The Most Promising Solar Hot Spots in India Development and Policy: The Thar Desert of Rajasthan

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Abstract - **The sun produces an unbelievable amount of energy that reaches the earth. The amount of energy that is absorbed by the earth in one hour is more energy than mankind uses in one year. The total amount of solar energy reaching the earth in one year is huge twice as much energy as ever existed from all sources of coal, oil, natural gas, and uranium combined. With its abundance of sunlight, India has tremendous potential to emerge as one of the leaders in solar power generation. According to the Government of India's policy for the solar sector – Jawaharlal Nehru Nationaln Solar Mission (JNNSM) – a target of 20 GW of solar installations by 2022 has been set. India is endowed with vast solar energy potential, About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Solar energy intensity varies geographically in India, but Western thar Rajasthan receives the highest annual solar radiation energy. Its western thar part blessed with abundant natural resource with more then 325 days of sunshine every year. Jodhpur , popularly known as the sun city of india. A dedicated 400 kV network with associated 220 & 132 kV strong transmission network in Barmer, Jaisalmer, Jodhpur, Bikaner area was created. Indeed, Rajasthan is the only State in India which has established a strong power evacuation network in desert area. Hence current status, various issues, regulatory policies and incentives for promotion of Solar PV Power Parks in Rajasthan along with a case study , site report and geotechnical investigation for Photovoltaic Solar Power Plant has been discussed in this Paper.**

Keywords - **PV Solar Power, Renewable Energy, JNNSM, Research and Devlopment in Solar Projects of Rajasthan**

I. INTRODUCTION

The sun produces an unbelievable amount of energy that reaches the earth. The amount of energy that is absorbed by the earth in one hour is more energy than mankind uses in one year. The total amount of solar energy reaching the earth in one year is huge twice as much energy as ever existed from all sources of coal, oil, natural gas, and uranium combined.The sun strikes the surface of the earth at different angles ranging from 0 degrees (no sun) at the poles to 90 degrees at the equator during spring and fall. At the equator during noon time, the earth's surface gets the maximum amount of energy. As one moves away from the equator, the sun's rays have to travel longer through the atmosphere. Along the way some rays are reflected into space or scattered by clouds causing loss of energy as they go. On average, about 50% of the sun's energy makes it through the atmosphere and strikes the earth. The tilt in the earth's axis of rotation also causes variations in the amount of sunshine received. The north pole receives little sunshine in the winter months and likewise the south pole receives little in the summer months. So the amount of solar energy that reaches any given location varies by latitude, time of year, time of day, and local weather. Solar energy is also appealing because stabilizing the carbon dioxide-induced climate change is mainly an energy problem, and thus stabilization will require the development of renewable sources that do not emit carbon dioxide to the atmosphere. Solar energy is abundant and offers a solution to fossil fuel emissions and global climate change. Earth receives solar energy at the rate of approximately 1,20,000 TW (1 TW = 1012W or 1 trillion watt). This enormously exceeds both the current annual global energy consumption rate of about 15 TW, and any conceivable requirement in future. Driven by perpetually rising demand for energy, more than 100 countries including India have enacted policies and programs for harnessing solar energy. The achievements, however, have been mixed so far. This review provides the practitioner perspective and reviews the progress made in development of solar energy in Thar desert, Rajasthan—among the most promising solar hotspots in India. We not only review the success but also critically evaluate the areas of concern. While envisioning the future, we identify sev-eral critical areas that have implication for practice and research, including the data gaps where serious attention would need to be given by practitioners and researchers. Understanding early ground-level efforts for solar energy development is essential, as these insights can prove vital for other regions in India and else-where. Rajasthan, the largest state of India constitutes about 10.4% geo-graphical area of India. Not with standing the recently discovered large hydrocarbon reserves of more than 3.6 × 109 barrel oil and oil equivalent in Barmer basin , there are limited available traditional sources of energy such as coal. There are only two perennial rivers, Chambal and Mahi, whose hydroelectric potential has been almost fully achieved. In view of the above, Rajasthan faces two unique challenges in terms of power generation from the conventional sources: one, there are not many hydropower projects due to non-availability of large rivers; two, as coal needs to be trans-ported from other states, the transportation alone contributes to 50% cost of energy production. Rajasthan has about 2,08,110 km2 of desert land, which is 60% of the total area of the state. Interest-ingly, Rajasthan receives solar radiation of 6.0–7.0 kWh/m2. As the area has low rainfall, about 325 days have good sunshine in a year, and in western areas in Thar desert it may extend up to 345–355 days as rains occur only for 10.4–20.5 days in a year .

