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Photovoltaic Energy Development in India

Innovation System

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General information

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Den Haag, Nov 16, 2014
Berry den Hartog

EXECUTIVE SUMMARY

The dominance of fossil fuels makes it difficulties for the development of photovoltaic energy (PV) because it locks in their usage (carbon lock in). Currently fossil fuel has the advantage of experience, which leads to high efficiency, low costs and optimal institutional arrangements (Unruh, 2000). PV is still in its development phase, and therefore less efficient. This makes fast diffusion a difficult process (Rosenberg, 1976).

To make PV technologies defuse faster policies can be put into place by the government. The reason to defuse PV technologies faster in India is the need for energy security, growing energy needs, increasing pollution, abundant renewable resources and for rural area development. Development of self-sustaining markets for PV technologies have been slowed down by their high up-front capital costs, inadequate access to credits, subsidies for fossil fuels and low purchasing ability among consumers (Chaurey, 2003).

An important question is how actors can accelerate the implementation of PV and break though the locked in fossil fuels system. To answer this question, information about the inner workings of the current energy system, the history of the system and the future plans from the major stakeholders needs to be analyzed. From this information, knowledge can be obtained about the possible PV technology development and diffusion within the energy system. This knowledge should allow us to locate the processes that block or reduce the development of PV technologies.

> *What are the factors that hamper or boost the photovoltaic technology development in India?*

The enablers derived from this research are the economic growth of India which increases energy demand. Grid losses, enabling off grid PV. The need for energy security. Positive expectations for PV by experts since the government is very clear. Many people are waiting to see what happens in the second phase of the solar mission. Many new entrepreneurs have joined in the PV innovation system and the since the creation of legitimacy is going good a positive feedback loop occurs. Another enabler is the awareness of pollution of current energy generation technologies like coal. Since most of the electricity generation is done by coal a big market share can be won by sustainable technologies like solar.

The barriers derived from both the MLP and FIS analysis are the high-levelized production cost of PV in comparisons to other technologies. However, The levelized production cost of PV is still decreasing while most others are increasing. The limited human resources is a big problem for India, Not many knowledgeable human resources are available to supply future needs. A big disadvantage for India is that they are generating allot of knowledge with regards to PV but most of it is not shared due to the fact that there is no legal framework available and because researchers are not encouraged to share their knowledge. Knowledge sharing between the research organizations and the industry is minimal. There are also some unneeded bureaucracy rules, which, if these would be removed might make it a bit easier for entrepreneurs. And last is the awareness by the populations of the possibilities of PV, both financially and technically. Another barrier is the uncertainty of data when investing in PV. There is no reliable information available which makes investors demand more return for their investments, which in turn makes money lending expensive.

The innovation system has a great inertia but some improvements could be done, the recommendations are spit into the 3 actors; companies, researchers and government. For companies the recommendation is to work to a closer cooperation between each other and to invest in human capital to ensure the future of PV innovation. For searchers the recommendation is to share their knowledge and make it freely available, For the government the recommendations are to reduce the risk for investors. Remove and improve bureaucratic processes. Creating standards to fight unfair competition between module developers and establish a national gird standard and the last recommendation is to create more consumer awareness, especially focused on technology, its financial opportunities and possible usage.

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1 INTRODUCTION

1.1 RESEARCH PROBLEM

The dominance of fossil fuels makes it difficulties for the development of photovoltaic energy (PV) because it locks in their usage (carbon lock in). Currently fossil fuel has the advantage of experience, which leads to high efficiency, low costs and optimal institutional arrangements (Unruh, 2000). PV is still in its development phase, and therefore less efficient. This makes fast diffusion a difficult process (Rosenberg, 1976).

India, being a tropical country receives adequate solar radiation for 300 days, amounting to 3,000 hours of sunshine equivalent to over 5,000 trillion kWh. Almost all the regions receive 4-7 kWh of solar radiation per sq mtrs with about 2,300–3,200 sunshine hours/year, depending upon the location. Many potential solar photovoltaic areas are available which could make photovoltaic a great addition to the current energy mix. (MNRE, 2014)

Technically, photovoltaic energy can replace parts of the energy system without requiring a big alteration in the current distribution system. In addition, photovoltaic energy is able to reach remote place where it was previously uneconomical to supply electricity.

To make PV technologies defuse faster policies can be put into place by the government. The reason to defuse PV technologies faster in India is the need for energy security, growing energy needs, increasing pollution, abundant renewable resources and for rural area development. (Chaurey, 2003).

An important question is how stakeholders can accelerate the implementation of PV by removing barriers and break though the locked in fossil fuels system. To answer this question, information about the inner workings of the current energy system, the history of the system and the future plans from the major stakeholders needs to be analyzed. From this information, knowledge can be obtained about the possible PV technology development and diffusion within the energy system. This knowledge should allow us to locate the processes that block or reduce the development of PV technologies. (Bergek A. , 2008).

The Indian PV innovation system has been developed quickly in the last few years. (Akhilesh). This thesis is making an analysis of this development Thereby extracting information for review and possible improvements. The Indian government is only subsiding PV until the technology can stand on its own two feet. (Ministry of New & Renewable Energy, 2014).

1.2 RESEARCH GOAL

This study intends to determine the factors that are hampering or boosting the development of photovoltaic technology in India. Also recommendations for specific stakeholders are going to be derived from the factors.

1.3 RESEARCH SCOPE AND LIMITATIONS

In general, photovoltaic technology can be categorized into two sections: off grid and grid connected applications. Currently the government is trying to develop both, Due to this reason; both categories will be analyzed in this research. The types of photovoltaic technology that will be analyzed are the current economically viable technologies either in the market or as research projects in the country.

This research will discuss the photovoltaic technologies, in terms of technical system, stakeholders, market situation, and sustainability issues related to each technology.

1.4 Research Questions

In order to achieve the research goals mentioned above, a main question is formulated which will act as a guideline. The main research question is

> ***What are the factors that hamper or boost the photovoltaic technology development in India?***

The answer to this question will be a functional analysis of all factors that influenced the photovoltaic technology development in India both positively and negatively. Furthermore, the interactions and connections between factors can also hamper or boost the technology development. Therefor the interaction also need to be discussed. Because most factors can be linked to an actor recommendations for further development of photovoltaic technology in India can be derived for specific actors.

In order to provide an approach that gives answers to the main question above, sub- questions are defined. The sub-questions are:

What theoretical framework can be best applied to the innovation system in order to give adequate answers on the main research question?

This question will lead to either an existing or a modified theoretical framework of Innovation System that is suitable to be applied in this research context. The innovation system framework used in this research should be suitable for the photovoltaic technology characteristic as well as the country characteristic.

What is photovoltaic technology?

In order to answer this question, a brief technical introduction is discussed. The main purpose of a technical introduction of photovoltaic technology is to find if there are issues from the technical side of the technology that can hamper the development of the technology.

What are the currently available types of photovoltaic technology in India?

The purpose of this question is to provide a comprehensive analysis of the currently available photovoltaic technology in India. Additionally, a brief description regarding the stages of technology development, photovoltaic industry, as well as the situation of the market and regulation regarding photovoltaic technology in the country is needed.

What are the current major energy generating technologies for the Indian energy system?

For Photovoltaic technology to defuse into the current energy system it must have an advantage over the existing energy generating technologies. This can be both technical, economic, environment and even social. This question will show where photovoltaic energy can have an advantage and can possibly replace existing technologies.

1.5 METHODOLOGY

The methodology of this research is a case study because the research question is to explore causation in order to find underlying system principles.

The technology that will be the analyzed is an emerging sustainable technology. Since India has its own characteristic geographical, demographical, social, and cultural it is not compared to other countries. This research is carried out by analyzing existing literature and data, verifying the result with other studies, a visit to India to meet experts and verifying the final results with expert in this field, Namely: Rob Raven. In general, this research is carried out through desk research. Data is gathered from academic journals, reports, news, and websites.

A theoretical framework will be selected that is best able to answer the research question. Then a general analysis of the current energy market will be done to determine landscape factors. Furthermore, a literature studies is conducted to determine the socio-technical system in India. In this studies, stakeholders related to photovoltaic technology and factors, networks, and institutions, related to the development of Photovoltaic technology. And lastly, the data gathered will be applied on the theoretical framework.

At last, conclusions and recommendations are derived from the analysis. Following the analysis, critical factors of the technology will also be stressed in the recommendations.

1.6 OTHER RESEARCH

Many papers about renewable energy in India have published in the last years in peer reviewed magazines like Energy Policy and Renewable and Sustainable Energy Reviews. Some give an overview of the market, analyze the current governmental policies, analyze all technologies or like this paper analyze the innovation system to improve the development of PV technology in India. Some of the more dominant examples are the “Indian solar photovoltaic industry: a life cycle analysis” (Sunderasan , 2007), “Analysis of barriers to implement solar power installations in India using interpretive structural modeling technique” (Ansari, 2013). “Solar energy in India: Strategies, policies, perspectives and future potential” (Kumar Sharma, 2012). And there are many more like the “India’s solar mission: A review” (Shrimali, 2012) and “Renewable energy certificate mechanism in India: A preliminary assessment” (Gupta, 2013) “Progress in renewable energy under clean development mechanism in India” (Nautiyal, 2012) and my personal favorite “When does unreliable grid supply become unacceptable policy? Costs of power supply and outages in rural India” (Harish, 2014)

All current research papers give an overview of the policies, PV as a technology and the energy market in India, Some even give suggestions on how to improve the policies so that PV might develop further.

The added value of this thesis is that this thesis not only focuses on governmental policies but all the actors. While some papers also do this. This paper also tries to understand the interaction between the different innovation drivers by using the motors of innovation. This will give an idea on how to accelerate innovation due to positive interactions between system function. No other research paper has been found that does this.

1.7 STRUCTURE OF THESIS

In chapter 2 the theoretical framework for the analysis of the PV innovation system is described. The 2 frameworks used are FIS and MLP. Section 3 provides a general insights in the PV technology. Section 4 is devoted to the global energy market in India. Section 5 is dedicated to the major stakeholders and there influences in PV. Here all information about the local PV system can be found, Section 6 contains external forces that influence the PV development. Here the environmental variables influencing the PV sector can be found. Section 7 contains the FIS analysis explaining the 7 functions, chapter 8 give an explanation of the motors of innovation and finally the 9 a conclusion is given.

2 THEORETICAL BACKGROUND

This research is aimed to determine what factors can positively and negatively influence PV technology development and diffusion in India. The theory needed for this research is an innovation system analysis tool that can analyze the effects on a specific technological innovation. However, it must not lose the overview of the whole innovation system since outside factors can influence the technological innovation system. Several methods have been developed to analyses an innovation system:

- National systems of innovation (Lundvall, 1992)
- Regional innovation systems (Asheim, 1997)
- Sectorial systems of innovation and production (Breschi, 1997)
- Technological innovation systems (Carlsson & Stankiewicz, 1991)

In this thesis, the focus is on the technological innovation systems (TIS) approach because the focus is on 1 technology, namely photovoltaic energy. TIS mainly explains the effects that the role and strategies of specific actors have on the innovation processes Since TIS mainly looks at the technological innovation system and neglects outside influence a combination with the multi-level perspective (MLP) is applied. (Geels, 2002). The strength of the MLP is that innovation processes can be explained by the stabilizing mechanisms at the regime level and destabilizing landscape forces combined with innovations at the niche level. MLP, however, is less useful when you look at the roles and strategies of actors. That's why combining these 2 analysis together would improve the overall quality of analysis. (Edquist, 2004) (Carlsson & Stankiewicz, 1991) (Hekkert, 2007) (Geels, 2002).

In the case of PV in India technology development are influenced by the established regime structures of centralized electricity regulation, co2 reduction and is also subject to landscape factors such as energy prices, transport costs ect. (Markard & Truffer, 2008)

2.1 MULTI-LEVEL PERSPECTIVE

The multi-level perspective (MLP) analyzes the innovation system as interactive processes of change. Simply said the MLP explains how a technology can evolve from a new technology to the norm.

To fully understand the relation between the FIS framework and the MLP the concept of regime and niche need to be explained. There are 3 distinguished levels. (Geels, 2002)

1.1.1 MICRO LEVEL - NICHE

The niche level represents a protected environment in which radical innovations are being developed. The niche is protected because new concepts cannot compete with existing technologies. The role of a niche is to provide an alternative selection environment and thus protect new innovations. (Elzen, 2004)

1.1.2 MESO LEVEL- REGIMES

The regime level are existing sociotechnical systems in society with all societal actors involved, such as law makers, producers, consumers and suppliers etc. A Regime can be defined as a set of rules by which different social groups work which cannot be influenced (much) by an individual group. The role of a regime is guidance of innovation processes. While regimes generate innovations that strengthen the regime, niches create and protect radical innovations, which may lead to destabilization and changes in the established regimes. (Markard & Truffer, 2008)

1.1.3 Macro level - Landscape

The macro level contains all external factors that influence the system. Examples are oil prices, political surroundings, economic growth etc. (Geels, 2002)

The relation between the above concepts can be understood as the multi-level perspective. The meso-level is constantly searching for stability of existing technological development. The macro-level of slow changing external factors. And the micro-level providing new options and disturbances. (Geels, 2002)

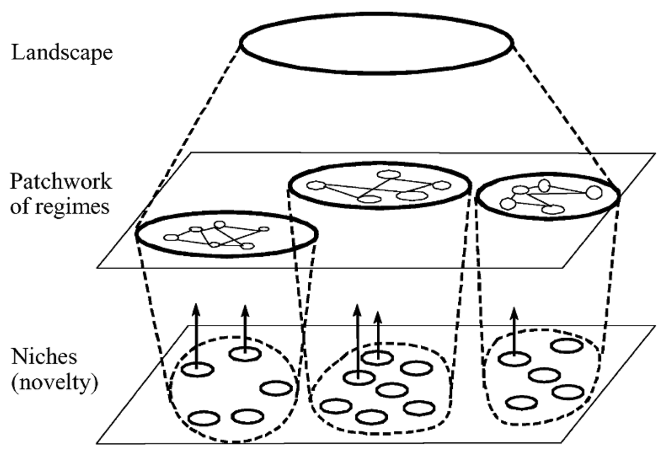

Figure 1: Multiple levels nested as hierarchy (Geels, 2002)

New options emerge in niches trying to solve problems within the existing regimes made by changing landscapes rules. New technologies are produced on the basis of knowledge. The figure bellow shows how a new radical innovation starts in niches and possibly develops.

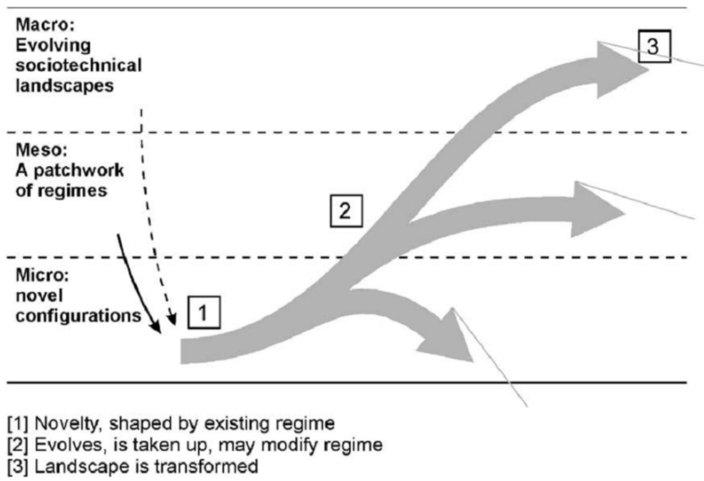

Figure 2: The Dynamics of a socio techno range: (Kemp, Constructing transition paths through the management of niches, 2001)

2.2 TECHNOLOGICAL INNOVATION SYSTEMS (TIS)

A Technological Innovation System is defined by Carlsson and Stanckiewicz as:

> *"a network or networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology."*

The Technological Innovation System method focuses on one specific technology (Carlsson B. , 1997). The advantage of this method is that you are not limited by geographical and sectorial dimensions (Hekkert, 2007). Another reason for choosing this method is that it can analyze emerging systems. Emerging systems evolves in time, starting small with only a few actors who are involved in the development, in time, the system will grow in actors and institutions assuming the technology is successful. Therefor the need for longitudinal studies is justified. (Carlsson B. , 1997)

Recent studies have shown some development in understanding the processes of innovation. The basic conclusion that follows from these studies is that there are 6 to 7 crucial functions. These processes are defined slightly different in literature studies and are shown in table 1

Hekkert (2007)	Van Alphen (2008)	Bergek
entrepreneurial activities	creating adaptive capacity	knowledge development
knowledge development	knowledge diffusion through networks	resource mobilization
knowledge diffusion through networks	articulation of demand	market formation
guidance of search	creation of legitimacy/counteract resistance to change	influence on the direction of search
market formation	resource mobilization	legitimation

resources mobilization	market formation	entrepreneurial experimentation
creation of legitimacy/counteract resistance to change	entrepreneurial activities	development of external economies

Table 1The van Alphen framework is designed to analyzing developing countries that import knowledge. (van Alphen, 2008)

- The Hekkert framework is focused on industrialized countries creating own knowledge. (Hekkert, 2007)
- Bergek tried to make a more functional framework for "researchers and policy makers" by setting up a framework identifying key policy issues. (Bergek, 2002)

Hekkert (2007)	Van Alphen (2008)	Bergek
entrepreneurial activities	creating adaptive capacity	knowledge development
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Table 1: Overview of FIS frameworks. Based on (Bergek A. , 2008)

A basic framework can be selected from 1 if these. The framework proposed by Hekkert will serve as a basis in this thesis since it gives a good first indebt analysis which can later be adjusted for the specific situation by adding or removing functions. (Bergek A. , 2008)

2.2.1 Functions of Innovation (FIS)

The important factors that influence the development, diffusion, and use of innovations, can be found by isolating the functions. The Function of Innovation System method analyzes the innovation system with regards to the functions they fulfill. It is not viable to research all functions that influence the development of PV in India. That is why Hekkert identified the most critical functions[1]. These functions can be used to identify the most important factors. (Hekkert, 2007)

The functions used in this thesis are listed in Table 2.

