transmission line from the switchyard of the substation of the megawatt-scale solar power plant to the GETCO substation shall be laid by GETCO. This is further reflected in GERC's last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010.

Hence, evacuation cost is not considered for calculation of solar tariff.

3.2.4 Operation and Maintenance Cost and its Escalation

The operation and maintenance costs of solar thermal power plants are higher than solar photovoltaic power plants. In addition to the cost of operating staff, solar thermal power plants also utilize fuels such as diesel for its auxiliary processes, water for cooling, and heat transfer fluids, which have a limited life.

Hence, the operation and maintenance cost of solar thermal power plants is considered at 1.5% of the capital cost.

Further, the annual escalation of the operation and maintenance cost is considered to be 5%.

3.3 Performance Parameters of Solar Thermal Power Plants

3.3.1 Capacity Utilization Factor

Taking into account the irradiation in the state of Gujarat, a capacity utilization factor of 23% is considered for solar thermal power plants.

3.3.2 Annual Degradation in Performance

Considering the nature of the solar thermal power plants, there are many components which may be subject to degradation. Based on learnings from working solar thermal power plants, the net degradation due to degradation in the heat transfer fluid, reflector assembly, thermal storage system, power block, etc. is in the range of 0.25-0.5% annually.

Hence, the annual degradation in performance of solar thermal power plants considered for this Discussion Paper is 0.25%.

3.3.3 Auxiliary Consumption

GERC, in its last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has considered an auxiliary consumption of solar thermal power plants at 10%. CERC, in its order dated 26th February, 2010 in suo motu Petition No. 53 of 2010 on *Terms and Conditions for Tariff determination from Renewable Energy Sources* also considered an auxiliary consumption of 10%.

Hence, the auxiliary consumption of 10% of the generation of solar thermal power plants is considered.

3.3.4 Useful Life

The useful life for solar thermal power plants is estimated between 20 and 25 years based on the technology. Both GERC, in its last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010, and CERC, in its order dated 26th February, 2010 in suo motu Petition No. 53 of 2010 on *Terms and Conditions for Tariff determination from Renewable Energy Sources* have considered the useful life for solar thermal power plants as 25 years.

Hence, the useful life of solar thermal power plants for discussion is considered as 25 years.

3.4 Finance Related Parameters

3.4.1 Debt-Equity Ratio

The GERC Multi Year Tariff Regulation, 2011, notified by the Commission provides a normative debt-equity ratio of 70:30 for Generating Companies/ Licensees. Further, Clause 5.3 (b) of the Tariff Policy, 2006, notified by the Ministry of Power, GOI, stipulates a debt – equity ratio of 70:30 for financing of power projects. Further, the GERC, in its current Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has stipulated the same debt-equity ratio.

Hence, the debt-equity ratio of 70:30 is considered for financing.

3.12.1 Loan Tenure

The GERC Multi Year Tariff Regulation, 2011, notified by the Commission provides for a loan tenure of 10 years. Further, GERC in its last Solar Tariff Order has stipulated the same loan tenure.

Hence, a loan tenure of 10 years is considered.

3.12.2 Interest Rate on Loan

As explained in 'Section 2.4.3 Interest Rate on Loan,' due to high volatility in the SBI base rate, the current base rate of 10% is further marked up by 200 basis points for consideration as the interest rate on long term loan for solar power projects.

Hence, the interest rate on loan for tariff computation is determined to be 12%.

3.12.3 Insurance Cost

Insurance cost at the rate of 0.35% of the capital cost is considered annually. This insurance cost is as per GERC's last Solar Tariff Order, and is considered over and above the operation and maintenance cost.

3.12.4 Working Capital

GERC, in its last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has considered the following to be included as working capital, which is also considered here:

(i) One month's expense on operation and maintenance expenses, and

(ii) Receivables equivalent to one month's energy charges for sale of electricity calculated on a normative CUF.

3.12.5 Interest Rate on Working Capital

As explained in 'Section 2.4.6 Interest Rate on Working Capital,' the interest rate on working capital is considered to be 75 basis points lower than that on the long-term loan.

Hence, the interest rate on working capital is considered to be 11.25%.

3.12.6 Rate of Depreciation

CERC, in Clause 15 of its Renewable Energy Regulation No. L-7/186(201)/2009-CERC dated 16 September, 2009 indicates that the value base for purpose of depreciation shall be based on the capital cost of the asset; salvage value of the asset shall be considered as 10% and depreciation shall be allowed up to maximum of 90% of the capital cost. Depreciation per annum shall be based on 'Differential Depreciation Approach' over loan tenure and period beyond loan tenure over useful life computed on 'Straight Line Method'. Depreciation shall be chargeable from the first year of commercial operation. Provided that in case of commercial operation of the asset for part of the year, the depreciation shall be charged on *pro rata* basis.

GERC, in its last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010 has considered a high rate of depreciation as a promotional measure during the loan tenure, and then the remaining depreciation is spread over the remaining useful life.

Hence, the depreciation of 6% per annum is considered for the first 10 years, and 2% for the next 15 years.

