Potential site identification in selected states & a brief note on Government (State/Centre) Policies for Grid connected Solar PV projects

Prepared for

Rattha Infrastructures (Pvt) Ltd., Chennai

Project Report No. 2010RT05

The Energy and Resources Institute

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Executive summary

With the announcement of **Jawaharlal Nehru National Solar Mission,** the Government of India has planned to add about 20,000MW of electricity generation capacity from solar energy by 2022. The mission envisages to ramp up capacity of grid connected solar power generation to 1000 MW with in three years- by 2013, an additional 3000 MW by 2017 through the mandatory use of renewable purchase obligation by utilities backed with preferential tariff. It has put a thrust in the solar energy sector and a lot of developers have shown the interest in solar plant development.

This report is prepared for M/s Rattha Infrastructure Pvt. Ltd. The company is keen to go to solar power generation using PV modules. They intended to do this on MW scale in few of the states. First chapter of the report deals with the solar energy potential in the country. The second chapter provides a brief of various solar PV technologies which are in existence for the MW scale solar power plant development. The third chapter focuses on districts in the selected states which are having very good solar energy potential. An estimation of Global solar radiation on the horizontal surface is presented in this chapter for the selected districts. Detailed monthly variations of climatic paremetrs are presented in the appendix section of the report. Chapter four talks about Solar mission, Electricity act 2003 and the CERC guidelines for tariff of solar PV plants. A comparison of central and states government polices for solar PV plants are presented in the same chapter which gives a bird eye view.

2 Potential site identification in selected states & a brief note on Government (State/Centre) Policies for Grid connected Solar PV projects

CHAPTER 1 Solar radiation potential in India

India is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun while its equivalent energy potential is about 6,000 million GWh of energy per year. In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The annual global radiation varies from 1600 to 2200 kWh/m², which is comparable with radiation received in the tropical and sub-tropical regions. Rajasthan, Gujarat, Maharastra, Andhra Pradesh etc. states are located in the best sunny regions of the country. Figure 1.1 presents solar radiation map of India.

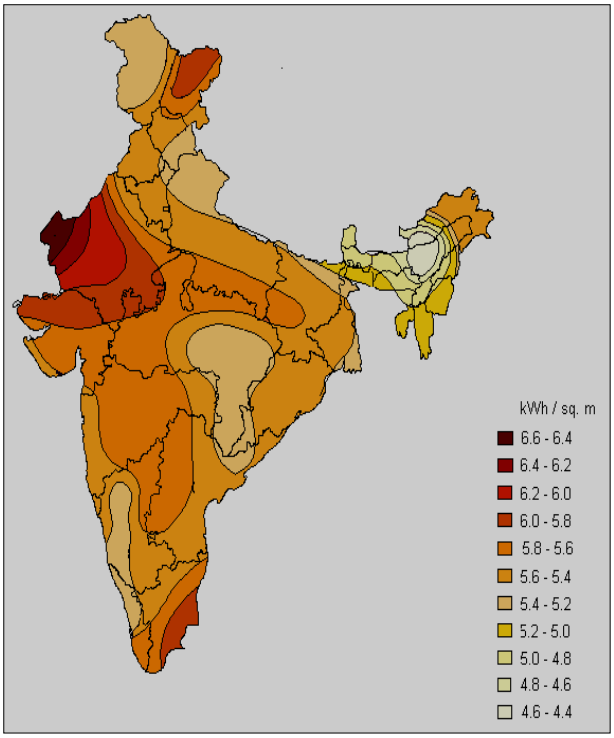


Figure 1.1 Solar radiation map of India

From the above figure, it is clear that Rajasthan and Gujarat are having very good potential in solar with daily radiation falling in the range of 6.4 -6.6 kwh/m² where as Madhya Pradesh, Maharashtra, Andhra Pradesh, some part of Karnataka are also having fairly good potential with daily solar radiation falling in the range of 5.6-5.8 kwh/m² . Closely analyzing the solar map of India, it can be traced that Tamilnadu is also having some potential areas for solar power generation.

CHAPTER 2 Solar PV technologies

Solar Photovoltaic (SPV) technology is primarily a solid-state semiconductor- based technology, which converts a fraction of the incident solar radiation (photons) in to direct electricity. PV system can deliver electric energy to a specific appliance and/or to the electric grid. Photovoltaic systems are flexible and modular; hence the technology can be implemented on virtually any scale size, connected to the electricity network or used as stand-alone or off grid systems, easily complementing other energy sources.

PV offers several advantages viz. (i) complementary to other energy resources; both conventional and renewable, (ii) flexibility towards implementation and (iii) environmental advantages.

Photovoltaic production has been doubling every two years, increasing by an average of 48 percent each year since 2002, making it the world's fastest-growing energy technology. At the end of 2007, according to preliminary data, cumulative global production was 12,400 MW. Roughly 90% of this generating capacity consists of grid0tied electrical systems. At the end of 2007, the cumulative global production of solar PV systems was 12,400 megawatts. Roughly 90% of this generating capacity consists of grid-tied electrical systems. Such installations may be ground-mounted or building integrated.

Grid-connected solar photovoltaic (PV) continues to be the fastest-growing power generation technology in the world, with 50 percent annual increases in cumulative installed capacity in both 2006 and 2007, to an estimated 7.8 GW by the end of 2007. This capacity translates into an estimated 1.5 million homes with rooftop solar PV feeding into the grid worldwide. Germany accounted for half the global market in 2006, with on the order of 850–1,000 GW added. Grid-connected solar PV increased by about 300 MW in Japan, 100 MW in the United States, and 100 MW in Spain in 2006. The solar PV industry produced 2.5 GW in 2006, up 40 percent from 1.8 GW in 2005. Production was expected to reach 3.5–3.8 GW in 2007.

Solar PV system

A PV system essentially consists of modules (array of solar cells generating the electricity) and a balance of system (BoS) including the cabling, battery, charge controller and DC/AC inverter, as well as other components and support.

Most of the systems are in flat-plate (having a fixed orientation) variety but these might be use sun-tracking (single

or double axis) concentrators in order to achieve high radiation on a small area and hence higher efficiency. The storage system (batteries) is not required in grid connected SPV systems.