[1] Do note that functions are identified by Hekkert for developed countries and may be different for developing countries

Function	Description
Function 1: Entrepreneurial activities	The role of the entrepreneur is to turn the opportunities of knowledge development, network changes and market changes into action to take advantage of business opportunities.
Function 2: Knowledge development	Knowledge development is of the ad most importance within the innovation system. This function includes 'learning by searching' and 'learning by doing' and is the motor of new business opportunities
Function 3: Knowledge diffusion	The essential function of a networks is the exchange information and lessons learned so people, companies and government will learn from each other to work more effectively.
Function 4: Guidance of the search	The activities that positively or negatively affect the demands and expectations among technology users fall under this system function.
Function 5: Market formation	A new technology often has difficulties to compete with incumbent technologies since it's more expensive. Therefore, it is important to create protected spaces for new technologies.
Function 6: Resources mobilization	Resources, financial, material and human, are necessary as a basic input to all the activities within the innovation system to generate a useful output.
Function 7: Creation of legitimacy	In order to develop well, a new technology has to become part of society. Parties with other interests will often oppose this. This functions will try to find resistance.

Table 2: Functions of Innovation. Based on (Hekkert, 2007)

Not only the performance of each function but also the interactions between functions is important. Functions are able to influence each other's performance both positively and negatively. Suurs labeled the interactions between functions 'motors of innovation'. These motors of innovation help to explain interactions around sustainable energy technologies. Identified 5 motors which are listed in Table 3. (Suurs, 2009)

Motor	Description
Motor 1: Science and technology push motor	The first motor is dominated by the functions knowledge exchange (F2) and –diffusion (F3), guidance of the search (F4) and resources mobilization (F6). The role of entrepreneurial activities (F1) and the creation of legitimacy (F7) played also a role but it is typically weak or even absent. This motor is expected to precede the initiation of a project, because it is plausible that a certain knowledge base and expectations are required before a complex project is initiated; the Science and Technology Push motor can provide this..
Motor 2: Entrepreneurial motor	The more elaborate entrepreneurial motor is stressed to replace the science and technology push motor, maintaining its virtuous cycle and adding to it the functions creation of legitimacy (F7) and entrepreneurial

	activities (F1). The cumulative causation is created by new entrants or diversifying incumbent actors that start experimenting (F1), positive expectations (F4) in turn leads to lobby activities for support (F7) from other actors (e.g. government) to mobilize resources (F6), which in turn leads to more entrepreneurial activities (F1).
Motor 3: System building motor	This motor resembles the entrepreneurial motor with some changes; it includes a more important role of market formation (F5). The main difference lies in the connection between creation of legitimacy (F7), on the one hand, and market formation (F5) and guidance of the search (F4) on the other. Outsiders are increasingly involved in networks by enacting new entrants, governments, intermediaries and stakeholders in their system. From this network, outsiders attempt to develop the innovation system by enhancing the motors virtuous cycles.
Motor 4: Market motor	The market motor is characterized by a strong fulfillment of all functions, except the creation of legitimacy (F7) is not strongly fulfilled. This function is not as important for this motor because market formation (F5) is no longer a political issue. The market environment has been created as the result of formal regulations. Market formation (F5) is taken up as part of regular business activities (i.e. marketing activities and promoting strategies) that are directly connected to entrepreneurial activities (F1).
Motor 5: Motor of decline	This motor does not explain structural barriers that block motors of innovation; it shows event sequences that constitute an accelerated breakdown of TIS structures..

Table 3: Motors of Innovation. Based on (Suurs, 2009)

Motors of innovation emerge from the factors of functions and in turn reorganize the factors by mutual influation. For the purpose of this thesis, the focus will be on the FIS. Some motors of innovation and their connection to factors will be identified. However, external factors, such as for example the development of other markets and technologies, are important as well. They will be considered as a part of the analysis wherever they affect the dynamics of the FIS. (Suurs, 2009)

2.3 Indicators

To quantify the research with data indicators for each function are used. Bellow a list of indicators for the innovation functions is given taken from a similar study done in the Netherlands (Negro, 2011) .

Function	Indicators
Function 1: Entrepreneurial activities	Company size (Income from PV) and time of existence Amount of existing and projected PV projects
Function 2: Knowledge development	R&D projects Scientific publications Patents Research organizations and activities
Function 3: Knowledge diffusion	Interaction between companies and research institutions Number of national and international conferences

	Demonstrations/pilot projects
Function 4: **Guidance of the search**	Role of PV in India energy policy Expectations of stakeholders
Function 5: **Market formation**	Estimation of market size Available subsidies Regulation/tax regime Costs of established electricity supply
Function 6: **Resources mobilization**	Financial resources Physical resources Human resources.
Function 7: **Creation of legitimacy**	Existence of advocacy coalitions Public and political opinions and expectations of PV technology.

Table 4: FIS indicators. Based on (Negro, 2011)

3 TECHNICAL INTRODUCTION OF PV TECHNOLOGIES

Since the observation of the photovoltaic effect by the French physicist Alexandre Edmond Becquerel in the 19th century, many scientists have tried to develop energy technologies based on this effect. It is a process in which electricity is generated in the boundary layers of certain semiconductor materials when they are illuminated. In the last decade allot of research has been done in solar panels. See figure 3 bellow.

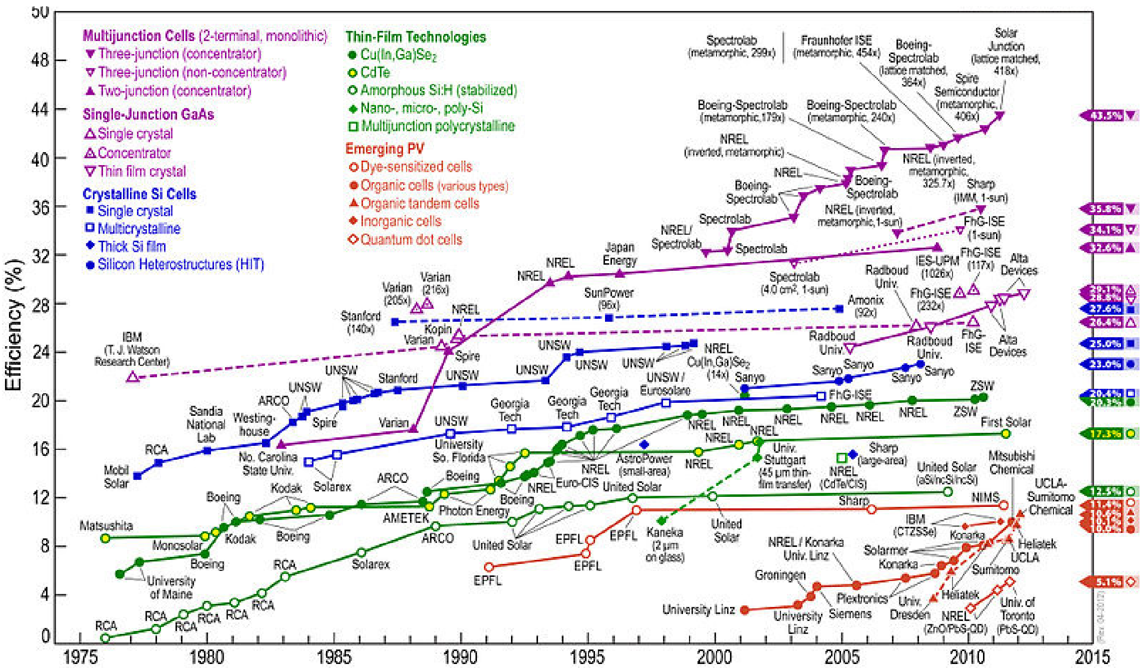


Figure 3: Global photovoltaic research-cell efficiencies (National Renewable Energy Laboratory, nrel, 2014)

Today's photovoltaic semiconductor materials include silicon, gallium arsenide, copper indium diselenide, cadmium sulfide, and cadmium telluride. From those 3 major PV technologies are emerging today, namely Crystalline, Polycrystalline and Thin-film. (National Renewable Energy Laboratory, nrel, 2014)

From these materials a variety of commercial products is produced, like consumer electronics, remote electric power systems, grid-connected power systems and building integrated systems. The PV material that is mostly used today is silicon, (Office of Energy Efficiency & Renewable Energy, 2014) due to being abundant in nature and thus cheap. Silicon solar technologies can be grouped in three basic areas namely, single-crystal silicon, polycrystalline silicon and thin-film amorphous silicon.

The primary distinctions among the three technologies are their sunlight-to-electricity conversion efficiency rates, the methods by which they are manufactured, and their associated manufacturing costs.. See Table 5

TECHNOLOGY	AREA SQ. CM	EFF	Group
SINGLE CRYSTAL	64.00	19.7	CEL

MULTI CRYSTAL	**100.00**	**16.8**	**Tata BP**
a-Si SINGLE JUNCTION	**1.00**	**12.0**	**IACS**
a-Si MULTI JUNCTION	**1.00**	**11.5**	**IACS**
a-Si/μc-Si(nc-Si)	**1.00**	**9.0**	**IACS**
CdTe	**1.00**	**12.0**	**NPL**
CIGS	**0.41**	**13.0**	**IISC**
Si FILMS	**0. 98**	**8.7**	**Jadavpur**
Dye Sensitized	**1.00**	**9.5**	**Amrita**
Organic cells	**1.0**	**6.2**	**NPL**

Table 5: best Photovoltaic efficiencies India 2011 (Central Electricity Regulatory Commission, 2014)

Solar panels generally have a life-time of around 20-30 years, (Bosco, 2010) for reliable power generation. After that amount of time they should be replaced. They have no moving parts, so maintenance is easy. In the rare case that a panel fails it can easily be replaced or by-passed in the case of a solar panel array. Moreover, solar panels do not produce any noise. It should be added that maintenance should include the whole power generation system, which can be also constituted by batteries and inverters. These extra components have their own lifetimes, but they are mature technologies, so their maintenance is the best possible. (Bosco, 2010)

3.1 Related technologies

Related technologies, needed to make pv panels deliver energy to the place where it is needed in the quality that it is needed in, are divided into 3 categories: Production, Supporting, Infrastructure.

For a energy delivering system the related technologies are important because they can make up 40 to 60% of the total cost, (National Renewable Energy Laboratory, NREL Reports Soft Costs Now Largest Piece of Solar Installation Total Cost, 2014)

3.1.1 *Production*

The production group includes mining of materials, material technology and production processes. Developments in these technologies can increase the efficiency and significantly lower the cost of a system. (McKinsey&Company, 2012)

3.1.2 *Support equipment*

In the supporting group are Inverters, Control Units, panels and wires. Most of these technologies are mature and no major developments are expected here. Control systems are needed in order to prevent both overloads and shortages of energy within the grid. They can be considered both an infrastructure and a support technology, since control systems should become part of the whole infrastructure in a decentralized energy market while having a supporting role. Control systems can vary in nature, from computer terminals to small electronic devices, such as switches. An efficient control of the system makes sure that no energy is lost and the system is never in shortage of energy. (McKinsey&Company, 2012)

Inverters are necessary in a PV energy system, as the PV panels produce DC current, most power applications use AC power. The inverter converts DC power to AC. The variety of inverters available for PV systems include single inverters, master-slave inverter configurations, modular inverters, and parallel independent or string inverters.

3.1.3 Infrastructure

In the infrastructure group there is the smart-grids technology and batteries. Smart grids, capable of both delivering and retrieving energy from a consumer/producer, allow for decentralized production of energy. This technology still needs development. (McKinsey&Company, 2012) . The most important related technology, especially for off grid application is energy storage, current mostly battery's. If a major breakthrough is achieved in this technology it will greatly influence the total cost of off grid pv system.

4 ENERGY MARKET IN INDIA

Energy can be recognized as one of the most important inputs for economic growth and human development. Economic Growth in India has been fluctuating between 5.8% and 9.7% from 2007 to 2012. (India Times, 2013). One harsh result of India's economic growth is the gap between energy demand and production. (Minestry of Finance, Annual report 2010-2011, 2011). With a peak shortage of an estimated 9% in 2012 and 12% in 2011. Total installed capacity in India is 209.27 GW as of oct 2012. (Minestry of new and renewable energy, 2014)

India consumed 600 Mtoe of primary energy in 2007.

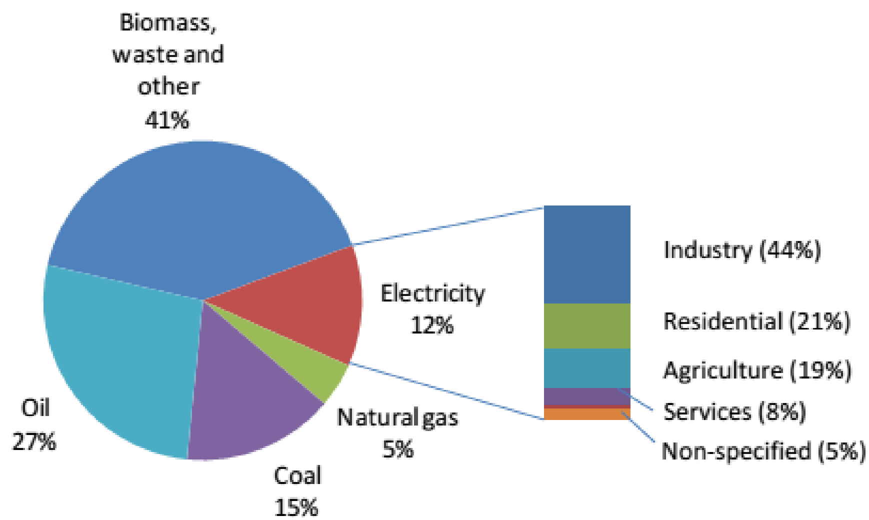


Figure 4: primary energy (International Energy Agency, 2009)

Coal represents a big part of the primary energy needs. However, Imports have increased despite the doubling of domestic coal production. The large biomass usage in India reflects the traditional heating and cooking, which represents the highest needs in the residential sector. (International Energy Agency, 2009)

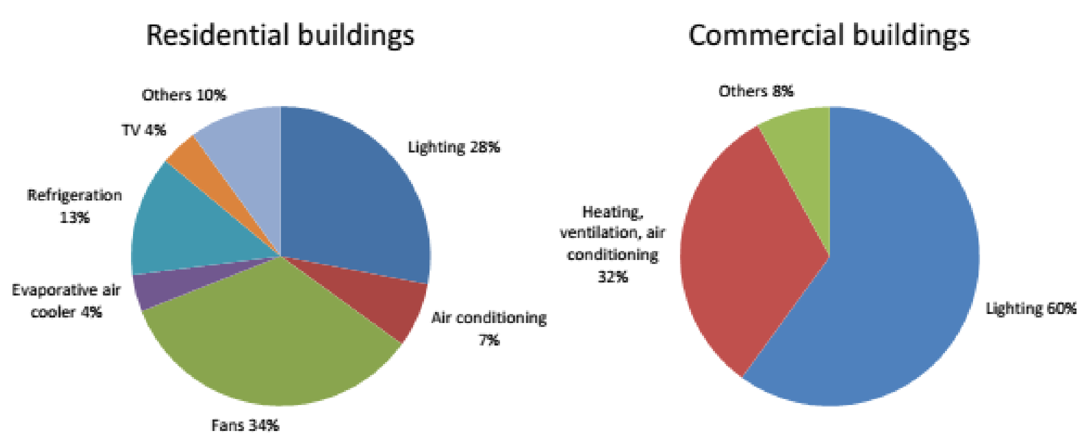


Figure 5: India's electricity usage (Bassil, 2011)

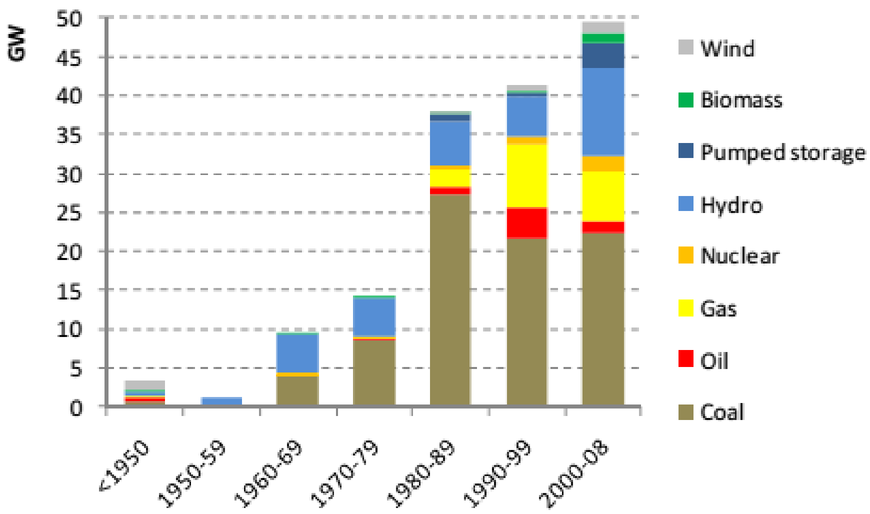


Figure 6: Existing power capacity (Bassil, 2011)

Wind and hydro have increased their share significantly over the last decade.