II. INDIA'S ENERGY SCENARIO AND THE ROLE OF SOLAR POWER

In January 2014, India had a total installed power generation capacity of 228 GW. Conventional sources of power, largely coal, account for around 60% of this. In comparison, solar barely contributes 1%10. In the "business as usual" scenario, projected by the International Energy Agency ('IEA'), India will have an installed power generation capacity of around 800 GW by 2035 (Compounded Annual Growth Rate (CAGR) of 6.4%), with coal growing in absolute terms but diminishing in relative terms and accounting for close to 40% of the total installed capacity. Solar, in this scenario, grows fast and reaches 85 GW by 2035. This will make solar the fifth most important energy source after coal, hydro, gas and wind.

The average intensity of solar radiation received over India is 200 MW/km2 (megawatt per kilometer square) with 250–325 sunny days in a year. Solar energy intensity varies geographically in India, but the highest annual global radiation (≥2400 kWh/m2) is received in Rajasthan and northern Gujarat. India receives the solar energy equivalent of more than 5000 trillion kWh/year. Depending on the location, the daily incidence ranges from 4 to 7 kWh/m2, with the hours of sunshine ranging from 2300 to 3200 per year. Recent research has shown that India has a vast potential for solar power generation since about 58% of the total land area (1.89 million km2) receives annual average Global inso-lation above 5 kWh/m2/day.

Figure : 'Business as usual' power generation capacity projection for India by IEA[12]

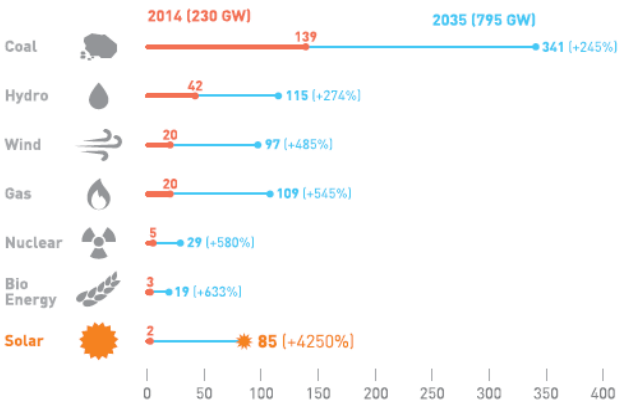

Figure : Country wise cumulative solar capacity till 2013 (GW)[45]

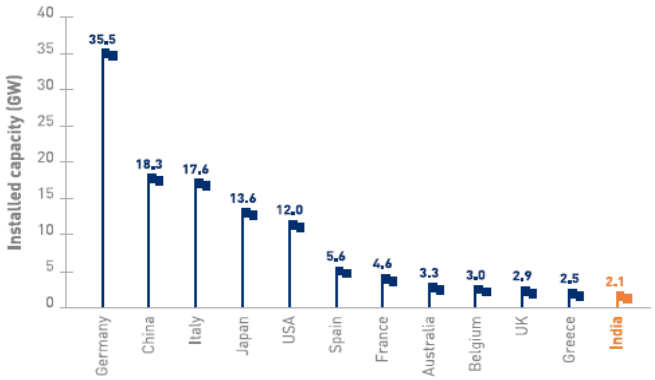

Fig 1

III. CURRENT POLICY, PRACTICE AND REGULATIONS IN INDIA

In terms of all renewable energy, currently India is ranked fifth in the world with 15,691.4 MW grid-connected and 367.9 MW off-grid renewable energy based power capacity. Development of alternate energy is administered through India's Ministry of New Renewable Energy (MNRE), National Thermal Power Corporation Vidyut Vyapar Nigam Ltd., (NVVNL) Energy development agencies in the various States and the Indian Renewable Energy Develop-ment Agency Limited (IREDA). In terms of solar, the amount of solar energy produced in India is less than 1% of the total energy pro-duced. It is almost entirely based on PV technology, and about 20% of the capacity is being used for off-grid applications. Promoting renewable energy has assumed great importance in view of high growth rate of energy consumption, high share of coal in domestic energy demand, heavy dependence on imports for meeting demands for petroleum fuels and volatility of world oil market. This has resulted faster overall growth of renewable energy sector in last two years in India. The scenario is likely to get better as India has one of the largest programs in the world for deploying renewable energy based products and systems.