Solar PV module is the smallest PV unit that can be used to generate substantial amounts of PV power. Although individual PV cells produce only small amounts of electricity, PV modules are manufactured with varying electrical outputs ranging from a few watts to more than 100 watts of direct current (DC) electricity. The modules can be connected into PV arrays for powering a wide variety of electrical equipment. The system components of SPV Water Pumping System are:

- PV Array
- Battery Bank
- Interface Electronics
- Connecting Cables & Switches
- Support Structure & Tracking System
- Charge Controller Unit
- Electrical loads, such as fans, lights, TV, etc.

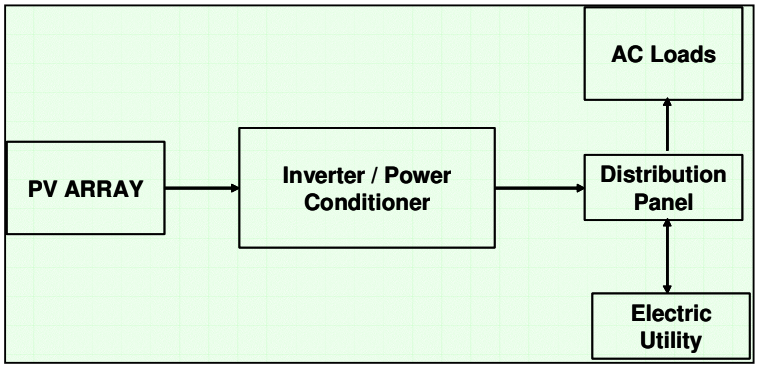


Figure 2.1 Schematic of grid-connected photovoltaic system

In every configuration all these components are not used. Components used depend upon the type of configuration, which in other way depend upon the application. For example: Storage battery is not used in case of direct coupled PV system and inverter is not used for DC load.

CHAPTER 3 Solar potential areas in selected states

Solar PV technologies are more concerned on the global solar radiation. Although crystalline technology can not work with diffuse solar radiation where as the thin film technology is able to generate power with diffuse radiation too, which favours them in the areas of more diffuse radiation or for building integration where they can be oriented in any direction to keep the aesthetic look. Solar radiation over few of the states is very good but a macro level study is required to identify the districts. A broad identification of some of the districts is done based on the solar radiation map and geographical conditions. NASA solar radiation data has been used for this purpose.

Following table gives a bird eye view of different districts which are having very good potential of solar radiation.

Table 3.1 Solar potential in selected state

State	District	Latitude ˚N	Longitude ˚E	Annual Solar Insolation on Horizontal surface kWh/m^2/year
Rajasthan	Jodhpur	26.3	73.0	2169.4
	Jaisalmer	26.9	70.9	1882.8
	Barmer	25.8	71.4	1861.8
	Bikaner	28.0	73.3	1810.4
Gujarat	Surendra Nagar	22.7	71.7	1960.0
	Bhuj	23.3	69.7	1918.4
	Patan	23.9	72.0	1905.3
	Palanpur	24.2	72.4	1898.4
	Banaskantha	23.3	71.0	1883.4
Maharashtra	Sholapur	17.7	75.9	2204.5
	Kolhapur	16.7	74.2	1889.7
Andhra Pradesh	Anantpur	14.7	77.6	1947.8
	Mahbubnagar	16.8	77.9	1930.9
	Kurnool	15.8	78.1	1897.0
Karnataka	Bijapur	16.8	75.7	1971.1
	Bagalkot	16.1	75.5	1960.1
	Belgaum	15.9	74.5	1863.0
Tamilnadu	Karur	11.0	77.3	1868.8
	Tiruvur	18.1	80.6	1850.6
	Dindigul	10.4	78.0	1836.6
Punjab	Ludhiyana	30.9	75.8	1918.0
	Bhatinda	30.2	75.0	1903.8
	Jalandhar	31.3	75.6	1899.4

It can be observed from the above table, that Jodhpur districts in Rajasthan is having the best potential for solar in India. Baap, and Bhadla districts were identified for harness this potential. One of the beauties of these villages is that there are a lot of barren land is available and the population is also very sparse. The other beauty is that most of the land is available with the government. These factors favours for the solar power development in these areas.

Of course, the solar PV plants are not located on the horizontal plane, but they are fixed at a certain inclination (mostly at the latitude of place) so as to get the maximum benefit from them or they can be kept with tracking mechanism. Hence the solar radiation which will be falling on the plane of solar PV panel will be 10- 30% more (depending on the tracking mechanism and orientation) than what is presented in the table. But a clear decision for the selection of the location can be made based on the solar radiation falling on the horizontal surface.

A detailed table consisting of the Monthly average of daily values for air temperature, solar radiation, and relative humidity for the above districts is presented in the appendix.

CHAPTER 4 Policy and regulatory status for solar power plant development in India

In India the government is very much focused towards the development of renewable energy projects. Among all renewable sources, the wind power development has been achieved at very good level. Now the focus is to tap the solar energy through the development of large scale solar grid connected power plants. It is also proposed to develop off-grid solar power systems for rural electrification and for heating purpose. In this regard Ministry of New and Renewable Energy (MNRE) has developed and released the Jawaharlal Nehru National Solar Mission (JNNSM) with a target of adding initial 1,000 MW grid interactive solar power plants by the year 2013 and total of 20,000 MW by 2022.

To achieve this target ministry has formulated supporting policies and regulations for the development of solar power projects like the generation based incentives (GBI), income tax benefits, regulation for renewable purchase obligations and so on. The description of these central government policies and also the state government policies for the states of Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, Tamilnadu, Karnataka and Punjab are given in the following paragraphs.