3.12.7 Return on Equity

GERC has notified Terms and Conditions of Tariff Regulations in which the Return on Equity norms is provided as 14% per annum. GERC has also allowed Income Tax at 20.008% (18.5% MAT + 5% Surcharge + 3% Education Cess) per annum for 10 years, and Corporate Tax at 32.445% per annum from 11th year onwards. Any further enhancement in the RoE will burden the consumers.

Hence, the return on equity considered is 14%.

3.13 Tariff for Solar Thermal Power Plants

3.13.1 Levelized Tariff

The various parameters for determination of tariff for solar thermal power plants can be summarized as follows:

Table 3.2: Summary of parameters for solar thermal power plants.

PARAMETER	VALUE		
Plant Cost			
Capital Cost	Rs.	1450	Lacs per megawatt
O&M Cost		1.5%	of Capital Cost
Escalation in O&M Cost		5%	Annually
Performance Parameters			
Capacity Utilization Factor		23%	
Performance Degradation		0.25%	Annually
Auxiliary Consumption		10%	of Energy Generation
Useful Life		25	Years
Financial Parameters			
Debt : Equity Ratio		70 : 30	
Loan Tenure		10	Years
Interest Rate on Loan		12.00%	

Insurance Cost		0.35%	Annually
Interest on Working Capital		11.25%	Annually
Working Capital	Sum of:	1	Month's O&M Expense
		1	Months' Energy Charges at normative CUF
Rate of Depreciation		6%	Annually for the first…
		10	Years
		2%	Annually for the next…
		15	Years
Minimum Alternate Tax Rate		20.008%	Annually for the first…
		10	Years
Corporate Tax Rate		32.445%	Annually
Return on Equity		14%	Annually

Based on the technical and financial inputs considered in this chapter, the levelized tariff including return on equity for a megawatt-scale solar thermal power plants availing accelerated depreciation benefit using a discount rate of 10.74% is calculated to be **₹ 12.32 per kWh**, while the tariff for such plants not availing the accelerated depreciation benefit is calculated to be **₹ 13.00 per kWh**.

Further, based on GERC's last Solar Tariff Order dated 29 January, 2010 in Order No. 2 of 2010, where the tariff was determined individually for two sub-periods, which is beneficial to the Developer from a financial standpoint. Similarly, the tariffs for solar thermal power plants commissioned between 29 January, 2012 and 31 March, 2015 are divided into two sub-periods as indicated in Table 3.3.

Table 3.3: Levelized tariff for solar thermal power plants commissioned between 29 January, 2012 and 31 March, 2015.

	Levelized Tariff	Phased Tariff	Period
With accelerated depreciation benefit	₹ 12.32 per kWh for 25 years	₹ 14.00 per kWh	for the first 12 years
		₹ 7.00 per kWh	for the next 13 years
Without accelerated depreciation benefit	₹ 13.00 per kWh for 25 years	₹ 14.68 per kWh	for the first 12 years
		₹ 7.68 per kWh	for the next 13 years

3.13.2 Tariff for Variants (Hybrid) in Technology

In case a Developer chooses to develop the system with thermal storage or as a hybrid, the tariff determination for such system could be taken up on case-to-case basis under 'project specific' tariff determination route, if necessary based on petition filed by such Developer.

:: End of Chapter 3 ::

4. Other Considerations

4.12 Plant and Machinery

Solar Power Projects established with only new Plants and Machinery would be eligible for the benefit of tariff determined within the scope of this Discussion Paper.

4.13 Auxiliary Power Supply

The Commission proposed that STU/Distribution Licensee shall provide auxiliary power for the solar generator under kWh to kWh adjustment basis.

4.14 Reactive Energy Charges

The Commission proposes that STU/Distribution Licensee shall provide auxiliary power for the solar generator under kWh to kWh adjustment basis.

4.15 Evacuation Facilities

Interfacing line of appropriate capacity and voltage as per the CEA (Technical Standard for connectivity to the grid) Regulations, 2007 shall be provided by the STU/ Distribution Licensee at their cost. The intending generator shall apply to the STU/ Distribution Licensee concerned well in advance.

Switchyard equipment, metering and protection arrangement and RTUs at generator end shall be provided by the owners of solar generators at their cost. The interconnection voltage at generator switchyard will depend on the quantum of power to be evacuated and as per the connectivity granted by the STU/ Distribution Company in line with the State Grid Code.

The transmission line from the switchyard of generator to the GETCO substation shall be laid by GETCO.

4.16 Transmission/ Wheeling Charge

4.16.1 General

Whenever the power is sold to a Distribution licensee, the generator will supply the power at the interconnection point of the generator-STU i.e. generator bus-bar. Thereafter, the transmission/ wheeling charges will be borne by the distribution licensee.

Regarding transmission /wheeling charges for self use (captive use) or third-party sale, the following is considered:

4.16.2 Wheeling at 66 kV or Above

As per the scope of the current Discussion Paper, this clause will be applicable to solar plants of capacity greater than 4 MW.

For wheeling of power to consumption site at 66 kV voltage level and above, the wheeling of electricity generated from the Solar Power Generators to the desired location(s) within the State shall be allowed on payment of transmission charges and transmission losses applicable to normal Open-Access Consumer.