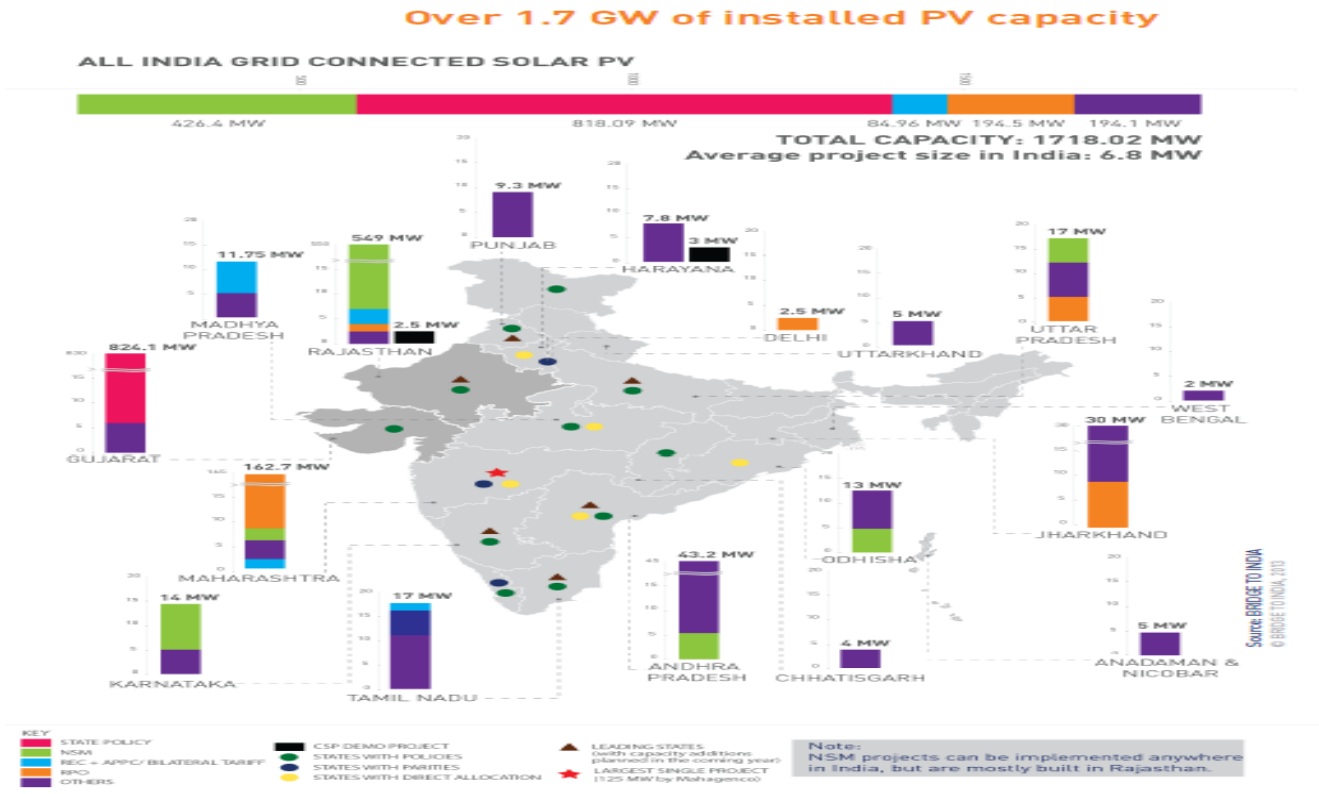

Fig 2

IV. Success for Renewable Energy in Rajasthan

Out of a total 1100 MW new project allocations, Rajasthan received the maximum share of 873 MW (i.e., 79.36% of all India allocations) through competitive bidding in the first phase of Jawaharlal Nehru National Solar Mission (JNNSM) and through JNNSM-II. This prefer-ence is often attributed to geographical and climatic advantage of Rajasthan. Yet it remains unclear why some other States with sim-ilar climatic and geographical factors are less favored by investors? We argue that the answer to this paradox lies in other determinants such as policy, infrastructure, facilitation and governance that make Rajasthan a lucrative investment opportunity. The fact that our argument originating from practitioner per-spective is robust is also validated by other independent studies that indentify critical barriers which if removed may provide enabling environment to solar energy development in India.