Central Government policies

Electricity Act 2003

The Electricity Act 2003 imposed an obligation on the regulator towards promoting renewable energy. The section 86(e) clause 1 of the Electricity Act 2003, as one of the functions of the state regulatory commission, read as "to promote co-generation and generation of electricity through renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any persons, and also specify, for purchase of electricity from such sources, a percentage of total consumption of electricity in the area of a distribution licensee". The state regulator hence plays an active role in development of renewable energy across states by creating a portfolio for renewable energy purchase as well as by pricing of energy generated from them. The tariff orders, which are the outcome of such regulation, state the wheeling charges, banking provisions, third part sales, grid interconnection requirements etc, in addition to purchase price for different renewable energy projects including wind energy

Renewable Energy Policy

MNRE has formulated a draft comprehensive renewable energy policy. The objectives of the policy are:

- Minimum energy needs to be met from renewables
- Decentralized energy options for agriculture, commercial, residential and industry using renewables

The policy also aims at enhancing public private partnerships, private investments as well as FDI also including fiscal and financial incentives. Simplification of procedures, technology up gradation, new technologies and export promotion are some of the features. Incentives include tax holidays, 80% depreciation benefits for first year of installation of the projects, custom duty concessions, excise duty reduction, exemption from central sales tax/octroi etc and financial assistance and soft loans.

Indian Renewable Energy Development Agency (IREDA) provides the financing for renewable energy projects. Apart from these there are various other financing agencies and private sector banks which are involved in the financing of renewable energy projects.

Generation Based Incentives

MNRE is actively promoting the establishment of grid connected solar power plants of large capacity (MW scale) by providing GBI for the first time. The policy has been released in the January 2008 for Solar PV power plants and in March 2008 for solar thermal power plants. The purpose is to develop and demonstrate the technical performance of grid-interactive solar power generation so as to bring down the cost of the grid connected solar systems. The silent features of the incentive schemes are as following;

- MNRE will provide, via IREDA, GBI of maximum Rs 12 per kWh for Solar Photovoltaic electricity and Rs.10 per kWh for Solar Thermal Power electricity if fed to the grid from a grid interactive solar power plant of a capacity of 1 MW and above. This incentive will be given to the eligible projects which are successfully commissioned by 31st December 2009. This will be done after taking into account the power purchase rate (per kWh) provided by the SERC (State Electricity Regulatory Commission) or a utility for that project.
- Any project that is commissioned beyond the above date would be eligible for a maximum with a 5% reduction and ceiling of Rs 11.40 per kWh.
- Further the incentive will continue to decrease, as and when the utility signs a PPA (power purchase agreement) for power purchase at a higher level. The proposed annual escalations agreed with the utility, as in force, should be reflected in the PPA.

- The incentive approved for a project may be available for a maximum period of 10 years from the date of approval and regular power generation from the project. This will be subjected to the condition that the utility under consideration continuously purchase power from the grid-interactive power plant.

Solar Mission

The objective of the National Solar Mission (NSM) is to create conditions, through rapid scale up of utility – scale solar power capacity and technological innovation to drive down costs towards grid parity by 2022 and parity with coal based thermal power by 2030.

NSM has a 3 phase approach to achieve its objectives i.e. Phase 1 (2010-2013), Phase 2 (2013-17) and Phase 3 (2017-2022). The first phase will focus on capturing of the low hanging options in solar thermal and on promoting off grid system; the second phase will be aggressively ramped up to create conditions for up scaled solar energy penetration in the country.

NSM targets

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

Proposed roadmap

As far as utility – scale, large solar power generation is concerned; the deployment targets are as follows:

Application segment	Target for Phase 1 (2010–13)	Target for Phase 2 (2013–17)	Target for Phase 3 (2017–22)
Utility grid power, including roof top	1,000–2000 MW	4000–10,000 MW	20000 MW

CERC guidelines for determination of tariff for renewable energy systems

The Central Electricity Regulatory Commission issued the terms and conditions for tariff determination from renewable energy sources, Regulations 2009 on 16 September 2009. Under these regulations the CERC specified the conditions for the determination of the tariff for renewable energy projects. The control period is specified as 3 years and the first year will be till 31-03-2010. The revision in the regulations for next control period shall be taken at least 6 month prior to the end of first control period. On 24 April 2010 CERC issued the order in the matter of determination of generic levelised generation tariff under Regulation 8 of the Central Electricity Regulatory Commission (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2009 and Central Electricity Regulatory Commission (Terms and Conditions for Tariff determination from Renewable Energy Sources) (First Amendment) Regulations, 2010. The control period for SPV power plant tariff would be till 31 March 2012 and for solar thermal power plant will be till 31 March 2013.

The main parameters defined under these regulations for the solar power projects are as follows

1. The tariff period will be of 25 years for both the SPV as well as solar thermal power plants and will be single part tariff.
2. The solar power projects shall not be subjected to merit order dispatch principles, these shall be treated as must run power plants.
3. The debt equity ratio shall be 70:30
4. Loan tenure shall be 10 years
5. Annual interest rate on loan is considered to be 13.39%
6. Depreciation shall be allowed up to maximum of 90% of the capital cost
7. Useful life of the project shall be 25 year
8. Depreciation rate shall be 7% per annum for the first year and the remaining depreciation shall be spread over the remaining useful life of the project from the 11th year
9. The return on equity shall be pre-tax 19% per annum for the first 10 years and pre-tax 24% per annum for the 11th year onwards
10. Rate of corporate income tax is equal to 33.99%
11. Rate of Minimum Alternate Tax (MAT) is equal to 16.995%
12. The proceeds of carbon credit from approved CDM project shall be shared between the generating company and the beneficiaries in the following manner

a. 100% of the gross proceeds on account of CDM to be retained by the project developer in the first year after the date of commercial operation of the generating station.
b. 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%, where after the proceeds shall be shared in equal proportion, by the generating company and the beneficiaries."

Considerations for SPV power plants

- Capital cost of Rs 1690 lakh per MW for SPV power plants for financial year 2010-11 is considered which include the cost of plant machinery, civil work, erection and commissioning, financing and interest during construction and evacuation infrastructure up to the inter-connection point.
- Operation and maintenance cost shall be Rs 9.51 lakh per MW per year for the financial year 2010-11. This shall be escalated at the rate of 5.72% per annum over the tariff period to compute the levelised tariff.
- The capacity utilization factor of 19% is to be considered

Considerations for solar thermal power plants

- Capital cost of Rs. 1530 lakh per MW for SPV power plants for financial year 2010-11 is considered which include the cost of plant machinery, civil work, erection and commissioning, financing and interest during construction and evacuation infrastructure up to the inter-connection point.
- Operation and maintenance cost shall be Rs 13.0 lakh per MW for the financial year, i.e. 2010–11. This shall be escalated at the rate of 5.72% per annum over the tariff period to compute the levelised tariff.
- The capacity utilization factor of 23% is to be considered
- Auxiliary consumption factor shall be 10%

The CERC as per its mandate based on the above regulation came out with the determination of levelised tariff for the renewable energy projects. The tariff determined for the SPV and solar thermal power projects are as follows.