4.1 History of electricity regulation

The electricity supply is the responsibility of the central and state governments. The Electricity Act (1948) introduced the State Electricity Board. This board has the responsibility to plan and implement power development programs. Power shortages and the bad financial situation of the boards let to the implementation of new regulations. from 1991 onward, changes to the Indian Electricity Act 1910 and Electricity Act 1948 gave birth to the beginning of the liberalization process. The changes include the participation of the private sector and allowed 100% foreign investor ownership. It also simplified administrative procedures. The Electricity Regulatory Commissions Act (Minestry of Power, 2014) introduced 2 independent regulatory bodies, the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commissions (SERCs). (Government of India, 2006)

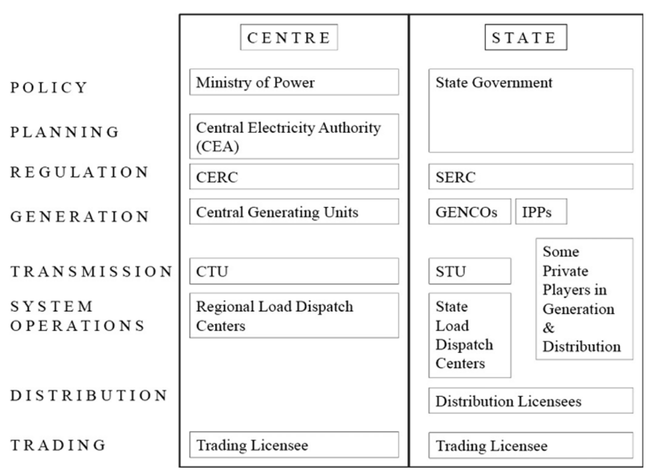


Figure 7: Indian power sector (Central Electricity Authority, Central Electricity Authority, 2013)

the Central Electricity Regulatory Commission (CERC) has two responsibilities. Regulating tariffs of generating companies and promoting competition in the electricity industry

the State Electricity Regulatory Commissions has more responsibilities. It regulates generation, transmission and distribution of electricity. Including issuing licenses to the companies involved in transmission and distribution of power. It also address disputes between stakeholders. SERC also decide the bulk and retail tariffs for power supply

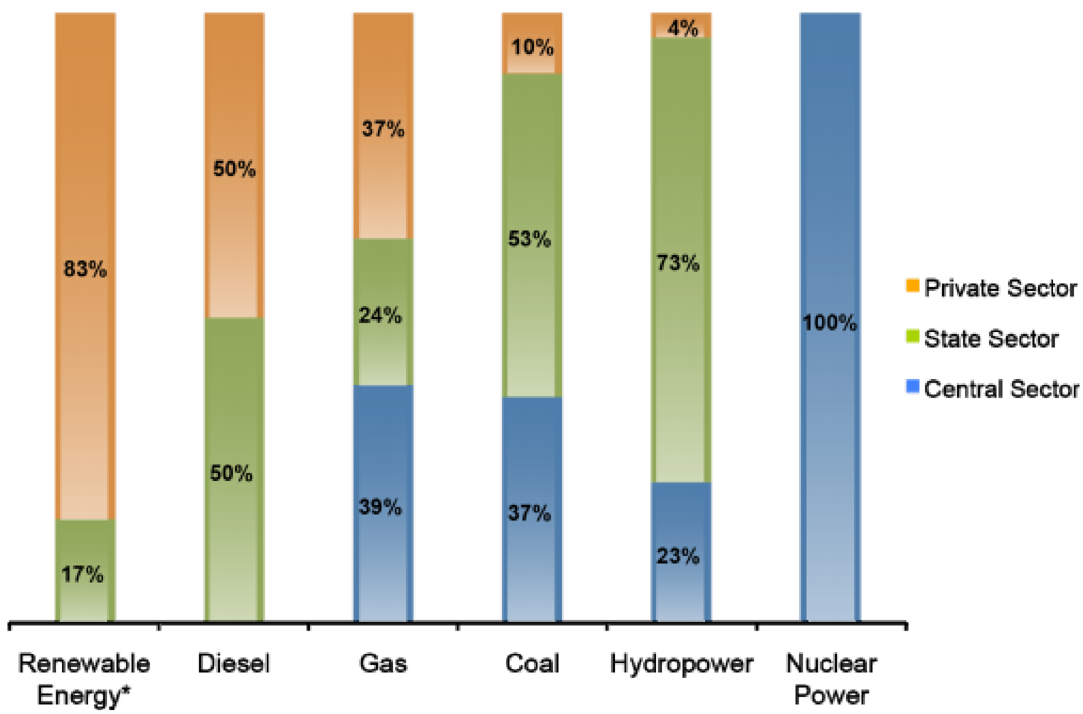


Figure 8: ownership of energy market (Bridge to India, 2009)

As of 2010, all the States except Arunachal Pradesh and Nagaland had set up a SERC. above a displays the ownership in the energy market.. What is interesting is the huge share of the private sector in renewable energy.

4.2 Technical challenges

The technical challenges for de India energy sector are the low efficiencies of thermal power plants, Reliance on coal plants, higher demand and an inadequate low efficient distribution network.

Improving efficiencies for thermal power plants are essential. India has a high domestic coal resource. However, this coal is of low quality and thus air pollution can become a problem. Moving to nuclear might be a solution because India could support a self-reliant nuclear program. (Bureau of Energy Efficiency, 2012)

To meet future energy demand and CO2 emissions at the same time india might need to develop low carbon energy generation solutions or improve energy saving methods.

The use of hydro power can make a significant impact in the north of India where India has allot of hydro potential, However, better power distribution is needed here. (Minestry of Power, 2014)

Another big technical challenge will be the grid expansion needed to supply this energy to areas that have been neglected. (Minestry of Power, 2014)

4.3 NON-TECHNICAL CHALLENGES

Non-technical challenged are often hard to change. Many non-technical challenges include behavioral change of the population.

A none technical challenges for the Indian energy market would be the encouragement of more efficient appliance and systems. Most of these equipment require high up front cost which many people cannot pay. (Bureau of Energy Efficiency, 2012)

An important challenge for the indian energy sector will be Becoming economically viable. Due to special regulations for farmers it has been almost impossible for the energy system to become economically viable.

In india allot of energy theft occurs. Especially in rural areas, it is socially acceptable to take energy for free. (Golden, 2012)

Challenge will be to convince the people of the importance of low carbon technologies such as nuclear and renewables. These technologies will require high up front cost but lower maintenance costs.

S. no.	Component of power generation	Description of the component
1.	Coal	Despite abundant reserves of coal, India is facing a severe shortage of coal to feed its power plants [24]
2.	Natural gas	The giant new offshore natural gas field has delivered less fuel than projected. India faces a shortage of natural gas
3.	Hydroelectric power	Hydroelectric power projects in India's mountainous north and northeast regions have been slowed down by ecological, environmental and rehabilitation controversies, coupled with public interest litigations
4.	Nuclear power	India's nuclear power generation potential has been stymied by political activism since the Fukushima disaster in Japan
5.	Efficiency	Ninety percent of the coal-fired generating units in India are subcritical, with a maximum thermal efficiency of 35–38%. The average thermal efficiency of these plants is below 30% due to the high ash content and low heat content of Indian coal and inefficiencies in management [28]
6.	Losses	Average transmission, distribution and consumer-level losses exceeding 30%
7.	Rural electrification	About 1.5 billion people in rural India have no access to electricity. Of those who do, almost all find electricity supply intermittent and unreliable [2]
8.	Government policies	Governments give away such as free electricity for farmers. This has financially crippled the distribution network, and its ability to pay for power to meet the demand. This situation has been worsened by government departments of India that do not pay their bills
9.	Inefficient technology	India's coal-fired, oil-fired and natural gas-fired thermal power plants are inefficient and as compared to the average emissions from coal-fired, oil-fired and natural gas-fired thermal power plants in European Union (EU-27) countries, India's thermal power plants emit 50–120% more CO2 per kWh produced [20]
10.	Power deficit	The country's overall power deficit was 8.4% in 2006 which has been risen up to 11% in 2009 [9]. During the year 2011–2012, the shortage conditions prevailed in the Country both in terms of energy and peaking availability as 8.5% and 10.6% respectively [21]
11.	Increasing demand	The electrical energy demand for 2016–2017 is expected to be at least 1392 tera watt hours, with a peak electric demand of 218 GW. The electrical energy demand for 2021–2022 is expected to be at least 1915 tera watt hours, with a peak electric demand of 298 GW [22]. If current average transmission and distribution average losses remain same (32%), India needs to add about 135 GW of power generation capacity, before 2017, to satisfy the projected demand after losses

Table 6: summary of the India's power sector problems (Ansari, 2013)

4.4 GENERATION

Generating companies are mostly public-owned utilities which operate and maintain a generating station. Many States have their own generating company. Central Generating Units are centrally owned electric plants producing power mainly from large hydro, thermal and nuclear.

Independent Power Producers are private corporations or persons which own or operate facilities for the generation of electricity for use primarily by the public, and which are not electric utilities.

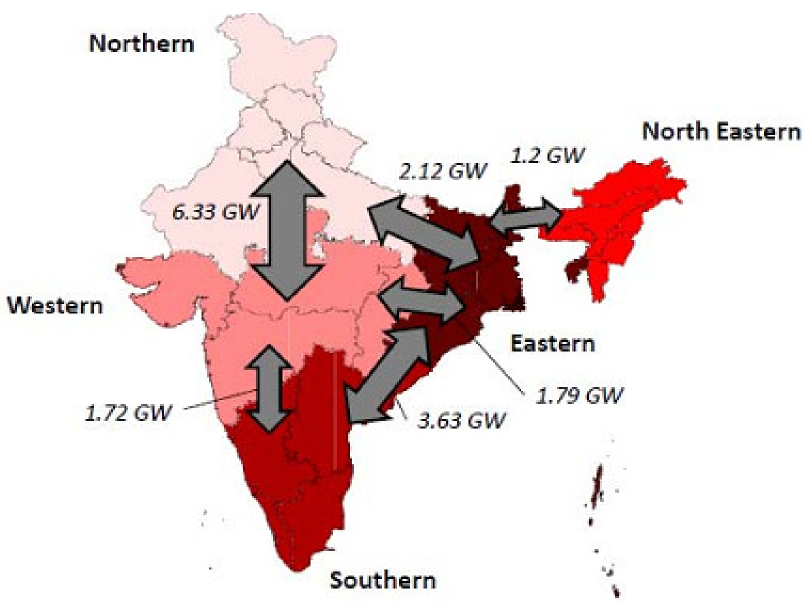
Captive power plants are power plants set up by any person to generate electricity primarily for his own use and include power plants set up by any co-operative society or association of persons for generating electricity primarily for use of members of such cooperative society or association.. (Minestry of Power, 2014)

4.5 TRANSMISSION

The transmission system can be grouped in 3 sections: the regional networks, the inter-regional connections that carry electricity across the five regions, and the state networks.

To get a transmission system that is able to transport high power, huge investments will have to be done. In the current situation, central and state utilities dominate the transmission market. (KPMG, 2010). The main transmission company is Power Grid Corporation of India Ltd. (POWERGRID), and state-owned transmission utilities.

There are five regions defined for transmission systems as shown in the picture bellow, namely the Northern Region, the North Eastern Region, the Eastern Region, the Southern Region and the Western Region. The interconnected transmission system within each region is also called the regional grid.



Note: The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.
Source: CEA, 2008b.

Figure 9: regional power grid system (Central Electricity Authority, All India Electricity Statistics 2009, General Review 2009, 2009)

The total transmission capacity of lines with a voltage level of 110 kV stands at 20.8 GW (Alagh, 2012). This corresponds to only 12% of the installed generation capacity. The 11 th Five- Year Plan has set the target to boost the transmission capacity from 14 GW in 2007 to 32.6 GW by 2012. This is an ambitious goal, given that during the first two years of the 11 Th Five-Year Plan only 5.9 GW have been built (Government of India, 2010)

India energy losses are averaging at 32% of total electricity generation, with losses in some states as high as 50% (Central Electrical Authority, 2008). These losses consist of Technical and commercial factors. Some experts estimate that technical losses are about 15% to 20% (Purohit, 2010). A high proportion of non-technical losses are caused by illegal energy tapping and faulty electric meters that underestimate actual consumption .

Energy Losses are also a result of the geographical spread of the system, especially for rural distribution systems with a small number of consumers spread over a large area. (Suresh, 2000). Due to historical development, the length of low voltage lines in these distribution networks exceeds the length of high voltage lines (Minestry of Power, 2014)

(Giga Watt hour) = (10^6 x Kilo Watt hour)

Year	Gross Electricity Generated from Utilities	Consumption in Power Station Auxiliaries	Net Electricity Generated from Utilities	Purchases from Non-Utilities + Imported from Other Countries	Net Electricity Available for Supply	Sold to Ultimate Consumers & Other Countries	Loss in transmission	Loss in transmission (%)
1	2	3	4=2-3	5	6=4+5	7	8=6-7	9
1970-71	55,828	2,863	52,965	66	53,031	43,724	9,307	17.55
1975-76	79,231	4,556	74,675	121	74,796	60,246	14,550	19.45
1980-81	110,844	7,230	103,614	120	103,734	82,367	21,367	20.60
1985-86	170,350	13,157	157,193	107	157,300	123,106	34,194	21.74
1990-91	264,329	19,604	244,725	2,216	246,941	190,420	56,521	22.89
1995-96	379,877	27,220	352,657	3,784	356,441	277,078	79,363	22.27
2000-01	501,204	34,932	466,272	5,596	471,868	316,795	155,073	32.86
2005-06	623,819	41,970	581,849	10,345	592,194	412,096	180,098	30.41
2006-07	670,654	43,577	627,077	11,931	639,008	455,964	183,044	28.65
2007-08	722,626	45,531	677,095	12,685	689,780	502,267	187,513	27.18
2008-09	746,626	47,573	699,053	13,487	712,540	527,564	184,976	25.96
2009-10	796,281	49,706	746,576	15,359	761,934	610,457	151,477	19.88
2010-11(p)	844,846	52,380	792,466	16,989	809,455	663,392	146,063	18.04
Growth rate of 2010-11 over 2009-10(%)	**6.10**	**5.38**	**6.15**	**10.62**	**6.24**	**8.67**	**-3.57**	**-9.24**
CAGR 1970-71 to 2010-11(%)	**6.85**	**7.35**	**6.82**	**14.50**	**6.87**	**6.86**	**6.95**	**0.07**

Source : Central Electricity Authority.