V. Renewable and Solar Policy

To promote the renewable energy sector in general and solar energy in particular, Government of Rajasthan has taken several important initiatives. To begin with "Policy for Promoting Gen-eration of Power through Non-Conventional Energy Sources" was enacted on 11 March 1999, which was updated in every year Also, Government of Rajasthan on 08.10.2014, issued Rajasthan Solar Energy Policy, 2014 to promote Solar Energy. The main objectives of this policy include:vison is to reduce the dependence on conventional sources of energy by promoting the development of non-conventional sources and mot importantly, solar power there by enabling the state in attanining self-sufficiency in its energy needs. Our aim is to create an enabling environment for installation of 25000MW of solar power through state or private enterprises or through public private partnership or through individual efforts. leverage maximum ben-efit from National Solar Mission, develop Solar Power Plants for meeting renewable purchase obligation of Rajasthan as well as other States, promote off-grid applications of solar energy, and the development of solar parks and other projects. Other important policy initiatives of Government of Rajasthan embodied in the Climate Change Agenda of Rajasthan, Rajasthan Environment Mission, Rajasthan Environ-ment Policy 2010 2014, and State Action Plan on Climate Change, recognize the role of solar energy for sustainable development and energy security.State nodal agency and single window clearance Government of Rajasthan established the Rajasthan Renewable Energy Corporation Limited (RRECL) in year 2003 by merging erst-while Rajasthan Energy Development Agency and the Rajasthan State Power Corporation Limited to act as state nodal agency for single window clearance of the renewable energy projects. This was also to facilitate the allotment of revenue land, power evac-uation approval, execution of PPAs and coordination with MNRE and State Agencies including State Transmission Utility (STU) and Discoms. RRECL is also working as a state nodal agency for promot-ing and developing non-conventional energy sources and as a State Designated Agency (SDA) for enforcement of provisions of Energy Conservation Act 2001. It is also engaged in creating awareness among people toward conservation of energy through demonstra-tion projects.

The main objective of rajasthan solar energy policy-2014

– Developing a global hub of solar power of 25000MW capacity to meet energy requirements of rajasthan and india.

– Contributing to long term security of rajasthan as well as ecological security by reduction in carbon emissions.

- Providing a long term sustainable solution for meeting energy needs and considerably reducing dependence on depleting fossil fuel resources like coal ,oil, gas etc.
- Generation direct and indirect employment opportunities in oil activited related to the generation of solar power.
- Envisaging a solar centre of exxellence that would work towards applied research and commercialization of nascent technologies to accelerate the march to grid parity.