Table 4.1 Levelised tariff for solar power plants

Solar power technology	Levelised total tariff	Benefit of accelerated depreciation, if availed	Net levelised tariff upon adjusting for accelerated depreciation benefit (if availed)
	Rs/kWh	Rs/kWh	Rs/kWh
Solar PV power plant	17.91	2.96	14.95
Solar Thermal Power Plant	15.31	2.46	12.85

Above tariff will be applicable for the year 2010-11 and 2011-12 for SPV power projects and for the year 2010-11, 2011-12 and 1012-13 for the solar thermal power projects. The regulations issued by the CERC are being considered at some level by the State electricity regulatory commissions as reference for their specific tariff determination for the solar power projects but not completely accepted as it is. States Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, Tamilnadu, Karnataka and Punjab have their own regulations and tariff declared. The description of the Renewable purchase obligations, and the tariff for solar PV and thermal power plants are given below (Tables 4.2a and 4.2b).

Table 4.2a Solar policies in different states

Description	Gujarat	Rajasthan	Maharashtra	Andhra Pradesh
Tariff order date	Jan 29th, 2010	Order dated April 02nd, 2008 and amendment order dated Dec 23rd, 2009	May 08th, 2009	Sept 29th, 2008
Tariff period	25 Years	10 Years	10 Years	10 Years
Control Period	Up to Dec 31st, 2011	-	-	-
Tariff (Rs/kWh)	Year SPV* Solar Thermal 1-12 15.0 11.0 13-25 5.0 4.0 **The above tariffs take into account the benefit of accelerated depreciation under the Income Tax Act and Rules. For a project that does not get such benefit, the Commission would, on a petition in that respect, determine a separate tariff taking into account all the relevant facts*	Total tariff inclusive of generation based incentives Up to SPV Solar Thermal Dec 31st, 2009 15.78 13.78 Dec 31st, 2010 15.18 13.18 Tariff applicable for 10 years only but the PPA can be executed for 20 year or life term.	Tariff applicable to plants commissioned up to Mar 31st, 2010 and comes under GBI scheme. Tariffs for plants under GBI scheme is Rs 3 each for SPV as well as Solar thermal. Maximum incentives to the project developer are Rs 15 for SPV and Rs 13 for solar thermal power plants. This includes the GBI given by MNRE plus the Rs 3.0 per kWh from the distribution licensee who will purchase the power. For projects not coming under GBI the tariff would be determined through competitive bidding process.	At Rs. 7/kWh which is the highest power purchase cost approved by the Commission for FY 2008-09 in its Tariff Order for Retail Supply escalated by the wholesale price index on annual basis for next 10 years .This tariff shall be applicable only to the extent of the capacity eligible for incentives under the scheme of MNRE ;
RPO % (Total for all renewables)	For year 2010-11 Minimum 5% of total energy consumption (4.5% wind, 0.25% Solar, 0.25% Others) For year 2011-12 Minimum 6% of total energy	For the year 2010-11, 8.5 % and For the year 2011-12, 9.5%	Minimum 6% of total energy consumption	Minimum 5% of total consumption per annum. Applicable for the period from 2008-09 to 2013-14

Description	Gujarat	Rajasthan	Maharashtra	Andhra Pradesh
	consumption (5% wind, 0. 5% Solar, 0.5% Others)			
Subsidy/Incentive by state government	Tariff is estimated based on accelerated depreciation benefit is considered	As per the GoI Policy	As per the GoI schemes	As per the GoI schemes
Sharing of CDM benefits	1st year 100% to developer 2nd year 10% to beneficiaries and to be increased 10@ per annum up to 50%. Thereafter to be shared on equal basis	To be shared in the ratio of 75:25 by the power producer and beneficiary	No specifications	Shared in the ratio of 90:10 by the power producer and beneficiary
Security deposits	Rs 50.0 lakh per MW at the time of signing of PPA with distribution licensee	Rs 5.0 lakh per MW	-	-
Wheeling charges	For drawl at >66kV line the transmission charges and losses as applicable to open access consumers and for power drawl below 66 kV line 10% (including transmission losses) +Transmission charges as applicable to open access	Transmission charges foe RE systems shall be 50% of the charges specified for others (open access consumers), Loss charges @4.4% to 8% depending upon the voltage at which power is consumed	Depending on the feeding point and the drawl point (taken as 9% wheeling losses +0.25 Rs per unit for 11kV HT Line)	Wheeling and transmission@5% of the energy wheeled
Other issues	-	Solar power projects with installed capacity up to 50 MW does not have to give ant free power to the state but the projects with capacity higher than 50 MW have to give free electricity to state as per the percentage specified by the government in the order.	-	-

Table 4.2b Solar policies in different states

Description	Karnataka	Tamilnadu	Punjab
Tariff order date	Nov 26th, 2008	July 11th, 2008	Dec 13th, 2007
Tariff period	10 years	10 years	-
Control Period	-	-	-
Tariff (Rs/kWh)	Based on Order for determination of tariff for solar power projects released on 26 Nov 2008. Tariff will be Rs 3.40/kWh for both SPV and solar thermal power plants. The tariff will be applicable for the plants which will get incentive of Rs 12/unit for SPV and Rs 10 per unit for solar thermal power plants from IREDA as per MNRE policy.	Rate for procurement of power by DISCOM is For SPV Rs 3.15/kWh and for solar thermal Rs 3.15/kWh. Maximum incentive of Rs 12/kWh for SPV and Rs 10/kWh for solar thermal power projects is admissible for projects commissioned up to Dec 31st, 2009.	Rs.7.00/unit (with base year 2006-07) with five annual escalations @ 5% up to 2011-12.
RPO % (Total for all renewables)	Minimum 5% of total energy consumption	Minimum 14% of total energy consumption in year 2010-11	Minimum percentage of purchase from renewable sources will be 3% for year 2010-11
Subsidy/Incentive by state government	As per GoI scheme	As per GoI scheme	-
Sharing of CDM benefits	100% of gross proceeds on account of CDM benefit are to be retained by project developer in the first year after the date of commercial operation of the generating station, b) In the second year, the share of beneficiaries shall be 10% which shall be progressively increased by 10% every year till it – reaches 50%, where after, the proceeds shall be shared in equal proportion by the generating companies and the beneficiaries.	Not specified	-
-Security deposits	-	-	-
Wheeling charges	5% including transmission charges	5% including transmission charges	2%

Source: orders and policies declared by state energy regulatory commissions and the state's renewable energy development agencies.