For wheeling of power to consumption site at a voltage below 66 KV, the wheeling of electricity generated from the solar power Generators to the desired location(s) within the State shall be allowed on payment of transmission charges as applicable to normal open-access customers and transmission and wheeling loss @ 7% of the energy fed into the grid. This loss shall be shared between the transmission and distribution licensees in the ratio of 4:3.

4.16.3 Wheeling at 11 kV or Above and Below 66 kV

As per the scope of the current Discussion Paper, this Clause will be applicable to ground-mounted or rooftop solar plant of capacity between 100 kW and 1 MW, and ground-mounted solar plants of capacity between 1 MW and 4 MW.

The wheeling of power generated by such generators to the desired location(s) within the area of same distribution licensee shall be allowed on payment (in kind) of distribution loss @ 3% of the energy fed in to the grid.

The wheeling of power generated by such generator to the desired location(s) within the State but in the area of a different distribution licensee shall be allowed on payment of transmission charges as applicable to normal Open-Access Customers and transmission and distribution loss @ 10% of the energy fed in to the grid. These losses shall be shared among the transmission licensee and two distribution licensees involved in the ratio of 4:3:3.

4.16.4 Wheeling at 415 V or below

As per the scope of the current Discussion Paper, this clause will be applicable to rooftop solar installations of capacity between 1 kW and 5 kW feeding at 220 V, 1ϕ; and rooftop solar installations of capacity between 5 kW and 100 kW feeding at 415 V, 3ϕ.

No wheeling charges shall apply for wheeling of power generated by such projects, to the desired locations(s), as such projects decrease the transmission and distribution losses for the utility, and increase the efficiency of the grid.

4.16.5 Wheeling at Two or More Locations

If a Solar Power Generator owner desires to wheel electricity to more than two locations, he shall pay ₹ 0.05 per unit on energy fed in the grid to Distribution Company in whose area power is consumed in addition to the abovementioned transmission charges and losses, as applicable.

4.17 Cross-Subsidy Charges

As a promotional measure for solar power, which is still in its nascent stage, no cross-subsidy surcharges would be levied in case of third-party sale. However, normal open-access charges as specified in the Section titled "Transmission/ Wheeling Charges" should be levied from Consumers/ Users.

No banking is allowed in case of third party sale. The energy wheeled is required to be consumed in the same time block. Any unutilized energy is to be considered as sale to the utility and for the same the distribution licensee should pay 85% of the tariff determined by the Commission.

4.18 Applicability of Intra-State ABT

The Intra-state ABT order will not be applicable to solar power generation projects.

4.19 Energy Accounting

Solar based energy generation projects shall be out of the purview of the Intra-State ABT. However, for the purpose of energy accounting, such projects will have to provide ABT compliant meters at the interface points. Interface metering shall conform to the Central Electricity Authority (Installation and Operation Meters) Regulations, 2006. The electricity generated from the Solar Power Generators shall be metered and readings shall be taken jointly by the solar power project Developer with the Gujarat Energy Development Agency (GEDA), Gujarat Energy Transmission Company Ltd. (GETCO) or Distribution Company at the interconnection point of the generator bus-bar with the transmission or distribution system concerned, as the case may be.

In case of solar rooftop power projects, a separate metering system shall be provided at the output terminal of solar roof-top power project to measure gross energy generation from such project.

4.20 Power Purchase Agreement

The term of the power purchase agreement that the solar Developer signs with the Distribution Licensee will be 25 years. The distribution licensee will sign the PPA at the earliest from the date of submission of the application with all relevant details by the solar generators and get it approved from the Commission.

4.21 Sharing of Clean Development Mechanism (CDM) Benefit

The sharing of CDM benefits as per the recommendation made by the Working Group for Renewable Energy Generation constituted by the Forum of Regulators and as per the CERC, in Clause 21 of its Renewable Energy Regulation No. L-7/186(201)/2009-CERC dated 16 September, 2009:

"100% of the gross proceeds on account of CDM benefit to be retained by the project Developer in the first year after the date of commercial operation of the generating station. In the second year, the share of the Beneficiaries shall be 10% which shall be progressively increased by 10% every year till it reaches 50%, whereafter the proceeds shall be shared in equal proportion, by the Generating Company and the Beneficiaries."

This order for sharing of CDM benefit may be retained for solar projects in Gujarat.

4.22 Control Period

The control period proposed for the solar energy tariff order is from 29 January, 2012 to 31 March, 2015.

It is already mentioned that the tariff for procurement of solar photovoltaic power will be revised year-on-year during this control period.

For solar thermal technologies, considering the lead time of such power projects, the tariff will be constant during the control period.

4.23 Non-Applicability of Merit Order

Considering the nature of solar energy, all solar energy power plants will be considered as 'must-run' facilities, and the power generated from such power plants will be kept out from the merit order dispatch principles.

[Dr. Ketan Shukla]
Secretary
GERC

Place: Ahmedabad
Date: 01/11/2011

:: End of Chapter 4 ::