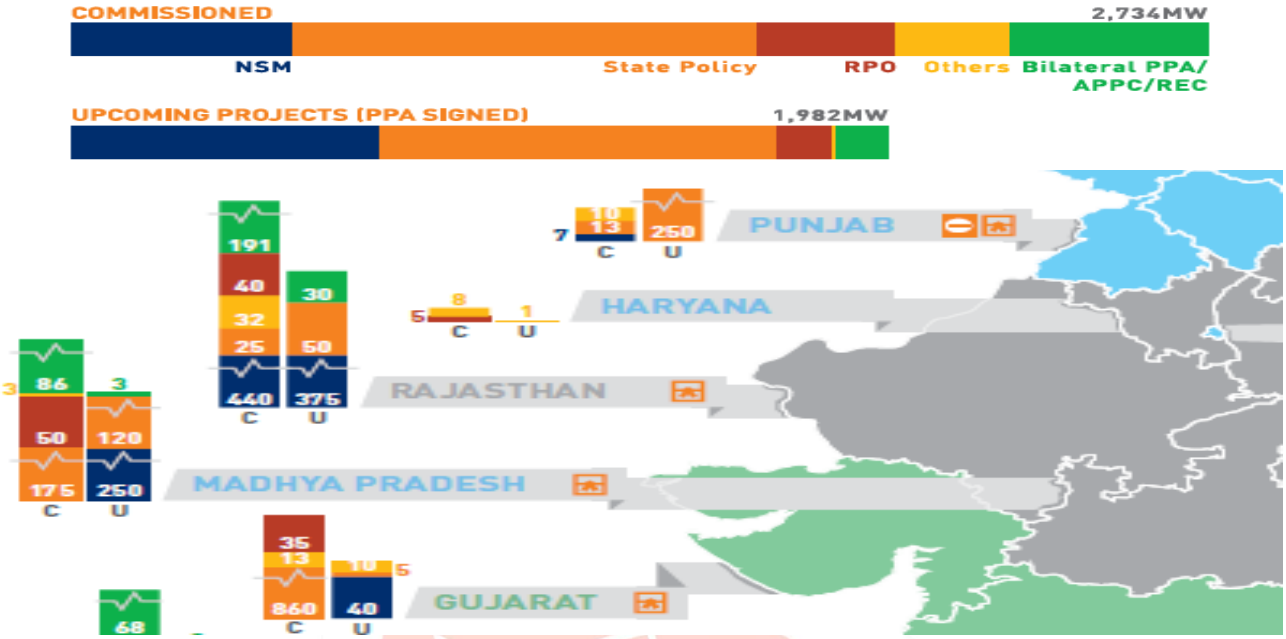

Fig 3

VI. Robust Power Evacuation System in Thar Desert

Energy production systems such as wind farms and solar sys-tems are mostly located in desert districts such as Jaisalmer, Jodhpur, Barmer, but load centers are situated away from these districts. Evacuation and transmission of power therefore was required to be strengthened. Accordingly, a dedicated 400 kV net-work with associated 220 and 132 kV strong transmission network in Barmer, Jaisalmer, Jodhpur, Bikaner area was created. Rajasthan is the only State in India, which has established a strong power evacuation network in a desert region. Existence of suitable trans-mission system for evacuating solar power in a desert area, a hotspot of solar energy, has been one of the key factors in early wins for Rajasthan compared to other states in India.

Table 1

District	Max. Solar Potential KWh/m^2
Jodhpur	5.89
Jaisalmer	5.58
Barmer	5.88
Jalore	5.81
Baran	5.79
Chittorgarh	5.74
Ajmer	5.74
Bikaner	5.73
Dungerpur	5.63

Source: RREC

6.1 India to Build World's Largest Solar Power Plant in Rajasthan

India will build the world's largest solar plant to generate 4,000 mw from sunlight near the Sambhar lake in Rajasthan that will sell electricity at an estimated rate of Rs 5.50 per unit. The proposed solar project's capacity is about three times India's total solar power capacity and comparable with coalfired ultra mega power project. "Being the first project of this scale anywhere in the world this project is expected to set a trend for large scale solar power development in the world," a government statement said. It would be set up and run by a joint venture of five public sector utilities Bhel, Powergrid Corporation of India, Solar Energy Corporation of India, Hindustan Salts limited and Rajasthan Electronics & Instruments Limited, the statement said. The first phase of the project, which would be 1,000 mw is expected to be commissioned in 2016. "Based on the experience gained during implementation of the first phase of project, the remaining capacity would be implemented through a variety of models," it said. The project would 23,000 acre of land out of which 18,000 acre would be provided by Hindustan Salts limited. The tariff is expected to be competitive. "Government is considering a tariff of Rs 5.50 per unit of solar power generated for this project,". Notably, Rs 5.50 per unit would be the lowest ever tariff for solar power in the country, which is expected to be the benchmark reference tariff for the upcoming phase of the national solar mission as well.

6.2 Envisioning the Future

The potential of Rajasthan for harnessing solar energy and facilitating role of the Government of Rajasthan is now being acknowledged. As discussed here, Rajasthan state is in the advanced stage of preparedness for installation of grid Interactive solar power plants . Encouraged by new initiatives such as single window clearance, solar power producers have registered with Rajasthan Renewable Energy Corporation under renewable energy policy 2004 and now Solar Energy Policy 2014. Thus, 722 reputed companies have already registered their interest for setting up of solar power plants amounting to a total capacity of 25000 MW in Rajasthan. In coherence with the Rajasthan Solar policy, state is poised to develop Solar Parks of more than 1000 MW capacity in Jodhpur, Jaisalmer, Bikaner, Barmer and districts in various stages. To begin with, solar park at Jodhpur has already been initiated. Clinton Foun-dation signed a memorandum of understanding (MoU) with the Government of Rajasthan in January 2010 for setting up 3000 MW Solar Parks. Rajasthan solar Park Private Ltd. It has been suggested that PV systems in Rajasthan may require a minimum weekly cleaning , but cleaning thrice a week and washing once a month may be essential in most of the Indian locations. But these suggestions are not based on robust science or long-term field experience.Thus effective approaches would need to be evolved by practitioners, and informed by good science, for appropriate cleaning cycles in Thar desert to mitigate the impact of dust deposition on PV performance. At present this issue is being addressed with trial-and-error approach without any scientific or experiential data. Water use efficiency is another area of concern.