The details given above are based on the latest available orders and policies from the state electricity regulatory commissions and the state's renewable energy development agencies. Most of the states except Rajasthan and Gujarat the solar power tariff is declared for the capacity and period as mentioned in the MNRE's GBI policy.

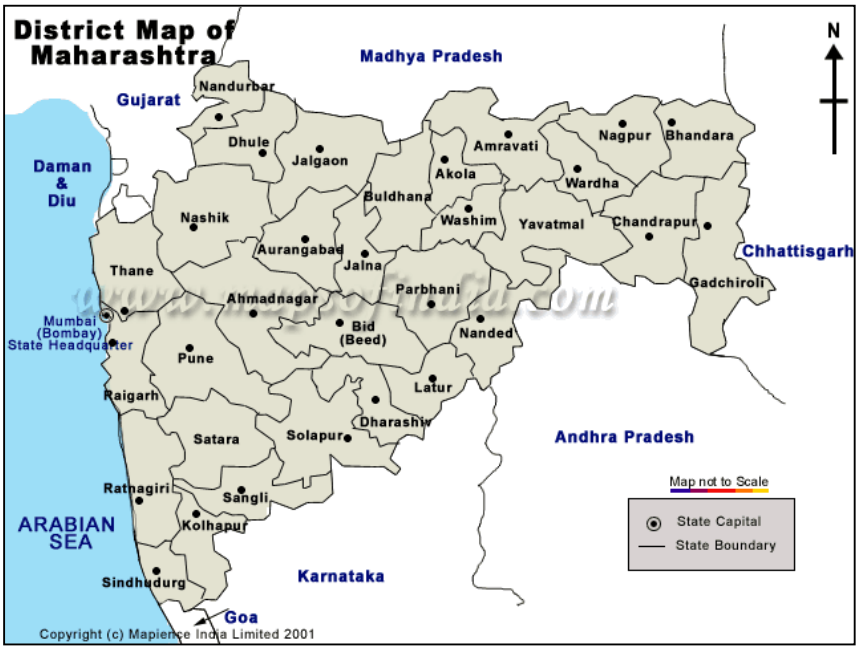
Appendix I: Monthly average daily values of climatic parameters

State	District	Parameter	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rajasthan	Jodhpur	Air temperature	°C	16.7	18.9	24.2	29.2	33.3	33.9	31.4	29.4	29.2	26.7	22.0	18.1	26.1
		Relative humidity	%	36.0%	33.0%	25.0%	23.0%	30.0%	45.0%	60.0%	67.0%	57.0%	32.0%	29.0%	36.0%	39.5%
		Solar Radiation-Hor	kWh/m²/d	4.64	5.45	6.48	7.29	7.57	7.20	5.97	5.64	6.05	5.78	4.90	4.36	5.94
	Jaisalmer	Air temperature	°C	16.3	18.8	24.6	29.0	31.8	31.9	30.6	29.5	29.4	27.8	22.9	18.2	25.9
		Relative humidity	%	34.5%	29.6%	25.0%	29.1%	37.9%	51.7%	63.7%	66.4%	53.4%	31.9%	27.1%	31.0%	40.2%
		Solar Radiation-Hor	kWh/m²/d	3.53	4.31	5.27	6.27	6.77	6.78	6.01	5.68	5.42	4.71	3.81	3.31	5.16
	Barmer	Air temperature	°C	18.0	20.2	25.8	29.7	31.8	31.2	29.6	28.8	29.1	28.2	24.0	19.8	26.4
		Relative humidity	%	33.9%	29.2%	24.6%	29.6%	39.4%	55.8%	67.7%	68.9%	55.5%	34.5%	27.3%	31.3%	41.6%
		Solar Radiation-Hor	kWh/m²/d	3.68	4.43	5.39	6.26	6.68	6.53	5.47	5.15	5.33	4.79	4.00	3.49	5.10
	Bikaner	Air temperature	°C	14.5	17.8	24.1	30.2	35.0	35.2	32.6	31.4	30.9	27.4	21.2	15.6	26.4
		Relative humidity	%	53.5%	45.5%	37.4%	28.1%	27.6%	40.7%	58.9%	63.2%	52.7%	41.6%	43.4%	51.4%	45.4%
		Solar Radiation-Hor	kWh/m²/d	3.20	3.96	5.01	6.11	6.68	6.64	5.96	5.53	5.21	4.48	3.61	3.09	4.96
Gujarat	Surendra Nagar	Air temperature	°C	23.1	24.9	29.2	31.4	31.7	30.0	28.1	27.7	28.7	29.9	27.6	24.3	28.1
		Relative humidity	%	33.0%	29.8%	28.8%	34.5%	46.6%	64.6%	76.3%	74.2%	62.3%	41.4%	30.3%	32.2%	46.3%
		Solar Radiation-Hor	kWh/m²/d	4.49	5.29	6.17	6.80	6.86	5.94	4.80	4.61	5.33	5.30	4.67	4.21	5.37
	Bhuj	Air temperature	°C	17.4	21.2	26.2	29.9	31.9	32.2	30.1	29.0	29.1	28.6	23.7	18.8	26.5
		Relative humidity	%	60.5%	56.2%	55.5%	54.7%	60.7%	65.8%	74.6%	74.8%	71.4%	58.5%	54.0%	56.5%	62.0%
		Solar Radiation-Hor	kWh/m²/d	4.12	4.85	5.68	6.50	6.67	6.31	5.26	5.01	5.39	5.08	4.34	3.87	5.26
	Patan	Air temperature	°C	21.1	23.3	28.3	31.4	32.3	30.4	28.1	27.7	28.6	28.8	25.9	22.4	27.4
		Relative humidity	%	34.3%	29.6%	25.5%	29.6%	40.8%	61.4%	75.2%	73.7%	60.8%	39.7%	29.7%	33.0%	44.4%
		Solar Radiation-Hor	kWh/m²/d	4.5	5.12	5.96	6.41	6.59	5.93	4.73	4.49	5.14	5.12	4.55	4.15	5.22
	Palanpur	Air temperature	°C	19.5	21.7	27.0	30.6	31.8	30.4	28.3	27.6	28.3	28.0	24.6	20.9	26.6
		Relative humidity	%	34.8%	29.9%	25.1%	29.5%	40.6%	59.9%	73.5%	73.6%	60.0%	38.2%	29.4%	33.4%	44.1%
		Solar Radiation-Hor	kWh/m²/d	4.10	4.84	5.77	6.44	6.75	6.32	4.91	4.65	5.32	5.07	4.37	3.89	5.20
	Banaskantha	Air temperature	°C	21.9	24	28.7	31.4	32.1	30.7	28.7	28.4	29.4	30	27.1	23.4	28
		Relative humidity	%	33.0%	29.3%	27.2%	32.6%	43.8%	61.0%	73.0%	71.2%	58.4%	38.4%	28.6%	31.4%	44.0%
		Solar Radiation-Hor	kWh/m²/d	4.2	4.81	5.67	6.36	6.68	6.17	5.05	4.8	5.19	4.87	4.23	3.92	5.16
Maharastra	Sholapur	Air temperature	°C	23.1	25.6	28.9	32.0	32.8	28.9	27.0	26.7	26.7	26.7	23.9	22.2	27.0
		Relative humidity	%	37.0%	30.0%	25.0%	28.0%	33.0%	61.0%	69.0%	67.0%	65.0%	49.0%	41.0%	39.0%	45.4%
		Solar Radiation-Hor	kWh/m²/d	5.81	6.39	7.22	7.33	7.44	5.69	4.64	5.00	5.22	6.03	6.17	5.58	6.04
	Kolhapur	Air temperature	°C	24.6	26.5	29.1	29.7	28.2	24.9	23.9	23.5	24.0	25.6	25.6	24.2	25.8
		Relative humidity	%	41.6%	36.5%	36.5%	43.0%	57.9%	81.0%	85.5%	85.2%	78.9%	62.5%	46.3%	43.8%	58.4%
		Solar Radiation-Hor	kWh/m²/d	5.15	5.88	6.51	6.78	6.39	4.34	3.73	3.81	4.77	5.03	4.99	4.82	5.18