Figure 10: electricity generated, Distributed, sold and lost in india (Central Electricity Authority, Central Electricity Authority, 2013)

4.6 Distribution

The distribution of electricity is provided by public and private (licensed) owned companies at the state level. All 3 phase generation, transmission and distribution can be performed by the same utility service. While generation and transmission of electricity involve the participation of both the central and the state governments, distribution falls only within the competence of the States. (Minestry of Power, 2014)

4.7 RESOURCES

4.7.1 COAL AND LIGNITE

India has allot of coal an lignite reserve. In March 2011 the estimated reserves where around 286 billion tones for coal and 41 billion tons of lignite. For the state wise distribution see the two tables bellow. (Ministry of Coal, 2014)

(In billion tonnes)

States/ UTs	Proved		Indicated		Inferred		Total		Distribution (%)	
	31.03.2010	31.03.2011	31.03.2010	31.03.2011	31.03.2010	31.03.2011	31.03.2010	31.03.2011	31.03.2010	31.03.2011
Andhra Pradesh	9.26	9.30	9.73	9.73	3.03	3.03	22.02	22.05	**7.95**	**7.72**
Arunachal Pradesh	0.03	0.03	0.04	0.04	0.02	0.02	0.09	0.09	**0.03**	**0.03**
Assam	0.35	0.46	0.04	0.05	0.00	0.00	0.39	0.51	**0.14**	**0.18**
Bihar	0.00	0.00	0.00	0.00	0.16	0.16	0.16	0.16	**0.06**	**0.06**
Chhattisgarh	12.44	12.88	30.23	32.39	4.01	4.01	46.68	49.28	**16.86**	**17.24**
Jharkhand	39.63	39.76	30.99	32.59	6.34	6.58	76.96	78.94	**27.80**	**27.61**
Madhya Pradesh	8.51	8.87	11.27	12.19	2.22	2.06	21.99	23.13	**7.94**	**8.09**
Maharashtra	5.36	5.49	2.98	3.09	1.97	1.95	10.31	10.53	**3.72**	**3.68**
Meghalaya	0.09	0.09	0.02	0.02	0.47	0.47	0.58	0.58	**0.21**	**0.20**
Nagaland	0.01	0.01	0.00	0.00	0.31	0.31	0.32	0.32	**0.11**	**0.11**
Odisha	21.51	24.49	32.07	33.99	12.73	10.68	66.31	69.16	**23.95**	**24.19**
Sikkim	0.00	0.00	0.06	0.06	0.04	0.04	0.10	0.10	**0.04**	**0.04**
Uttar Pradesh	0.87	0.87	0.20	0.20	0.00	0.00	1.06	1.06	**0.38**	**0.37**
West Bengal	11.75	11.75	13.03	13.13	5.07	5.07	29.85	29.95	**10.78**	**10.48**
All India Total	**109.80**	**114.00**	**130.65**	**137.47**	**36.36**	**34.39**	**276.81**	**285.86**	**100.00**	**100.00**
Distribution (%)	**39.67**	**39.88**	**47.20**	**48.09**	**13.13**	**12.03**	**100.00**	**100.00**		

Figure 11: State wise estimated reserves of coal in India as in march 2011 (Ministry of Coal, 2014)

(In billion tonnes)

States/ UTs	Proved		Indicated		Inferred		Total		Distribution (%)	
	31.03.2010	31.03.2011	31.03.2010	31.03.2011	31.03.2010	31.03.2011	31.03.2010	31.03.2011	31.03.2010	31.03.2011
Gujarat	1.24	1.24	0.26	0.32	1.16	1.16	2.66	2.72	**6.67**	**6.66**
Jammu & Kashmir	0.00	0.00	0.02	0.02	0.01	0.01	0.03	0.03	**0.07**	**0.07**
Kerala	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	**0.02**	**0.02**
Puducherry	0.00	0.00	0.41	0.41	0.01	0.01	0.42	0.42	**1.04**	**1.02**
Rajasthan	1.17	1.17	2.14	2.15	1.50	1.52	4.80	4.84	**12.04**	**11.82**
TamilNadu	3.74	3.74	22.52	22.90	5.72	6.26	31.98	32.89	**80.15**	**80.41**
India	**6.15**	**6.15**	**25.34**	**25.79**	**8.41**	**8.97**	**39.90**	**40.90**	**100.00**	**100.00**
Distribution (%)	**15.40**	**15.02**	**63.52**	**63.06**	**21.07**	**21.92**	**100.00**	**100.00**		

Source:Office of Coal Controller, Ministry of Coal

Figure 12: State wise estimated reserves of lignite in India as in march 2011 (Ministry of Coal, 2014)

The coal and lignite reserves are mainly in the middle and east of India. This is a big problem because much of the coal is needed elsewhere. This induces high transport costs and uses limited railway road capabilities.

4.7.2 PETROLEUM AND NATURAL GAS

India has significant of crude oil and natural gas reserve. In march 2011 the estimated reserves where around 757 million tones for crude oil and 1241 billion cubic meters of natural gas. For the statewise distribution see the table below. (Minestry of Power, 2014)

States/ UTs	Crude Petroleum (million tonnes)				Natural Gas (billion cubic metres)			
	31.03.2010		31.03.2011		31.03.2010		31.03.2011	
	Estimated Reserves	Distribution (%)	Estimated Reserves	Distribution (%)	Estimated Reserves	Distribution (%)	Estimated Reserves	Distribution (%)
Andhra Pradesh	3.94	**0.51**	5.23	**0.69**	41.24	**3.59**	40.58	**3.27**
Arunachal Pradesh	3.49	**0.45**	3.39	**0.45**	1.10	**0.10**	1.08	**0.09**
Assam	168.10	**21.70**	170.34	**22.49**	95.20	**8.29**	93.64	**7.55**
CBM	0.00	**0.00**	0.00	**0.00**	39.83	**3.47**	97.63	**7.87**
Eastern Offshore[1]	26.52	**3.42**	26.19	**3.46**	420.44	**36.61**	438.03	**35.30**
Gujarat	136.67	**17.64**	137.42	**18.14**	76.57	**6.67**	78.97	**6.36**
Nagaland	2.69	**0.35**	2.69	**0.36**	0.12	**0.01**	0.12	**0.01**
Rajasthan	80.48	**10.39**	75.33	**9.95**	12.47	**1.09**	12.04	**0.97**
Tamil Nadu	7.84	**1.01**	8.49	**1.12**	34.27	**2.98**	36.88	**2.97**
Tripura	0.08	**0.01**	0.08	**0.01**	32.78	**2.85**	33.09	**2.67**
Western Offshore[2]	344.85	**44.52**	328.27	**43.34**	394.55	**34.35**	408.88	**32.95**
Total	**774.66**	**100.00**	**757.44**	**100.00**	**1148.57**	**100.00**	**1240.92**	**100.00**

CBM : Cold Bed Methane

@ Proved and indicated Balance Recoverable Reserves.

1 Includes JVC/Pvt. Parties for Crude Oil and includes West Bengal for Natural Gas

2 Includes Bombay High offshore, Rajasthan and JVC for Crude Oil and Bombay High offshore, Rajasthan and Madhya Pradesh (Coal Bed Mathane) for Natural Gas

Source: Ministry of Petroleum & Natural Gas

Figure 13: State wise estimated reserves of crude oil and natural gas on march 2011 (Ministry of Petroleum & Natural Gas, 2014)

The crude oil is mainly located in the western offshore, The natural gas are mainly on the east shore and west shore.

1.1.4 Uranium

Large deposits of natural uranium have been found in March 2011. The Atomic Minerals Directorate for Exploration and Research of India, which explores uranium in the country, has so far discovered 49,000 tons of natural uranium in just 15 kilometers and there are indications that the total quantity could be three times that. This significantly opens up possibilities for India's nuclear program. Currently India imports most of its uranium usage. (Minestry of Power, 2014)

4.7.3 Renewable energy sources

There is high potential for generation of renewable energy from various sources like wind, solar, biomass and small hydro generation. The total potential for renewable power generation in the country as of march 2011 is estimated at 89760 MW. See the table below for the state wise distributions.

(in MW)

States/ UTs	Wind Power	Small Hydro Power	Biomass Power	Cogeneration-bagasse	Waste to Energy	Total	
						Estimated Reverses	Distribution (%)
1	2	3	4	5	6	7	8
Andhra Pradesh	5394	560	578	300	123	6955	7.75
Arunachal Pradesh	201	1329	8	0	0	1538	1.71
Assam	53	239	212	0	8	512	0.57
Bihar	0	213	619	300	73	1205	1.34
Chhattisgarh	23	993	236	0	24	1276	1.42
Goa	0	7	26	0	0	33	0.04
Gujarat	10609	197	1221	350	112	12489	13.91
Haryana	0	110	1333	350	24	1817	2.02
Himachal Pradesh	20	2268	142	0	2	2432	2.71
Jammu & Kashmir	5311	1418	43	0	0	6772	7.54
Jharkhand	0	209	90	0	10	309	0.34
Karnataka	8591	748	1131	450	151	11071	12.33
Kerala	790	704	1044	0	36	2574	2.87
Madhya Pradesh	920	804	1364	0	78	3166	3.53
Maharashtra	5439	733	1887	1250	287	9596	10.69
Manipur	7	109	13	0	2	131	0.15
Meghalaya	44	229	11	0	2	286	0.32
Mizoram	0	167	1	0	2	170	0.19
Nagaland	3	189	10	0	0	202	0.23
Odisha	910	295	246	0	22	1473	1.64
Punjab	0	393	3172	300	45	3910	4.36
Rajasthan	5005	57	1039	0	62	6163	6.87
Sikkim	98	266	2	0	0	366	0.41
Tamil Nadu	5374	660	1070	450	151	7705	8.58
Tripura	0	47	3	0	2	52	0.06
Uttar Pradesh	137	461	1617	1250	176	3641	4.06
Uttaranchal	161	1577	24	0	5	1767	1.97
West Bengal	22	396	396	0	148	962	1.07
Andaman & Nicobar	2	7	0	0	0	9	0.01
Chandigarh	0	0	0	0	6	6	0.01
Dadar & Nagar Have	0	0	0	0	0	0	0.00
Daman & Diu	0	0	0	0	0	0	0.00
Delhi	0	0	0	0	131	131	0.15
Lakshadweep	16	0	0	0	0	16	0.02
Puducherry	0	0	0	0	3	3	0.00
Others*	0	0	0	0	1022	1022	1.14
All India Total	**49130**	**15385**	**17538**	**5000**	**2707**	**89760**	**100.00**
Distribution (%)	**54.73**	**17.14**	**19.54**	**5.57**	**3.02**	**100.00**	

* Industrial waste
Source: Ministry of New and Renewable Energy

Figure 14: State wise estimated potential of renewable energy as of march 2011 (Minestry of new and renewable energy, 2014)

The geographical distribution of the renewable energies needs to be carefully studies to see the usefulness of certain resources.

For hydropower the new potentially is mainly in the mountains in the north of India.

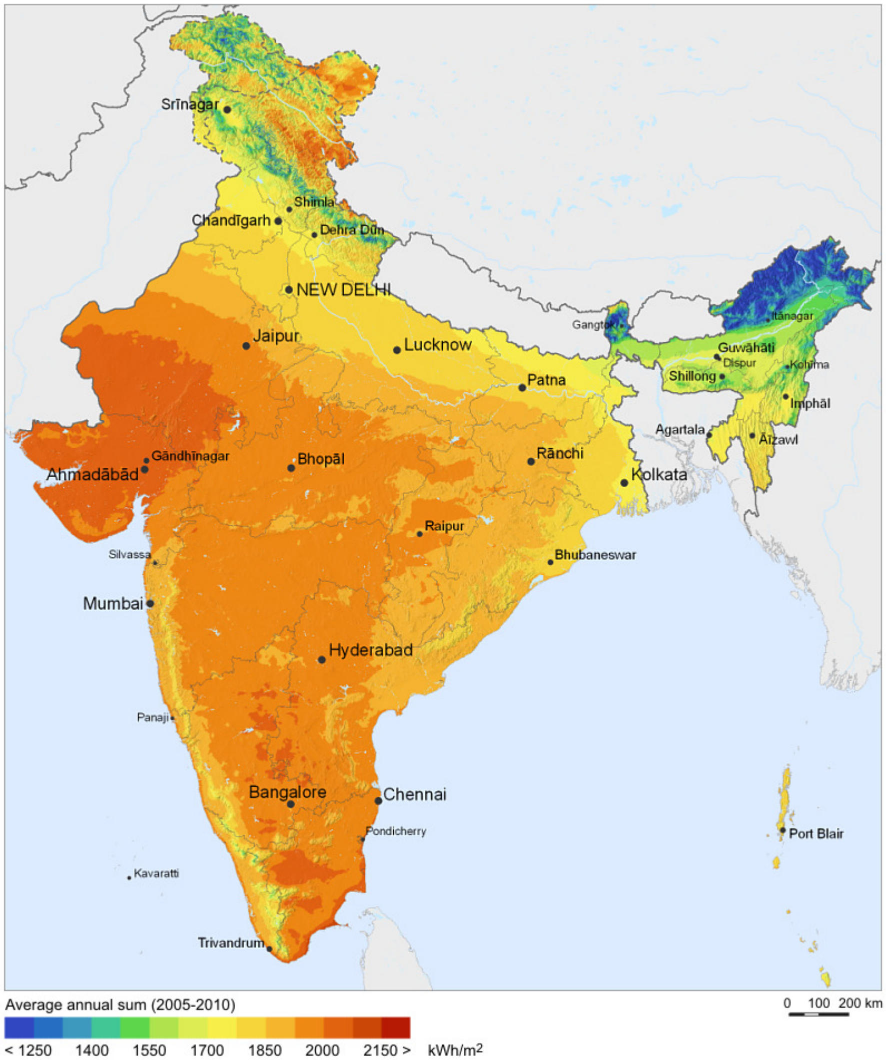


Figure 15: solar irradiance in india (Geomodel solar, 2010)

For solar power the best place would be in the west of india. This part has the highest solar irradiation.

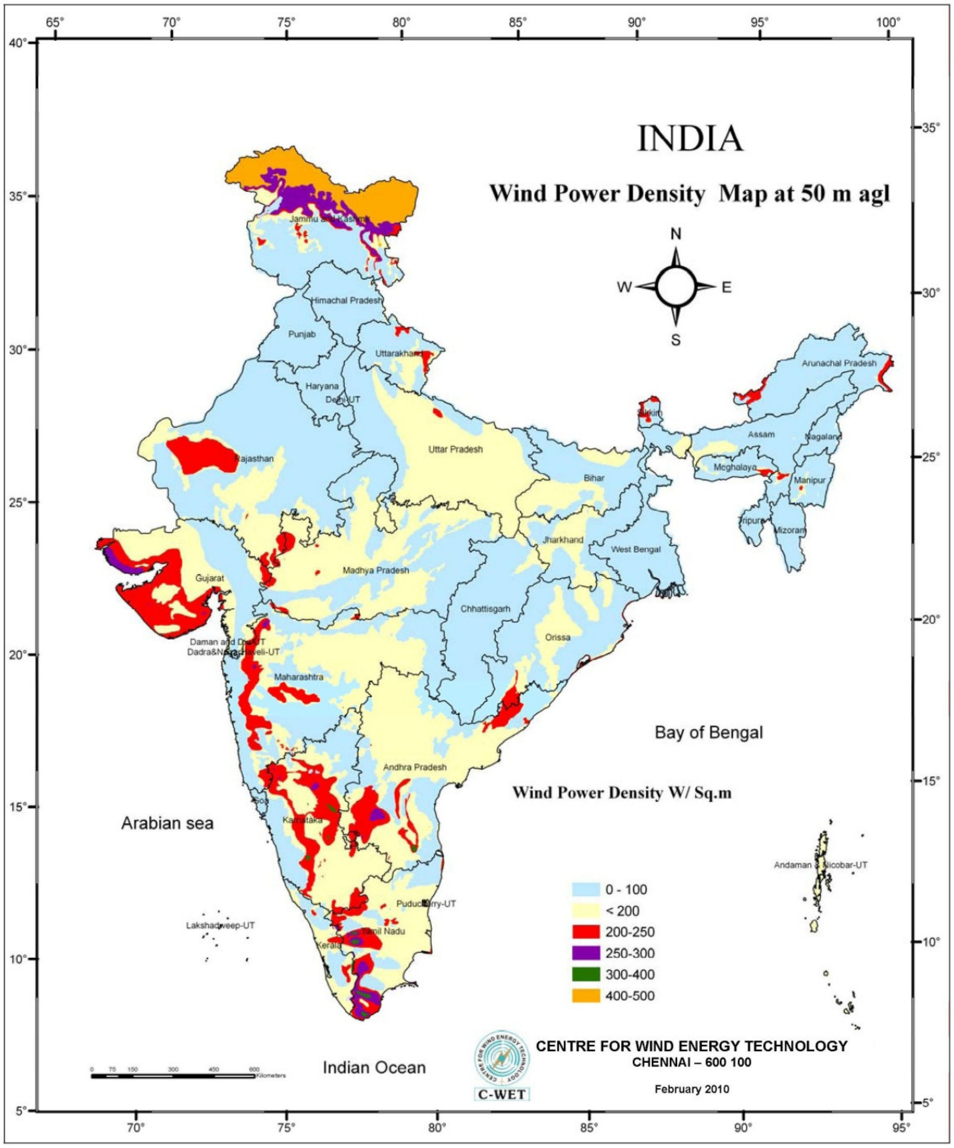


Figure 16: wind power density in india (Center for wind energy techonolgy, 2010)

For wind the main resources would be near the ocean

5 PHOTOVOLTAIC TECHNOLOGY IN INDIA

India has the potential to generate 35MW per square kilometer using solar photovoltaic and solar thermal energy. The currently generate electricity is 210.951 GW as of December 2012, from where 33% is generated from renewable energy (nuclear 0,02%, hydro 19%) (Central Electricity Authority, Central Electricity Authority, 2013). Most parts of India receive 4–7 kWh/m2 of solar radiation with 2300 to 3200 hours sun per year. The highest annual energy is received in Western Rajasthan while the North- Eastern region of the country receives the lowest annual radiation. In 2012 about 40% of households in India have no lighting. (Minestry of Power, 2014)

The goal of this chapter is to give an overview of all the important actors that influence the development of PV. This information will give a broad overview of the PV innovation system.

Bellow a overview is shown of all the stakeholders that are of importance in the solar energy market on governmental level. Not included is the industry that make the solar panels and additional equipment.