Solar Power Project applications in Rajasthan

Fig 4

(i) Solar Thermal Power Project Nokha Jaisalmer (ii)Solar PV Plant at Phagi (iii) Solar Water Pumping Set at Bassi ,Jaipur (iv)Solar PV Project at Ramgarh Jaisalmer (v) Solar Power Plant at Gajner Bikaner (vi) Solar Project at Kolayat Bikaner (vii)Solar Water Heater at Sirsi Road Jaipur (viii)Solar Domestic Lighting at Barli Jodhpur

There are no studies to determine the water efficiency of solar installations in already water-stressed arid regions such as Rajasthan. There are other issues that have been over looked in Rajasthan. As the solar energy development progresses, it would be useful to revisit several other propositions that still remain to be addressed but may have the potential to bring sustainability in the region through solar energy. While strong power evacuation system is being strengthened in Rajasthan, the challenge remains because production systems need to be connected and optimally integrated into the grid through the implementation of smart grid technologies. Currently, multiple sources of power production are in operation in Rajasthan. Thus an intelligently optimized auto-balancing and self-monitoring smart power grid capable of accepting power from various sources of fuel including coal, lignite, solar, hydro or wind is necessary . Such grid shall also be necessary to implement the efficient delivery of electricity to large number of distributed consumers. The digitalization of the electricity grid opens the way to bundle value added services to the electric-ity commodity, and potentially shift business value to electricity services in coherence with the philosophy of efficiency, conser-vation and sustainability Urgent efforts would be required in this direction. While we have noted the large availability of land and abundant solar radiation in Rajasthan, we want to make it clear that the real issue is not the availability of solar radiation as much as the societal availability of open land. Indeed, contested claims and conflicts over vacant common lands by various stakeholdersincluding local farmers, cattle herders, villagers, and conserva-tionists are already emerging. Unless there is a fast and reliable conflict resolution and mediation mechanism in place, it will be highly unlikely to sustain the pace of solar energy development in Rajasthan.

Electrification by mini hybrid PV-solar and wind energy sys-tem for rural, remote and hilly areas in Rajasthan has been demonstrated to be feasible and could prove to be boon for poor households. These issues are not currently in priority of the State. Large efforts would need to be made to realize the potential.

Exploring the potential of ultra-large scale solar farms may be another area of interest. Studies note that to meet 50% of the total energy demands the proposed area for collection of solar and wind energy by means of ultra-large scale farms in fact will occupy a mere fraction of the available land and near-offshore area, e.g. a solar PV electricity farm of 26 km2 area required for India represents 0.01% land area of Rajasthan.

6.3 Technology in Solar Energy Systems

Currently, solar energy systems in India are almost entirely based on PV technology. Since this solar thermal technology has been successfully implemented in developed countries, with high solar potential, the development of this technology is imperative

in Rajasthan. The vital role of solar power in the energy security of India is accepted, but renewable sources alone may not be suf-ficient to supply India's electricity needs in the future. Thus, in the future as fossil fuels are exhausted, renewable sources alone will not suffice for meeting India's needs . While these claims require further refinement, energy security shall be an exciting area of multidisciplinary research involving technology, governance and economics to find sustain-able solution.

Finally, we need to watch future trends and take appropriate actions as a number of other factors are likely to decide the future prospects of renewable energy, including global pressure and vol-untary targets for greenhouse gas emission reduction, a possible future oil crisis, intensification of rural electrification program, and import of hydropower from neighboring countries.

6.4 Environmental Issues

Based on the environmental assessment and site surveys conducted for the project, there are very minimal associated potential adverse environmental impacts, which can be mitigated to an acceptable level by adequate implementation of the measures as stated in the Environment Management Plan (EMP) documents. Overall, the major social and environmental impacts associated with project are limited to the construction period and can be mitigated to an acceptable level by implementation of recommended measures and by best engineering and environmental practices. Adequate budget provisions should be made in the project to cover the Environmental mitigation and monitoring requirements, with associated costs.

VII. CONCLUSIONS

For a region that has been more successful in implementing solar energy development, we have highlighted critical success factors and aspects of the enabling environment. The pace of development of solar energy systems has been generally slow globally, because power generation from solar energy is expensive and requires special enabling environment for success. As socio-political and historic framework conditions matter for the implementation of new renewable energy options , the pace is now likely to get enhanced because of the Rajasthan Solar Energy Policy 2011, and commitment of the Government of Rajasthan to further develop the crucial infrastructure such as solar parks and power evacuation system. Hopefully Rajasthan will be prepared to exploit the opportunity provided the challenges we described here are addressed quickly and appropriately.

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