State	District	Parameter	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Andhra Pradesh	Anantpur	Air temperature	°C	24.4	27.3	30.7	32.7	33.0	30.0	28.5	27.9	28.1	26.9	25.3	23.8	28.2
		Relative humidity	%	57.3%	47.0%	39.9%	41.5%	46.5%	58.7%	63.4%	66.4%	66.8%	71.7%	68.2%	65.5%	57.8%
		Solar Radiation-Hor	kWh/m²/d	5.08	5.93	6.46	6.57	6.24	5.21	4.74	4.78	5.09	4.75	4.63	4.62	5.34
	Mahbubnagar	Air temperature	°C	24.3	27.2	30.7	31.1	31.7	28	26.9	26.7	27.2	26.5	25.2	23.9	27.4
		Relative humidity	%	49.6%	39.4%	33.8%	43.8%	44.5%	64.4%	67.7%	67.3%	63.2%	60.5%	52.6%	50.0%	53.1%
		Solar Radiation-Hor	kWh/m²/d	5.18	5.93	6.41	6.51	6.23	5.07	4.38	4.42	4.78	4.86	4.91	4.82	5.29
	Kurnool	Air temperature	°C	24.5	27.5	31.2	33.3	33.9	30.8	28.6	27.7	27.8	27.1	25.6	23.7	28.5
		Relative humidity	%	54.3%	44.5%	36.5%	38.8%	41.2%	55.8%	64.9%	70.7%	70.0%	70.5%	66.0%	61.6%	56.3%
		Solar Radiation-Hor	kWh/m²/d	4.89	5.74	6.32	6.63	6.27	5.07	4.46	4.50	4.78	4.58	4.65	4.54	5.20
Karnataka	Bijapur	Air temperature	°C	24.4	26.9	30.1	31.1	29.5	25.4	24.3	24.0	24.9	26.2	25.4	23.8	26.3
		Relative humidity	%	42.8%	33.7%	31.0%	36.4%	49.5%	74.8%	79.3%	79.0%	71.1%	57.4%	46.8%	45.6%	54.1%
		Solar Radiation-Hor	kWh/m²/d	5.12	5.83	6.45	6.61	6.47	5.12	4.67	4.63	5.10	5.11	4.97	4.77	5.40
	Bagalkot	Air temperature	°C	24.4	26.9	30.1	31	29.6	25.5	24.3	24	24.9	26.2	25.4	23.8	26.3
		Relative humidity	%	43.5%	34.5%	31.2%	36.7%	48.8%	74.7%	79.3%	79.0%	71.1%	57.4%	46.8%	45.6%	54.1%
		Solar Radiation-Hor	kWh/m²/d	5.27	5.91	6.46	6.48	6.4	5.01	4.56	4.53	4.95	4.98	5.02	4.88	5.37
	Belgaum	Air temperature	°C	25.0	26.3	28.0	28.4	27.4	25.0	24.2	23.8	24.0	25.3	25.7	24.7	25.6
		Relative humidity	%	46.3%	43.6%	46.7%	53.4%	64.8%	82.7%	85.8%	85.9%	81.4%	69.4%	52.5%	48.3%	63.5%
		Solar Radiation-Hor	kWh/m²/d	5.23	5.94	6.54	6.74	6.14	3.96	3.48	3.74	4.73	4.94	5.02	4.87	5.10
Tamilnadu	Karur	Air temperature	°C	23.3	25.6	27.7	26.9	26.4	25.2	24.9	25.1	25.6	24.7	23.6	23	25.2
		Relative humidity	%	63.8%	54.5%	51.2%	68.5%	73.5%	76.3%	74.5%	72.5%	69.8%	74.4%	72.4%	68.9%	68.4%
		Solar Radiation-Hor	kWh/m²/d	5.07	5.84	6.5	6.08	5.85	4.85	4.5	4.64	4.99	4.45	4.22	4.46	5.12
	Tiruvur	Air temperature	°C	23.1	25.6	28.7	29	31.1	29	27.1	26.6	26.6	25.5	24	22.5	26.6
		Relative humidity	%	50.0%	47.2%	44.2%	55.8%	52.6%	67.4%	75.0%	75.7%	73.8%	67.5%	53.0%	48.1%	59.2%
		Solar Radiation-Hor	kWh/m²/d	4.86	5.63	6.29	6.68	6.4	4.58	3.81	3.64	4.44	4.84	4.93	4.75	5.07
	Dindigul	Air temperature	°C	23.5	25.6	27.5	26.5	25.6	24.7	24.5	24.6	25.1	24.5	23.7	23.1	24.9
		Relative humidity	%	67.1%	57.4%	54.8%	73.0%	80.0%	81.4%	79.5%	77.6%	75.5%	79.1%	77.5%	73.9%	73.2%
		Solar Radiation-Hor	kWh/m²/d	4.85	5.59	6.24	5.89	5.68	4.73	4.50	4.80	5.17	4.48	4.18	4.32	5.03
Punjab	Bhatinda	Air temperature	°C	11.1	14.2	20.6	27.0	31.2	32.8	30.8	29.3	27.9	23.9	18.5	13.1	23.4
		Relative humidity	%	54.5%	47.4%	36.6%	30.8%	32.3%	43.7%	64.8%	71.2%	61.6%	42.7%	38.7%	47.4%	47.7%
		Solar Radiation-Hor	kWh/m²/d	3.19	4.28	5.35	6.29	7.01	6.89	6.09	5.79	5.58	4.92	3.98	3.19	5.22
	Ludhiyana	Air temperature	°C	10.9	13.9	20.1	26.2	30.2	31.6	29.4	28.0	26.5	22.8	17.8	12.8	22.6
		Relative humidity	%	54.3%	48.7%	37.8%	31.5%	33.9%	46.4%	69.1%	74.7%	65.8%	46.4%	40.3%	47.2%	49.7%
		Solar Radiation-Hor	kWh/m²/d	3.25	4.31	5.50	6.45	7.08	6.89	5.91	5.71	5.60	5.02	4.09	3.22	5.25
	Jalandhar	Air temperature	°C	9.4	11.9	17.4	23.5	27.7	29.2	27.2	25.7	24.1	20.5	15.8	11.3	20.3
		Relative humidity	%	52.2%	49.4%	40.2%	32.3%	33.4%	45.2%	69.6%	76.1%	66.1%	45.0%	38.6%	44.1%	49.4%
		Solar Radiation-Hor	kWh/m²/d	3.12	4.17	5.30	6.50	7.20	7.08	5.93	5.51	5.51	5.01	3.99	3.10	5.20