<table>
<tr><th></th><th colspan="2">Central Government</th><th>State</th><th>Private</th></tr>
<tr><td>Policy</td><td colspan="2">MoP, MNRE</td><td>State governments</td><td>-</td></tr>
<tr><td>Planning</td><td colspan="2">CEA</td><td>SEB</td><td>-</td></tr>
<tr><td>Regulation</td><td colspan="2">CERC</td><td>SERCs</td><td>-</td></tr>
<tr><td>Generation</td><td colspan="2">National generation utilities</td><td>State generation utilities</td><td>Independent power producers</td></tr>
<tr><td>Transmission</td><td>-</td><td rowspan="2">Power Grid Corporation of India Limited</td><td>State transmission utilities</td><td>Increasing number of private service providers</td></tr>
<tr><td>Execution</td><td>Regional load dispatch centers</td><td>State load dispatch centers</td><td></td></tr>
<tr><td>Distribution</td><td colspan="2">-</td><td>State distribution utilities</td><td>Small number of private service providers</td></tr>
<tr><td>Trade</td><td colspan="2">PTC India Ltd.
Licensee</td><td>Licensee</td><td>Licensee</td></tr>
<tr><td>Law</td><td colspan="4">Appeal tribunal</td></tr>
</table>

Figure 17: stakeholders in the Indian Power Market (Ministry of Power, Ministry of Power, 2014)

5.1 POLICIES

The biggest need in the Indian energy sector is to improve management of the power sector, especially governance of distribution entities. In 2006 Nearly 40% of energy supplied into the transmission systems is lost, not billed, incorrectly billed, or the payment not collected. in 2012 it's 22% (Electrical monitor, 2013) while other countries have around 15% (World bank, 2014). Given these major challenge, enhanced governance is the key to improve the power sector (World bank, 2014). The prices of PV technology are dropping due to global investment into this technology. The government of India has set up its own system to promote PV technology en enhance its development. The governmental institutions responsible for PV are described below

Organization	Scope of Work
Ministry of Power	Overall responsibility for power sector planning and investment.
Bureau of Energy Efficiency	Established to reduce energy intensity in the Indian economy by spearheading the improvement of energy efficiency through various regulatory and promotional instruments.
Ministry of New and Renewable Energy	Responsible for development, demonstration and investment in renewable energy-based technologies.
Indian Renewable Energy Development Agency	Promotion, development and extension of financial assistance for renewable energy.
Bureau of Indian Standards	Operates a product certification program.
Ministry of Environment and Forests	The nodal agency for the planning, promotion, coordination and overseeing the implementation of environmental and forestry programs
Central electricity authority	The CEA is responsible for the technical coordination and supervision of energy programs and is also entrusted with a number of statutory functions
Central Electricity Regulatory Commission	Promotes efficiency, economy and competition in bulk electricity supply, generation and transmission for interstate transmissions

Table 7: Key governmental PV institutions (Ministry of New & Renewable Energy, 2014)

India's long term energy policy is described by the 'Integrated Energy Policy Report'. The Renewable Energy Plan hereby is an achievement of 10 % renewable energy. In addition to the grid-connected renewable energy goal, other initiatives include, installment of 1 million household solar water heating systems, the electrification by renewable mini-grids for 24,000 villages without electricity, deployment of 5 million solar lanterns and 2 million solar home lighting systems and establishment of an additional 3 million small biogas plants. (Government of India, 2006)

In 2003 the government transformed the energy market by liberalization it. After that, it added new policies to improve the chance of new technologies and make the system more efficient. In Table 8 a list of the most important policies are given. (Singh, 2006).

Year	Policy	Goal
2003	Electricity act, by government	Legislates a comprehensive reform and liberalization process for the power sector
2005	National electricity policy, by CERC	Provides guidelines for accelerated development of the power sector
2006	Rural electrification policy, by MoP	Establishes a national goal for universal access, assigns responsibilities for implementation, and creates new financing arrangement
2006	National tariff policy, by CERC	Provides guidance on establishing power purchase tariffs by State Electricity Regulatory Commissions
2006	Integrated Energy Policy Report, by the planning commission	Plan to reliably meet the demand for energy services for all sector.

2009	Jawaharlal Nehru National Solar mission, by MNRE	To promote ecologically sustainable growth while addressing India's energy security challenges
2010	Clean energy fund, by government	Imposes a tax per tonne of coal and will be spent on the development of Renewable energy Technology.

Table 8: Key PV policies (Minestry of new and renewable energy, 2014)

5.1.1 JAWAHARLAL NEHRU NATIONAL SOLAR MISSION,

Officially launched in November 2009 this is the most important policy for PV. It aims to incentivize the installation of 22,000 MW of on- and off-grid solar power using both Photovoltaic (PV) and Concentrated Solar Power (CSP) technologies by 2022, as well as a large number of other solar applications such as solar lighting, heating, and water pumps. As the power trading arm of the National Thermal Power Corporation, NTPC Vidyut Vyapar Nigam Ltd (NVVN) has been designated as the nodal agency to ensure the execution of Phase 1 of the mission The Solar Mission will be implemented in three stages, with specific targets defined for the respective segments. (Ministry of new and renewable energy, 2014)

Application segment	Phase I (2010-2013)	Phase II (2013-2017)	Phase III (2017-2022)
Solar collectors	7 million m^2	15 million m^2	20 million m^2
Off grid solar applications	200 MW	1,000 MW	2,000 MW
Utility grid power, including roof top	1,000 - 2,000 MW	4,000 - 10,000 MW	20,000 MW

Source: (Ministry of new and renewable energy, 2014)

5.1.1.1 Phase 1

The focus during Phase 1 is to experiment with incentive structures and to create a market for solar power in India by bringing in investors, engineer-procure-construct (EPC) contractors, and equipment manufacturers. Both on- and off-grid projects will be promoted during this phase with the expectation that 500 MW of grid-connected and 200 MW of off-grid solar PV will be installed. (Ministry of new and renewable energy, 2014)

The allocation of 500 MW of grid-connected PV projects will be decided in two batches. The first will be in financial year 2010–2011 and the second in financial year 2011–2012. The first batch will allocate 150 MW. Under migration guidelines, projects migrating from older incentive schemes to newer ones should be selected prior to new projects. If applications exceed 150 MW, projects will be chosen based on the discount offered by project developers on the CERC tariff. Under the second batch, additional projects will be selected up to 350 MW of remaining capacity. Projects will feed into the grid at 33 kV or above. Individual projects will have a capacity maximum of 5 MW (± 5%), and each company can only apply for one PV project under Phase 1 (but can also apply for one CSP project). (Ministry of new and renewable energy, 2014)

Applying for a project under Phase 1 of JNNSM requires a company to have an audited net worth of at least INR 30 million (USD 600,000) per MW of a project's installed capacity or INR 150 million (USD 3 million) for a 5 MW project in at least one of the last four financial years. A company must provide a "Bid Bond," or third-party guarantee, per megawatt for any discount on the offered tariff. The higher the discount, the higher the amount of the bond, ranging between INR 10,000 (USD 200) and

INR 50,000 (USD 1,000) per MW on a graded scale. Furthermore, the company must provide an earnest money deposit (EMD) in the form of a bank guarantee of INR 2 million (USD 40,000) per MW along with the initial request for selection and, later, a performance bank guarantee of INR 3 million (USD 60,000) per MW at the time of signing the PPA. A project shall achieve financial closure within 180 days before the signing and must be commissioned within 12 months after the signing of the PPA. To ensure PV module quality, modules proposed for the project must qualify to the latest edition of the following International Electrotechnical Commission (IEC) PV module qualification test or equivalent from the Bureau of Indian Standards: for crystalline silicon solar cell modules—IEC 61215; for thin-film modules—IEC 61646; and for concentrator PV modules—IEC 62108. For the first batch of Phase 1, it will be mandatory for projects using crystalline silicon technology to use modules manufactured in India. (Ministry of new and renewable energy, 2014)

5.1.1.2 Phase 2

During Phase 2, the goal is to build on the experience of Phase 1 to facilitate a substantial increase in capacity additions, significantly bring down the cost per kilowatt-hour, and achieve additional installations of 3,000–10,000 MW of combined PV and CSP capacity. JNNSM identifies the need for international support in the form of technology transfer and financial assistance in order to meet the higher goal. The central government will work to create a favorable environment for solar manufacturing, particularly for solar thermal technology manufacturing. By 2017, the goal is for the installation of 15 million m2 of solar thermal collector area and for off-grid solar capacity to reach 1,000 MW. For Phase 2, it will be mandatory to use cells and modules manufactured in India. (Ministry of new and renewable energy, 2014)

5.1.1.3 Phase 3

Solar power is expected to achieve grid parity by 2022 through the final goals of the JNNSM: off-grid solar capacity installations will reach 2,000 MW, on-grid capacity will reach 20,000 MW, 20 million m2 of solar thermal collector area will be installed, and 20 million solar lighting systems will be deployed in rural households. (Ministry of new and renewable energy, 2014)

5.1.2 State level initiatives

The State Electricity Boards and respective agencies for renewable energy at the state level, play a key role in implementation at a state level. Independent of national efforts, states are promoting solar power. Gujarat, for example, is promoting the installation of 350 MW solar PV by 2011. It offers a feed-in tariff of Rs. 15/kWh for the first 12 years and Rs. 5/kWh for the following 13 years. Prevailing tariffs for solar power across Indian states are shown in the table below.

State/agency	Order dated	Tariff period	Counter period	Tariff (Rs./kWh)
Chattisgarh	08.09.2008	Levelised for 10 years	08.09.2008 to 31.8.2018	Applicable for plants commissioned up to 31.12.2010 Tariff- Rs. 15.84/kWh Incentives to developer/licensees – Rs. 3.84/kWh
Gujarat	Draft order–23.07.2009	Levelised for 25 years		1–12 years of operation- Rs. 14.0/kWh 13–25 years of operation – Rs. 4.0/kWh
Haryana	25.04.2008			Applicable tariff for solar PV plants only commissioned up to 31.12.2009 – Rs. 15.96/unit 31.12.2010 – Rs. 15.16/unit Generation based incentive from State Government for plants commissioned up to 12.2009 – Rs. 12.00/unit 12.2009 – Rs. 11.40/unit Only net rate after deducting incentive amount shall be payable by distribution companies Tariff to remain constant for period of 5 years
Kerala	Draft regulation 2008–27.08.2008	Levelised tariff for 10 years		Tariff – Rs. 15.18/kWh Developer to provide energy to the distribution companies at Rs. 3.18/kWh (for 10 years) and collect incentive at Rs. 12/kWh from IREDA
Maharashtra	08.05.2009	10 years		Applicable for plants commissioned up to 31.03.2010 and under Generation Based Incentive scheme Tariff under GBI scheme – Rs. 3/kWh Max. incentive to the project developer – Rs. 12/kWh
Rajasthan	Regulation, 2009–23.01.2009	10 years		Total tariff inclusive of generation incentive COD upto 31.12.2009 15.78 31.12.2010 15.18 Applicable for 10 years only PPA can be executed for life of plant
Tamil Nadu	11.07.2008	10 years		Rate for procurement of power by distribution companies: COD up to 31.12.2009 3.15 Max. incentive of Rs. 12/kWh is admissible for COD up to 31.12.2009
Uttar Pradesh	Draft regulation- 09.09.2009	20 years	5 years	For plants covered under MNRE scheme and commissioned up to 31.12.2009, Max, incentive – Rs. 12/kWh Projects commissioned after 31.12.2009 – Rs. 11.40/kWh For plants not covered under GOI incentive scheme- Rs. 15/kWh
Uttarakhand	Draft regulation 2009 – 30.12.2009	20 years	2009–2010 to 2012–2013	For plants commissioned up to 31.03.2010: Rs. 17/kWh

Figure 18: Regional tarief in india (Minestry of new and renewable energy, 2014)

5.2 INDUSTRY

As of September 2013 the Indian industry consist of around 83 PV module companies, with 2 GW installed capacity, 15 solar cells companies , with 700 MW installed capacity and manufacturing of various raw materials, components, devices and systems is coming up. (Ministry of New & Renewable Energy, 2014). The India development has a lagging domestic PV industry, with five of the top ten PV module suppliers coming from China. (Bridge to India, 2013). Vikram solar is the only Indian manufacturer to feature in the top 10. In crystalline modules, Canadian solar has the highest market share. About only 18% market is catered by the domestic manufacturers. Around 42% of the modules installed are thin film. Most module developers import cell from china because they are cheaper and better. (Indian times, 2012)

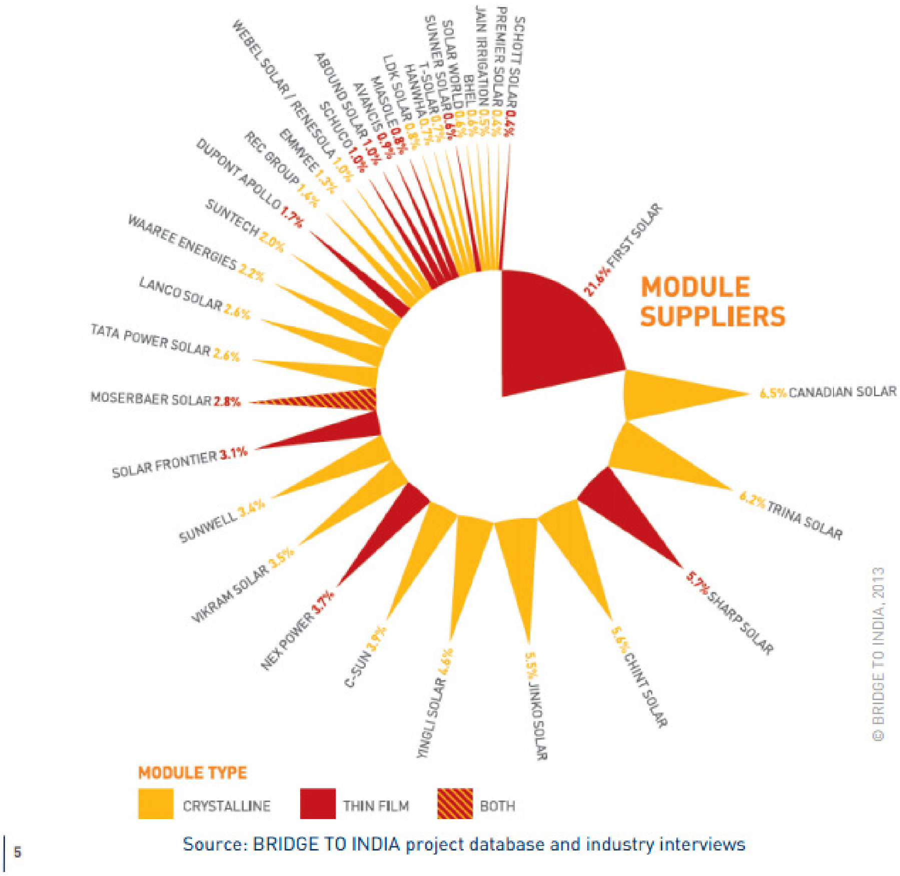


Figure 19: Market share PV modules (Bridge to India, 2013)

As for the engineering, procurement and construction (EPC),. In the start phase, you saw many companies jumping in the PV industry to make some fast money. Some project developers they claim that the government is slowing down there project by excessive permit waiting times. The engineering, procurement and construction division of India’s solar market is 40% dominated just three EPC companies, Moserbaer, Welspun Urja and Lanco Solar. (Bridge to India, 2013)

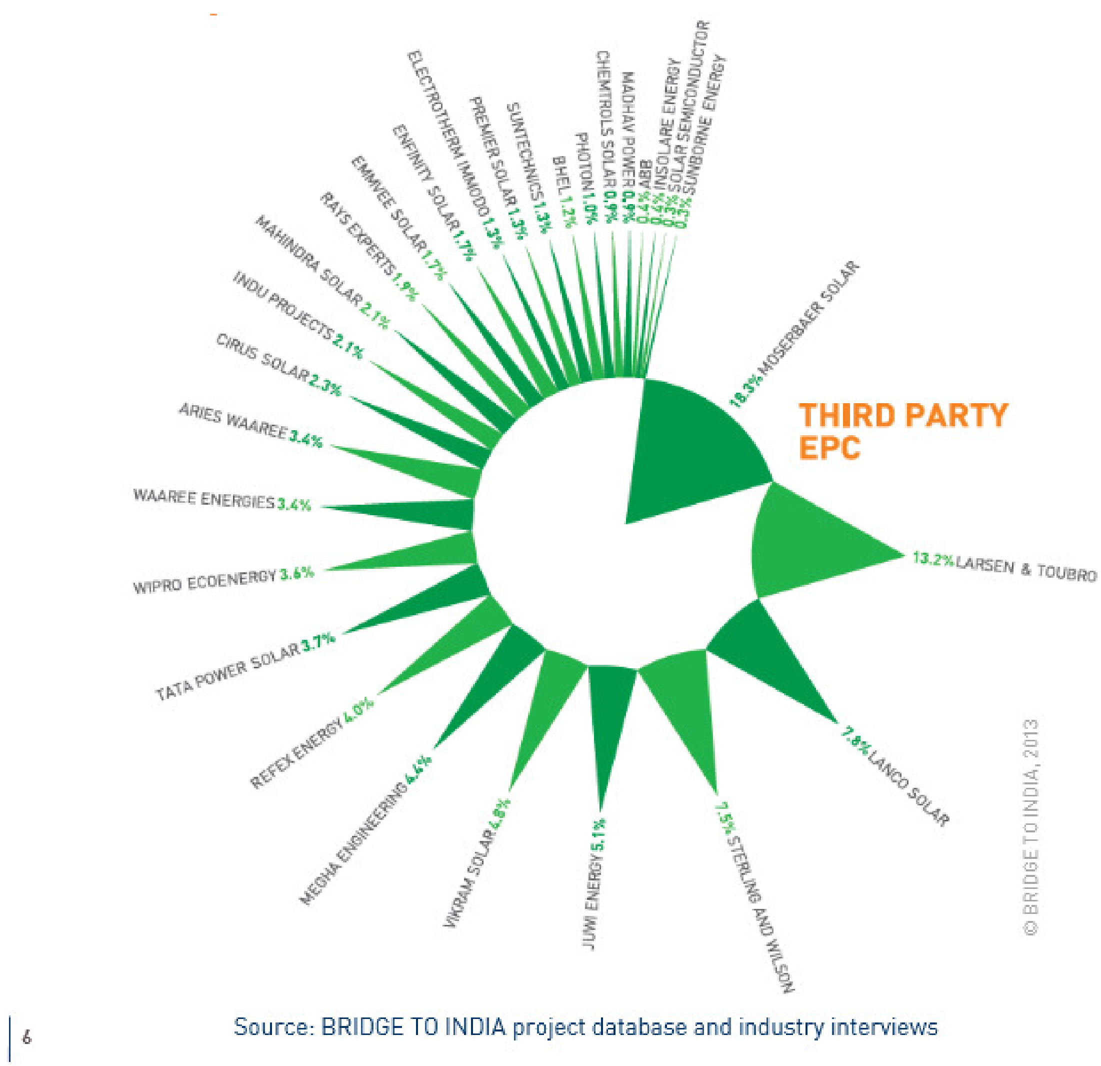


Figure 20: Market share EPC . (Bridge to India, 2013)

Inverters are an important part of the PV industry. The invert supplies are dominated by two companies which supply almost 50% of all inverter supplies to India. Namely SMA and Bonfiglioli

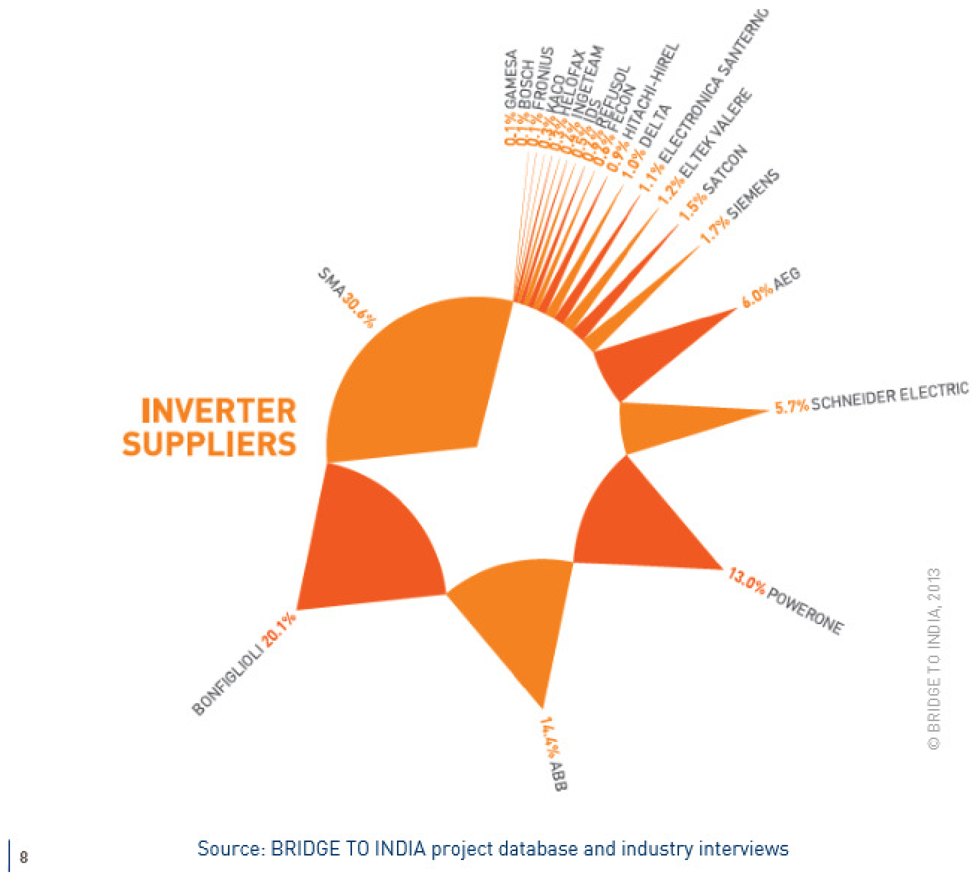


Figure 21: Marketshare inverter suppliers . (Bridge to India, 2013)

5.3 RESEARCH

Through the JNNSM, the government has set specific research goals for de research in PV. The outcome of the research should lead to improvements in the efficiencies, reduction in the material and energy consumption in manufacturing or improving the reliability, quality and life expectancy of the balance of system components. India focuses on goal driven research, mainly in the field of materials for solar cells. Much attention is being put on reducing the cost of pv cells, decreasing uncertainty and raising the efficiency of the overall system. In order to realize these goals the R&D strategy would comprise dealing with five categories (Ministry of new and renewable energy, Jawaharlal Nehru National Solar Mission, 2012):

- Basic research having long term perspective for the development of innovative and new materials, processes and applications
- Applied research aimed at improvement of the existing processes, materials and the technology for enhanced performance, durability and cost competitiveness of the systems/ devices,
- Technology validation and demonstration projects aimed at field evaluation of different configurations including hybrids with conventional power systems for obtaining feedback on the performance, operability and costs

- Development of R&D infrastructure in public and private partnerships
- Support for incubation and startups.

Two of the most important PV research institutions of India for PV are TERI and The National Centre for Photovoltaic Research and Education (NCPRE). The objective of the Indian government is to be one of the leading PV research and education centers in the world within the next decade. Under TERI there also is a Solar Energy Centre which will be the lead Centre for testing and training in solar energy in the country. Recent initiatives in the PV R&D sector are: (Ministry of new and renewable energy, 2014)

- Development of poly silicon material
- 20 - 22% efficiency single crystal silicon cells
- 10 - 12% efficiency Nano crystalline thin film modules
- 12- 15% efficiency CIGS cells
- 10- 12 % efficiency Dye sensitized cells
- 6% efficiency organic-inorganic hetero junction cells
- Long term performance evaluation and training facility for Grid Solar PV Power
- Long term performance evaluation and testing of solar
- Long term performance evaluation of PV modules at SEC
- Development of batteries
- Development of inverters

5.4 FINANCING

Solar projects in India struggle to obtain debt finance. Only a small percentage of projects have attained non-recourse financing. Most have worked with either limited recourse or full recourse finance. Below is shown how a typical project cash flow goes.

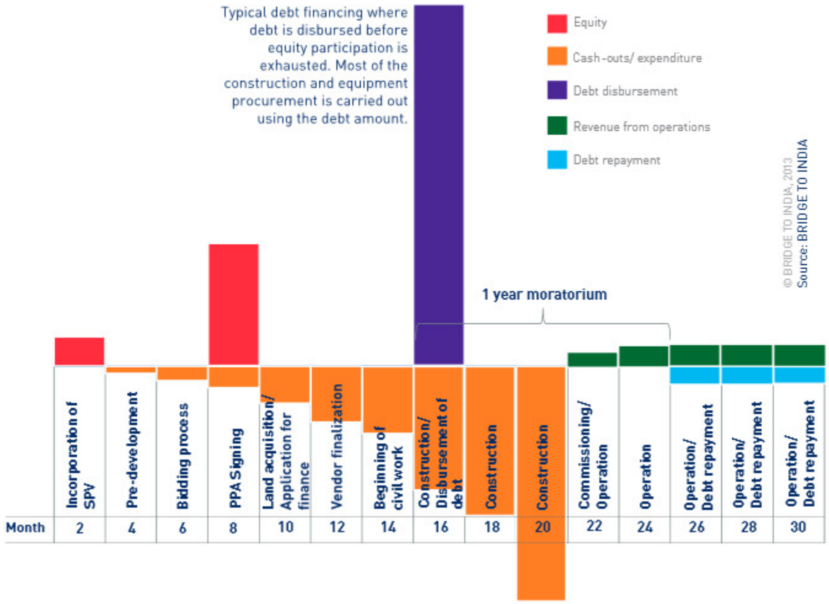


Figure 22: Typical project cash flow on a timeline . (Bridge to India, 2013)

For a developer to get a project he has to offer a feed in tariff, The project developer with the lowerst fede in tariff gets the projects. Currently this happens with reverse auction, it is expected that this will change to Viability Gap Funding in the future due to limited governmental resources.

* Levelized tariff has been calculated considering 5% escalation for 10 years.

Figure 23: Average tariffs . (Bridge to India, 2013)

Requirement	Timeline

PPA	For most projects under the policies, a pre-development and bidding process takes upto eight months. During this, developers need to discuss their projects with possible lenders to understand the interest rates that can be made available through a single source or a syndicated source (rupee loan, foreign currency loan or a combination). The interest rate will have a significant impact on the feed-in tariff that can be proposed.
Land	A clear holding of land is necessary for the loan to be processed. Typically,it takes up to three months to get a free holding of the land. This can be faster if the land is in a solar park.
EPC letter of intent	The EPC needs to have assessed the land and signed an LOI that will be submitted to the lender to begin the application process. During the course of the lending application process, the EPC will need to submit the final drawings and plans. This takes atleast another one month. The lender's counsel then scrutinizes all the documents, including the technical drawings and plans. This can take up to another one month.

Figure 24: typical project cash flow . (Bridge to India, 2013)

Banks that provided non-recourse financing are either Indian commercial banks or international lenders with a development mandate. There are several reasons why non-recourse finance is difficult to obtain.

- debt recovery and the legal enforceability of claims in India in general.
- Limited availability of irradiation data, which forms the basis for projecting future revenues.
- the strength of public power purchasing agreements (PPAs) due to the weak financial health of india's public utilities

First movers in terms of financing solar projects in India have been Bank of Baroda, Axis Bank, ICICI Bank, State Bank of India, IDBI Bank and Yes Bank with a interest rate between 10 and 14. (Bridge to India, 2013)

Prominent non-banking financial companies (NBFCs) that are open to financing solar projects include: L&T Infrastructure Finance Company (subsidiary of L&T Financing Holdings), Power Finance Corporation (PFC), Mahindra Finance, IDFC, IL&FS, SBI Capital Markets and Indian Renewable Energy Development Agency (IREDA) with interest rate between 12 and 13. (Bridge to India, 2013))

For small projects Under a scheme, banks may extend subsidized loans to entrepreneurs at interest rates not exceeding five per cent. In addition, exemption of excise duty on procurement of transmission equipment for initial setup of solar power plant are available (Indian Renewable Energy Development Agency, 2014).

For small PV installation in rural areas, people can get a subsidy up to 90% of the total cost + 5 year maintenance cost. This is part of the rural area development plan. To get this subsidy you have to get a special permit, which is not easy to obtain. (Indian Renewable Energy Development Agency, 2014)

6 MULTI-LEVEL PERSPECTIVE ANALYSIS

In this chapter, an overview is giving on external factors influencing the Energy industry of India with relation to the PV Market. The purpose of this multi-level perspective analysis is to understand what indicators influence the integration of the niche technology PV into the regime.

6.1 LANDSCAPE ANALYSIS

As explained in the theoretical chapter The Landscape level contains all external factors that influence the regime. (Geels, 2002). In this paragraph, we research the landscape factors as indicated in the paper by Bree. (Bree, 2010)

6.1.1 ENERGY PRICES

Electricity prices are always on the move due to global and local disturbances. Most of the conventional energy resources that are used for electricity generation are increasing in prices. This is worrisome for the India energy regime since it wants to supply affordable energy to its population. On one hand, the prices of energy are increasing, particularly for petroleum products and electricity. On the other hand, the depreciation of the Rupee has led to a situation where the prices are not only likely to stay high, but also can rise further. (International Energy Agency, 2009)

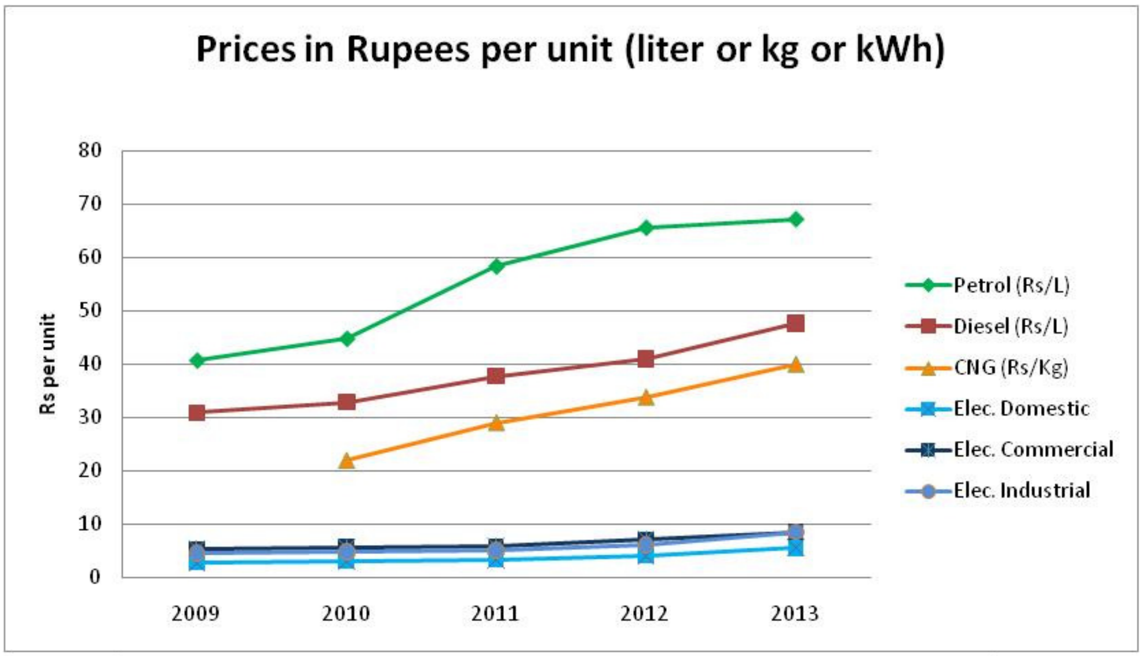


Figure 1: Energy Prices have seen a significant rise in India over the past five years
Data compiled from publicly available sources by Energy Efficiency Influence Team at Schneider Electric India Pvt. Ltd.

As seen in the image above the last few years the prices have increased significant. This is partly due to the high inflation of the Indian rupee. (International Energy Agency, 2009)

6.1.2 ENERGY SECURITY

Energy security is the association between national security and the availability of natural resources for energy consumption. Access to cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities.

Self-sufficiency or energy independence is a frequently occurring theme in the energy policy dialogue in India (Madan, 2006). This is a useful concept to understand India's approach to energy security. Although India adopted strategies of supply or fuel diversification to enhance energy security, it has placed a stronger emphasis on maximum utilization of domestic sources, including hydrocarbon, thorium and renewables. In 2007, former Indian President APJ Abdul Kalam announced an ambitious plan to realize energy independence based on hydro, nuclear and renewable energy (Indian times, 2012).