Source: NASA, TERI analysis

Appendix II: State maps


District Map of Maharashtra
N
Madhya Pradesh
Gujarat
Nandurbar
Dhule
Jalgaon
Amravati
Akola
Nagpur
Bhandara
Wardha
Daman & Diu
Buldhana
Washim
Yavatmal
Chandrapur
Chhattisgarh
Nashik
Aurangabad
Jalna
Thane
Parbhani
Gadchiroli
Ahmadnagar
Mumbai (Bombay) State Headquarter
Bid (Beed)
Nanded
Pune
Raigarh
Latur
Dharashiv
Satara
Solapur
Andhra Pradesh
Ratnagiri
Sangli
Map not to Scale
State Capital
State Boundary
ARABIAN SEA
Kolhapur
Sindhudurg
Karnataka
Goa
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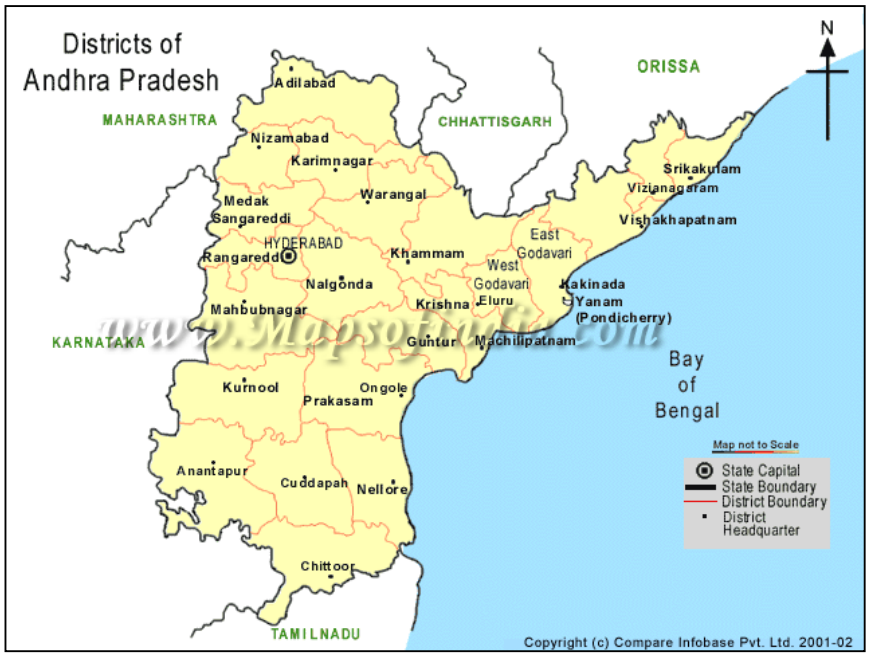
Districts of Andhra Pradesh
N
ORISSA
Adilabad
MAHARASHTRA
CHHATTISGARH
Nizamabad
Karimnagar
Srikakulam
Vizianagaram
Warangal
Medak
Sangareddi
Vishakhapatnam
East Godavari
HYDERABAD
Rangareddi
Khammam
West Godavari
Nalgonda
Kakinada
Krishna
Eluru
Yanam (Pondicherry)
Mahbubnagar
KARNATAKA
Guntur
Machilipatnam
Bay of Bengal
Kurnool
Ongole
Prakasam
Map not to Scale
State Capital
State Boundary
District Boundary
District Headquarter
Anantapur
Cuddapah
Nellore
Chittoor
TAMILNADU
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Karnataka
(District Map)
N
MAHARASHTRA
Bidar
Gulbarga
Bijapur
Belgaum
Bagalkot
Raichur
GOA
Dharwad
Koppal
Gadag
Bellary
ANDHRA PRADESH
Uttar Kannad
Haveri
Devangere
Tumkur
Chitradurga
Shimoga
ARABIAN SEA
Udupi
Chikmangalur
Tumkur
Kolar
Hassan
Bangalore
Dakshin Kannad
Mandya
Kodagu
Mysore
Chamrajnagar
TAMILNADU
KERALA
Map not to Scale
State Capital
State Boundary
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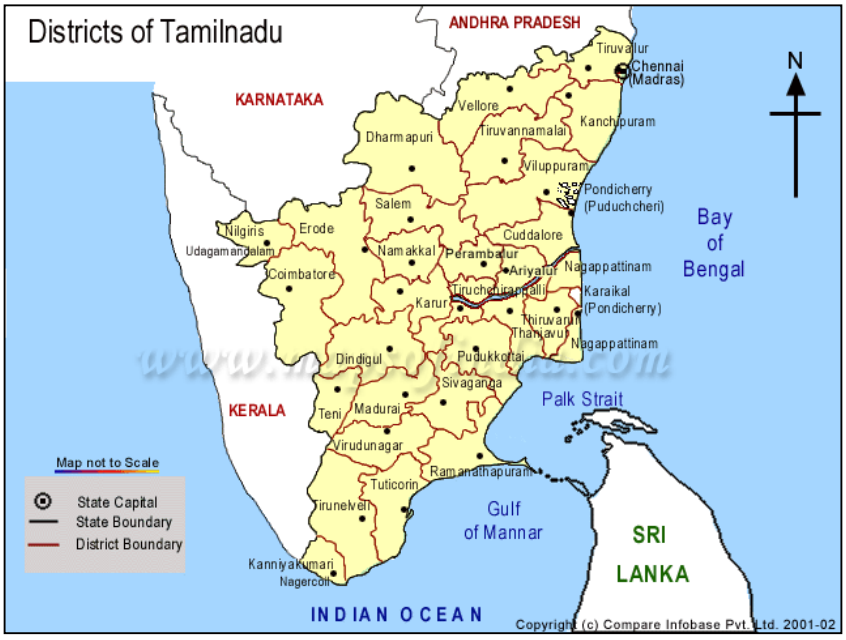
Districts of Tamilnadu
ANDHRA PRADESH
Tiruvallur
Chennai (Madras)
N
KARNATAKA
Vellore
Kanchipuram
Dharmapuri
Tiruvannamalai
Viluppuram
Pondicherry (Puduchcheri)
Salem
Bay of Bengal
Nilgiris
Erode
Udagamandalam
Cuddalore
Namakkal
Perambalur
Nagappattinam
Coimbatore
Ariyalur
Tiruchchirappalli
Karaikal (Pondicherry)
Karur
Thiruvarur
Thanjavur
Nagappattinam
Dindigul
Pudukkottai
Sivaganga
Palk Strait
KERALA
Teni
Madurai
Virudunagar
Ramanathapuram
Map not to Scale
Tuticorin
State Capital
State Boundary
District Boundary
Tirunelveli
Gulf of Mannar
SRI LANKA
Kanniyakumari
Nagercoil
INDIAN OCEAN
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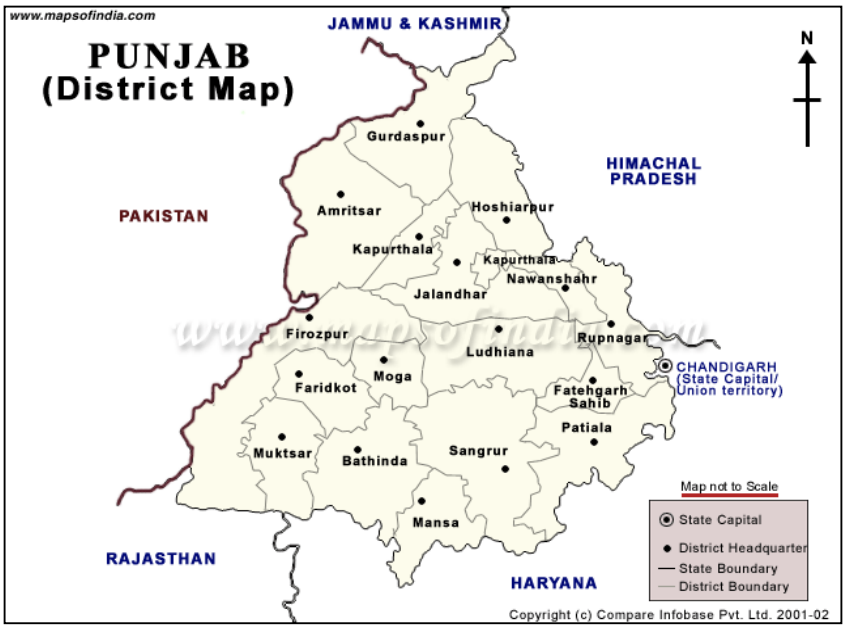
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PUNJAB
(District Map)
JAMMU & KASHMIR
HIMACHAL PRADESH
PAKISTAN
RAJASTHAN
HARYANA
N
Gurdaspur
Amritsar
Hoshiarpur
Kapurthala
Kapurthala
Nawanshahr
Jalandhar
Firozpur
Rupnagar
Ludhiana
CHANDIGARH
(State Capital/
Union territory)
Moga
Faridkot
Fatehgarh
Sahib
Patiala
Muktsar
Bathinda
Sangrur
Mansa
Map not to Scale
State Capital
District Headquarter
State Boundary
District Boundary
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