6.1.3 Environmental stresses

There is well-accepted recognition of the impacts of climate change among Indian policy makers and the public, although priority is given to economic and social development. India is a signatory to the United Nations Framework Convention on Climate Change, but is not obliged to contain its carbon emissions. Regarding international attempts to establish an internationally binding regime to curb carbon emissions, India finds it unacceptable, stating that most emissions were produced by developed countries and that India needs economic development and industrialization. India's per-capita emissions are only one-third of the world average and 14% of per-capita emissions of OECD member countries. India took a leading role in the G77 during the COP 15 in 2009, denouncing any attempt by industrialized countries to impose carbon reduction targets on developing countries. (International Energy Agency, 2009)

India is increasingly engaged in reducing carbon emissions and alleviating environmental degradation. India announced its National Action Plan on Climate Change in 2008, and during COP15 in Copenhagen in 2009, India's environment minister reconfirmed India's goal to reduce carbon emissions per unit of GDP by 20% to 25% below 2005 levels by 2020. Frequent flooding and droughts, deforestation and desertification as well as possible glacial melting in the Himalayas have focused on climate change and provide strong impetus towards India's transition to a low-carbon economy. (International Energy Agency, 2009)

6.1.4 Economic growth

With GDP of 1.847 billion US, India was the tenth largest economic in the world in 2011. In terms of PPP india ranked third. However, indias nominal per capital income remained much lower. (International Energy Agency, 2009)

The indian economy is moving toward a free market economy, with some remaining traced of the socialistic economy model. The economy has increased at an average rate of approximately 7% since 2000. (International Energy Agency, 2009)

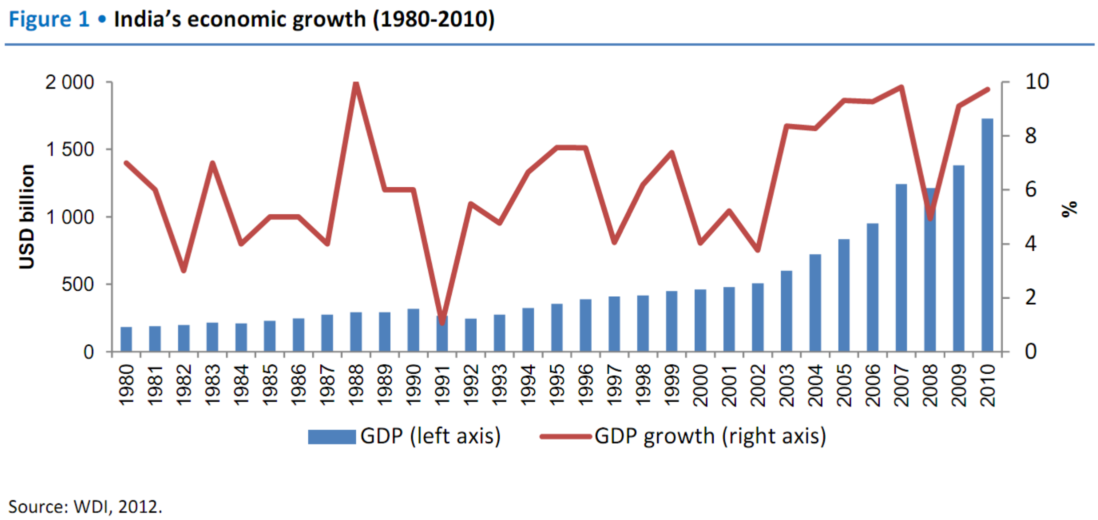


Figure 25: India's economic growth (worldbank, 2012)

Although there has been significant progress in human development through economic growth, India still has a long way to go. It ranked 134 out of 187 countries in the 2011 United Nations Human Development Index because of poor performance in the education and health indicators (United Nations Development Programme, 2011). Recent rapid economic growth reduced the absolute number of people living in poverty, but failed to achieve a balanced economic growth between rural and urban areas. For instance, 37.2% of the national population and 42% of the rural population live below the poverty line of USD 1.25 PPP, whereas 26% of the urban population is considered below the poverty line (United Nations Development Programme, 2011). The average urban monthly expenditure is nearly twice that of the rural level (International Energy Agency, 2009)

6.2 Regime Analysis

The regime level are existing sociotechnical systems in society with all societal actors involved, such as law makers, producers, consumers and suppliers etc. A Regime can be defined as a set of rules by which different social groups work which cannot be influenced by an individual group. The role of a regime is guidance of innovation processes. While regimes generate innovations that strengthen the regime, niches create and protect radical innovations, which may lead to destabilization and changes in the established regimes. (Markard & Truffer, 2008)

6.2.1 Electricity Demand

In 2009, India provided 74% of its total primary energy needs from domestic energy resources. Where around 60% comes from coal. This represents a high degree of self-sufficiency compared to other countries. However, primary energy imports are increasing yearly. (World bank, 2014)

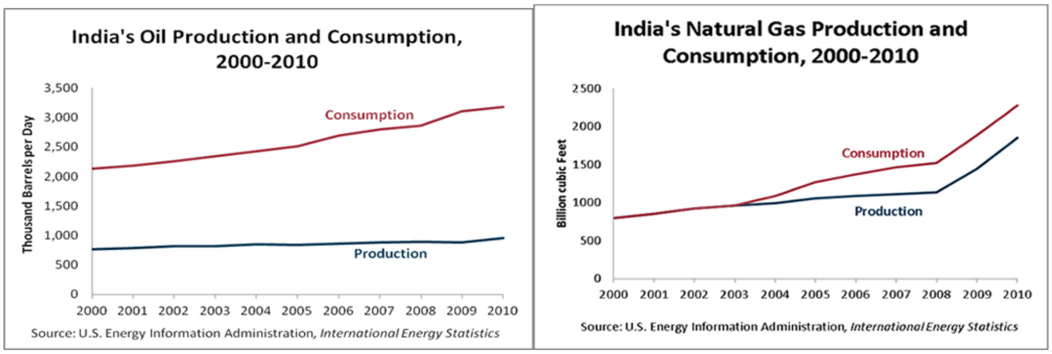


Table 9: Consumption and production of oil (Energy information administration, 2014)

shows the consumption per capita. You can see that with economic growth the average energy consumption increases. However electricity consumption varies allot per region. Where goa is using around 2000 and Mizoram around 450 kwh/capita.

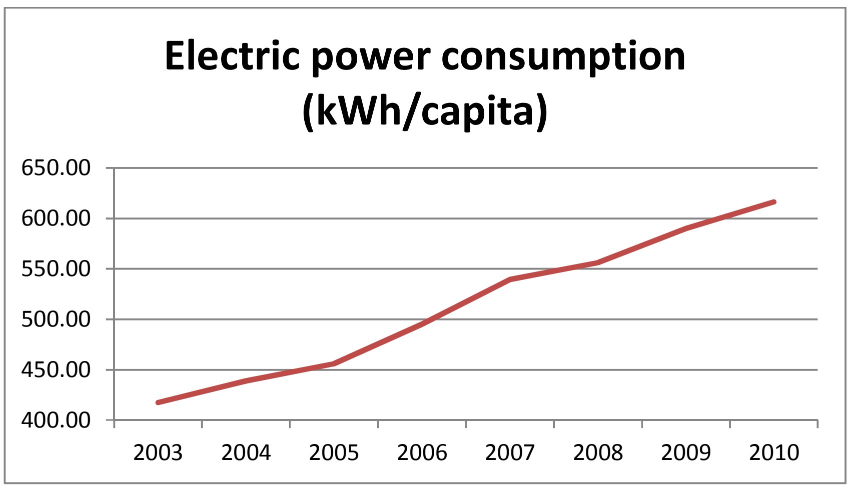


Table 10: electricity demand per capita (Energy information administration, 2014)

India's primary energy consumption per capita in 2007 was with 0.53 toe per capita (/cap) much lower than that of China (1.50 toe/cap) and also below the world average of 1.82 toe/cap. For electricity consumption the difference is even more pronounced: India's consumption of 543 kWh/cap was only one-fifth of the world average. If India keeps developing this way it does eventually it will reach the global average. (worldbank, 2012)

This development would be good for PV because if that much energy would be needed Solar would be a good option in the energy mix.

6.2.2 ELECTRICITY SUPPLY

The electricity sector in India had an installed capacity of 212.000 GW as of January 2013, 11.45% of which Renewable Capacity. India generated 855 TWh electricity during 2011-12. Coal-fired plants account for 56% of India's installed electricity capacity. After coal, renewable hydropower accounts for 19%, renewable energy for 12% and natural gas for about 9%. (Ministry of Power & Government of India, Power sector at a glance: All India data, 2012)

India currently suffers from a major shortage of electricity generation capacity. The International Energy Agency estimates India needs an investment of at least $135 billion to provide universal access of electricity to its population. (U.S. Energy Information Administration, 2011)

As of December 2011, India had an installed capacity of about 22.4 GW of renewal technologies-based electricity.

Natural gas production in February 2013 was 20% lower than a year ago. The government had a target of 3.19 billion cubic meters; production came in at 2.88 billion cubic meters (9.7% shortfall). A similar decline and shortfall for crude oil production was also reported. India imports about 80% of its crude oil requirements. (Econintersect, 2014)

Total installed power generation capacity of India

Fuel	MW	%
Total Thermal	119040.98	65.16
Coal	1,00,098.38	54.79
Gas	17,742.85	9.71
Oil	1,199.75	0.65
Hydro (Renewable)	38,706.40	21.18
Nuclear	4,780.00	2.61
Other- Renewables -SHP, BG, BP, U&I and Wind Energy	20,162.24	11.03
Total	**1,82,689.62**	**100**

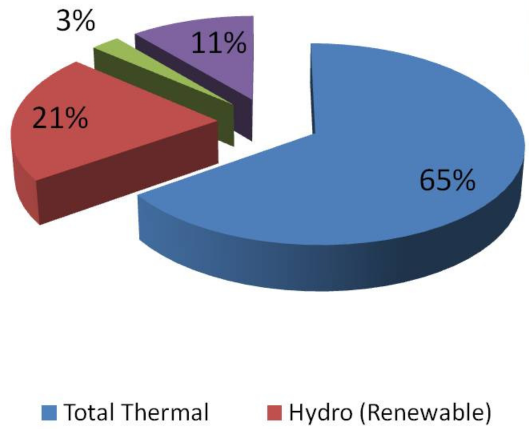


Figure 26: Total installed power generation (Green Clean Guide, 2014)

6.2.3 PRICE

One of the most important factors of a technology, In our current society where everything is measured through price, is its price per kwh. If a technology becomes cheaper than the current regime it will slowly take over the market. An example of this can already been seen in wind energy. Since most of the prices are determined by the global economy this is seen as a landscape factor.

For a price of a resource like PV influencing the regime it must become cheaper. The price is most fairly measured in levelized production costs. The levelized production costs of a kwh in 2009 is shown below. It must be noted that India is a huge country and that these costs have a high variability due to local conditions. In 2013 the levelized production cost for PV solar are 6.8 Rs/Kwh

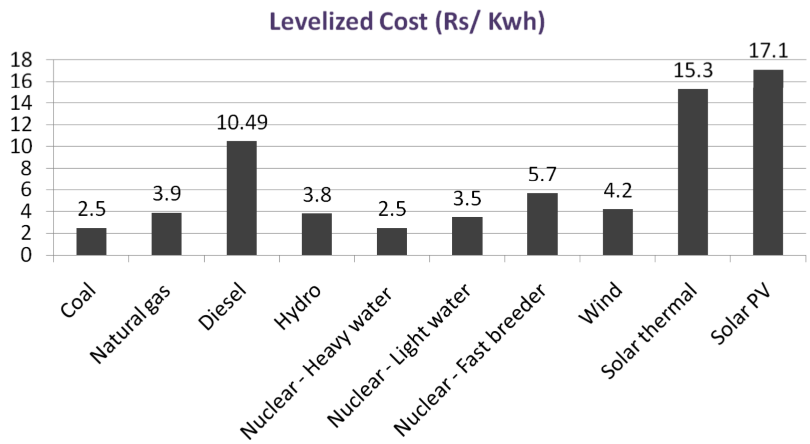


Figure 27: levelized production cost (2009) (Bridge to India, 2009)

It is also interesting to analyze which way the leveled production costs are moving. For this, we need to get an understanding how these prices became into being.

When analyzing coal, transport costs are important. Since India's coal reserves are not located to where the energy is needed, transport cost will be high. The rail transport costs of coal are going up. Also the quality of coal in India is fairly low, Containing much ash. It can be expected that due to stricter environmental regulation the price of coal will go up.

The price of oil and gas is a very global parameter; almost no one has control over this, it is a fine balance between supply and demand, It can be expected that supply will not increase greatly but demand will. Therefore it is expected that the price will go up.. The main trend between 2007and 2013 is that it is fluctuating between 60 and 100 dollar. India has some of its own reserves in this sector. Therefor it can compensate for extremely high prices, However since 2007 India has become an oil and gas importing instead of exporting country. The oil and gas price is in the end limited by competing technologies and some say this is at 150 dollar, however this is blunt speculation, and Oil cannot easily be replaced in every application.

For big PV installations, India uses auctions for its project developers where the lowest bids get the project. 2012 lowest bid was 7.5 rupee per kwh. (Power engineering int, 2014) The average was around 8.5 rupees (coal was around 3.5). Global solar power prices are plunging because of declining equipment costs and dumping of solar panels. KPMG LLP predicted in May 2013 solar power may be as cheap as coal by 2017. The government said in an August report that solar could reach grid parity by 2019 (Energy matters summit, 2014). It must be noted that these low prices can only be accomplished in specific regions and that financing cost and land cost are of great importance.

For wind an important factor is the material costs. However, since wind like PV is still in its development phase it is expected that the wind price will decrease by scaling up turbine sizes.

Lower prices for PV and higher for coal oil and gas is a good development for PV. However since PV can not replace all applications of non-renewable and it also has to fight other energies like nuclear and wind it is an ongoing battle.

6.2.1 POWER GRID

About 25% of the indian population, that are about 300 million people, have no electricity at al. Most of these people are in remote areas. It will cost a significant amount of money to connect all people by wire. India has missed every capacity addition target since 1951 India suffers from frequent power outages that can last as long as 10 hours This has cost india an average of 1.4% growth in GDP. (Bloomberg, 2014).

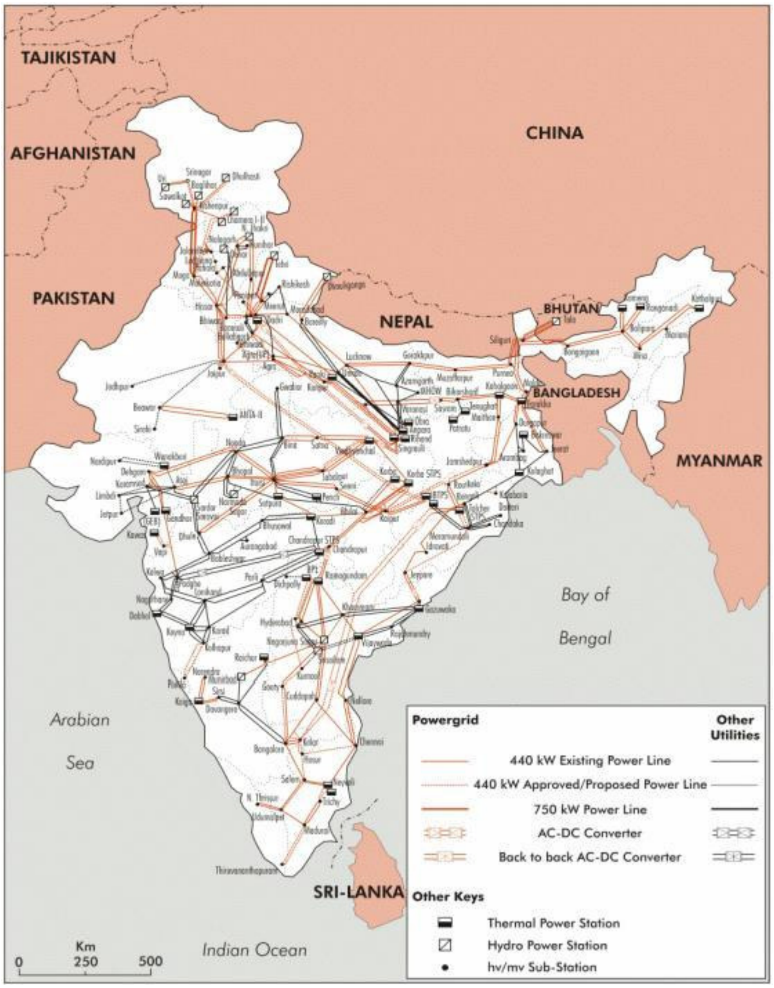


Figure 28: Electrity network india, 2011 (Power Grid Corporation of India Limited, 2011)

6.2.2 OPERATIONAL EFFICIENCY

India's electricity grid losses exceeded 32% in 2010 including non-technical losses, compared to the world average of less than 15%. A Bad grid is beneficial for small solar power plants however, it is not good for big solar plants. Reasons for this high percentage of loss include a lack of investment into the grid, widespread power theft, and a lack of consumption monitoring. In addition, a large amount of electricity is freely provided to certain consumers (e.g., farmers). Both the losses and the wasteful distribution of free electricity weaken the financial position of the SEBs, thereby reducing their capabilities to invest in grid infrastructure.

The July 2012 blackout, affecting the north of the country (and me), was the largest power grid failure in history by number of people affected. Many struggles are currently between regions fighting for electricity.

In December 2011, over 300 million Indian citizens had no access to electricity. Over one third of India's rural population lacked electricity, as did 6% of the urban population. Of those who did have access to electricity in India, the supply was unreliable. In 2010, blackouts and power shedding interrupted irrigation and manufacturing across the country. (Guardian, 2012).

6.2.3 Political

An important political factor is elections, As seen in march 2013 the delay of the national solar mission almost halted the PV industry in India because there was a high uncertainty what the new government would do. And since other problems are higher on the agenda then PV it can get neglected by a new government.

Currently the political environment it not greatly helping PV. Political changes in the past do provide a basis of PV implementation however, there is allot of disturbance and uncertainty for the future of these political acts. This needs to be removed for PV to completely flourish, else financing will become expensive due to uncertainty.

6.3 Niche

The niche level represents a protected environment in which radical innovations are being developed. The niche is protected by government because new concepts cannot yet compete with existing technologies. The role of a niche is to provide an alternative selection environment and thus protect new innovations. (Elzen, 2004). Many examples of niches exist in India. The niches chosen here are the one that the government is stimulating through the ministry of renewable energy which are producing electricity and thus competing with solar.

6.3.1 Biomass energy

Biomass has always been an important energy source for India considering the benefits it offers. It is renewable, widely available, carbon-neutral and has the potential to provide significant employment in the rural areas. About 32% of the total primary energy use in the country is still derived from biomass and more than 70% of the country’s population depends upon it for its energy needs. The government has understood the potential of biomass energy and has initiated a number of programs. Biomass power generation in India is an industry that attracts investments of over Rs.600 crores every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million person-days in the rural areas. (Ministry of New & Renewable Energy, 2014)

The current availability of biomass in India is estimated at about 500 million metric tons per year. Studies have estimated biomass availability at about 120 million metric tons per annum covering agricultural and forestry residues corresponding to a potential of about 18,000 MW. (Ministry of New & Renewable Energy, 2014)

A total of 288 biomass power and cogeneration projects having 2665 MW capacity. In addition, around 30 biomass power projects aggregating to about 350 MW are under various stages of implementation. Around 70 Cogeneration projects are under implementation with surplus capacity aggregating to 800 MW. (Ministry of New & Renewable Energy, 2014)

Besides the Central Financial Assistance, fiscal incentives such as 80% accelerated depreciation, concessional import duty, excise duty, tax holiday for 10 years etc., are available for Biomass power projects. The benefit of concessional custom duty and excise duty exemption are available on equipment's required for initial setting up of biomass projects based on certification by Ministry. In addition, State Electricity Regulatory Commissions have determined preferential tariffs and Renewable Purchase Standards (RPS). Indian Renewable Energy Development Agency (IREDA) provides loan for setting up biomass power and bagasse cogeneration projects. (Ministry of New & Renewable Energy, 2014)

6.3.2 WIND ENERGY

The Potential for wind power generation for grid interaction has been estimated at about 48,500 MW taking sites having wind power density greater than 200 W/sq. m at 50 m hub-height with 1% land availability in potential areas for setting up wind farms 12 ha/MW. (Ministry of New & Renewable Energy, 2014)

A total capacity of 17352 MW has been established up to February, 2011, mainly in Tamil Nadu, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Rajasthan. Wind electric generators of unit sizes between 225 kW and 2.1 MW have been deployed across the country. India now ranks 5th in the world after USA, Germany, China and Spain in grid connected wind power installations. A cumulative total of over 119 billions units of electricity have been fed to the State Electricity Grids up to January, 2011. (Ministry of New & Renewable Energy, 2014)

A package of fiscal and financial incentives is available for wind energy which includes concessions such as 80% accelerated depreciation, concessional custom duty on specified items, excise duty exemption, sales tax exemption, income tax exemption for 10 years, etc. In addition, State Electricity Regulatory Commissions (SERCs) are determining preferential tariffs. Indian Renewable Energy Development Agency (IREDA) provides loan for setting up wind power projects. (Ministry of New & Renewable Energy, 2014)

6.3.3 SMALL HYDRO ENERGY

The government is developing Small Hydro Power (SHP) projects up to 25 MW station capacities. The estimated potential for power generation in the country from such plants is over 15,000 MW. Most of the potential is in Himalayan States as river-based projects and in other States on irrigation canals. The SHP programme is now essentially private investment driven. Projects are normally economically viable and private sector is showing lot of interest in investing in SHP projects. The viability of these projects improves with increase in the project capacity. The Ministry's aim is that at least 50% of the potential in the country is harnessed in the next 10 years. (Ministry of New & Renewable Energy, 2014)

Small Hydro Power (SHP) Programme is one of the thrust areas of power generation from renewable in the Ministry of New and Renewable Energy. It has been recognized that small hydropower projects can play a critical role in improving the overall energy scenario of the country and in particular for remote and inaccessible areas. The Ministry is encouraging development of small hydro projects both in the public as well as private sector. Equal attention is being paid to grid-interactive and decentralized projects. (Ministry of New & Renewable Energy, 2014)

The Ministry's aim is that the SHP installed capacity should be about 7000 MW by the end of 12th Plan. The focus of the SHP programme is to lower the cost of equipment, increase its reliability and set up projects in areas which give the maximum advantage in terms of capacity utilization. (Ministry of New & Renewable Energy, 2014)

An estimated potential of about 15,000 MW of small hydro power projects exists in India. Ministry of New and Renewable Energy has created a database of potential sites of small hydro and 5,415 potential sites with an aggregate capacity of 14,305.47 MW for projects up to 25 MW capacity have been identified (Ministry of New & Renewable Energy, 2014)

CONCLUSION

India has about 600,000 villages of which 1/3rd does not have access to grid. This means that nearly 600 million Indians do not have access to electricity grid. Last year india had a Peak deficit of 12% and energy deficit of 11%. India copes with high losses, About one-third of power generated lost before getting used. India has about capita energy consumption of 704 kWh. Prices of PV are dropping while prices of the regime are increasing. The niches Wind and small hydro are doing really good in India.

7 Function of Innovation System Analysis

In this chapter, we will use the 7 functions of innovation from the publication of Hekkert. These functions give an good indication whether the innovation system is healthy. It is important to show information over a period of time so the information describes the change within the innovation system. Most interesting are the last few years of the Indian innovation system so it is crucial to use up to date information within this analysis wherever available. The functions are: entrepreneurial activities, knowledge development, knowledge diffusion through networks, guidance of the search, market formation, resources mobilization and creation of legitimacy/counteract resistance to change (Hekkert, 2007). The indicators to analyze the functions are discussed in chapter 2.3 and used extensively throughout this chapter.

7.1 Entrepreneurial activities

The role of the entrepreneur is to turn the opportunities of knowledge development, network changes and market changes into action to take advantage of business opportunities. Entrepreneurs are essential for a well-functioning innovation system. Entrepreneurs translate opportunity to measurable economic activity. There are different kind of entrepreneurial activity. You have the governmental entrepreneurial activity; most famous example would be the chines state owned companies. Governmental entrepreneurial activity is a forced activity by the government and should be analyzed with caution since it might not be a healthy environment for all companies to start a business. You have the existing market entrepreneurs trying to increase their market share. These entrepreneurs will flourish when it is hard for new entrance to start or when the innovation system is at its end phase becoming more efficient, these also include companies within the supply chain of a specific technology. For an emerging market the most important entrepreneurial activity is the new entrant. These entrepreneurs show the opportunity generation of new technologies. The indicators for this function are the number of companies within the supply chain, company sizes, company time of existence, number of projects and size of projects.

7.1.1 Companies

Since the start of PV development in the mid-seventies, programs for development, demonstration and utilization of PV have been implemented. From 2005, the programs of rural electrification gave a big boost to the solar energy use in India. When in 2008 the solar mission started it gave an even bigger boost to solar and the trust for solar. As shown in the graph bellow PV cell production is not keeping up with PV module production. This is mostly because there are not enough resources available for the pv cell production but more importantly because the modules produced by Indian companies are simply not competitive with module producers from china. (PV-magazine, 2012)

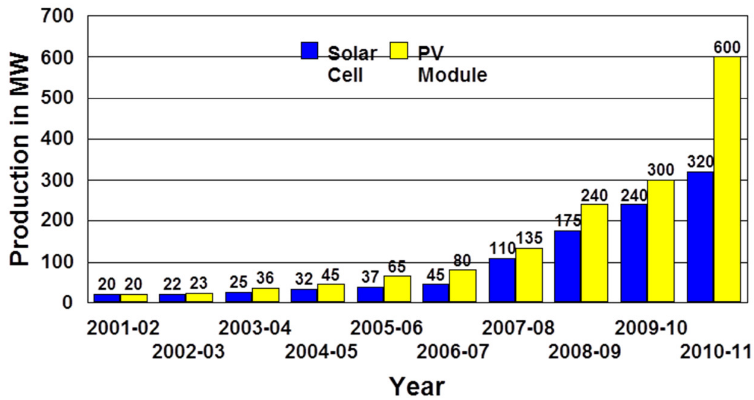


Figure 29:MNRE presentation, solar energy conclave, January 2012

In march of 2012 there are around 80 PV modules companies, with installed capacity of over 1.8 GW and 15 companies for solar cells with around 700 MW installed capacity. There are currently 83 Indian module manufactures. The 3 biggest india module manufactures by market share are Vikram solar (3.5%) operating since 1974, Moserbear solar(2.8 %) operating since 1983 and Tate power (2.6 %) since 1980. The market share of Indian companies is low. The top module manufactures are mainly Chinese. The companies from china simply create better and cheaper panels. Also debt financing in India is relatively expensive at 12% rates compared to 6-8% in Europe. (Bridge to India, 2013)

There are about 28 EPC companies active in India. However 40% of the market share goes to the top three EPC companies of which two are of India origin. What is very interesting to know is that many project developers are doing there EPC in-house of which Welspun urja(19,9%) is the biggest. (Bridge to India, 2013)

For the inverters market India mainly imports from german and USA based companies. (Bridge to India, 2013)

7.1.2 PV PROJECTS

The number of projects are increasing significantly yearly. However, huge fluctuation occur during the year. By January 2014 the installed grid connected solar power had increased to 2,208.36 MW , from 500 MW in 2012. India expects to install an additional 10,000 MW by 2017, and a total of 20,000 MW by 2022. Many expert think that these goals are to enthusiastic. As shown in the figure bellow The size and number of projects are linearly increasing. (Solar Energy cooperation of india, 2013)

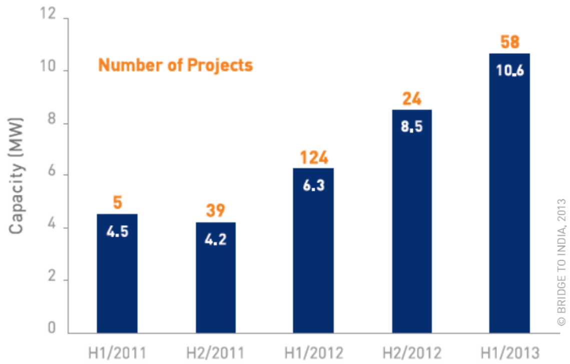


Figure 31: Average project size (Bridge to India, 2013)

7.1.3 Conclusion

Many New PV projects are started and the total PV energy installed is increase exponentially, If the Indian Module producing companies are able to benefit from these projects is not sure, there modules are not competitive with the modules from the Chinese competitor. Not many new PV module companies are started indicating the end of company growth in numbers, But Not in the size. To make entrepreneurial activity better the interest rate should be lowered, By making the investments more stable, y for example supplying better irradiation data. it should also become less complicated to build a PV plant since it now requires long waiting times for governmental permits.

7.2 Knowledge development

Knowledge creates disturbance in the regime. Increases efficiency and creates opportunities for entrepreneurs. Knowledge development is the heart of the innovation system. There are 3 different kinds of learning. Learning by doing. Learning by searching and learning by using. The indicators for this function are number of research and development projects, Number and quality of scientific publications, Number of patents and number of research organizations.

Learning by doing and learning by using is a derivative from entrepreneurial activity. New companies miss learning by doing but can obtain this through joint ventures. Since environmental conditions are significantly different, knowledge obtained through joint ventures might be wrong.

The goal of the India government is to be the leading country in PV research within 10 years. Learning by searching is thus subsided by the Indian government. The Ministry of New and Renewable Energy Sources has been supporting R&D in solar photovoltaic technology for more than three decades. The amount of research and development has increased significantly after the introduction on the national solar plan. (Ministry of New & Renewable Energy, 2014)

7.2.1 R&D projects

The Ministry of new and renewable energy has identified the so-called Thrust Areas of R&D in Photovoltaic Technology. In order to make solar cells and modules cost effective, the global R&D efforts are directed to reduce the consumption of silicon and other materials and improve the efficiency of solar cells/modules to achieve significant cost reduction. It is imagined that the cost of solar photovoltaic modules can be brought down to about Rs. 120 per Wp

Recent initiatives in the PV R&D sector are: (Ministry of new and renewable energy, 2014)

- Development of poly silicon material
- 20 - 22% efficiency single crystal silicon cells
- 10 - 12% efficiency Nano crystalline thin film modules
- 12- 15% efficiency CIGS cells
- 10- 12 % efficiency Dye sensitized cells
- 6% efficiency organic-inorganic hetero junction cells
- Long term performance evaluation and training facility for Grid Solar PV Power
- Long term performance evaluation and testing of solar
- Long term performance evaluation of PV modules at SEC
- Development of batteries
- Development of inverters

7.2.2 SCIENTIFIC PUBLICATIONS

Banarjee did a research on the amount of scientific publication in India. Between 2000 and 2009 1814 indexed journal publications where registered in PV which was 3.7% of the global total. There has been a low industry involvement with only 112 publications. The involvement of the industry is fluctuating.

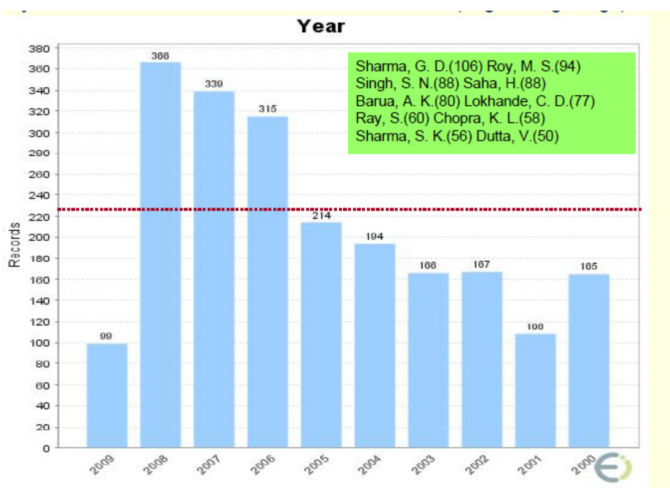


Table 11 Publications year wise - India (Banerjee , 2009)

7.2.3 PATENTS

For patents, no significant data could be found.

7.2.4 RESEARCH ORGANIZATIONS

During the National solar mission proposals were made to start specialized research centers. The goal of these research centers was to be the interface with international research institutions, high tech start-ups and coordinate activities with other agencies like the Indian Meteorological Department and Indian Space Research Organisation for detailed mapping of insolation levels across the country. In September 2013 The cabinet approved plans for the National Institute of Solar Energy to work alongside the ministry to advance solar technology capabilities in India. India is also home to the

Solar Energy Research Institute for India and the United States , a cooperation of the Indian Institute of Science and the US National Renewable Energy Laboratory. Solar Energy Research Institute for India and the United States jointly works towards India's national solar initiative and the US SunShot Initiative, to lower the cost per kWh of solar generated energy. (Minestry of new and renewable energy, 2014)

7.2.5 *CONCLUSION*

From the data found, it can be seen that knowledge development in India occurs in mainly two ways: firstly via government and secondly via joint ventures with foreign corporations. This trend is likely to change, as the India will gain experience. India is still far from being the number 1 in PV research but it is making steps in the right direction.

7.3 KNOWLEDGE DIFFUSION THROUGH NETWORKS

The essential function of a networks is the exchange information and lessons learned so people, companies and government will learn from each other to work more effectively. The indictors for this function are the interaction between companies and research institutions, the number of national and international conferences and the number and size of demonstrations or pilot projects

7.3.1 *INTERACTION BETWEEN ACTORS*

In networking some activity have been registered. Several big summits are given yearly like the solar summit and solarcon. Top-class speakers from the solar industry and supply industry as well as from market research and interest groups provided an overview of all aspects concerning solar production, project planning, quality assurance and financing.

An important system is missing in india for knowledge diffusion. This is the legal framework for transfer of university generated federally funded inventions to the commercial marketplace. More than 99% of Indian higher educational institutes do not have any open-access research content in their websites and are not encourage to publish their work openly, Only to highly reputable magazines for which an subscription is required. The lack of diffusion of knowledge becomes evident in absence of any planned efforts, to make the research done in local context available to the public

7.3.2 *CONFERENCES*

The amount of conferences of pv is increasing slowly and becoming more international. The more reputable conferences in India are.

- POWER-GEN India & Central Asia 2014
- Renewable Energy World India 2014
- HVI 2014
- Renergy 2014
- Renewable World 2014
- SolarTech Expo India 2014
- WRETC 2014

Most of these conferences attracted players along the supply chain of PV.

7.3.3 *DEMONSTRATIONS PROJECTS*

India is already far beyond demonstration projects. They are currently focusing on implementation

7.3.4 CONCLUSION

While India is doing well in the formation of knowledge development it has not done as well in spreading the knowledge. India has not taken sufficient advantage of the potential diffusion of internationally available knowledge and technology resources, as well as local knowledge. As a result, the absorption of knowledge by most Indian enterprises has been low.

7.4 GUIDANCE OF SEARCH

The activities that positively or negatively affect the demands and expectations among technology users fall under this system function. During technology development, it is impossible to explore every possible development path. Since resources are limited, specific paths have to be chosen. The indicators for this function are the role of PV for the Indian policy makers and the expectations of stakeholders.

7.4.1 *ROLE OF PV IN INDIA ENERGY POLICY*

The Indian energy sector is managed by a highly complex governmental structure. However clear goals have been made to develop the energy market and the PV market. In 2006 the government released its first integrated energy policy describing the broad vision behind the regulations.

The government has several policies into place. One is rural electrification act, which clarify the targets such as the amounts of households connected. There also is a policy for energy companies on how much electricity should come from renewable energy. As an addition many incentives in place for pv like tax reductions, feed in tariff and other mechanisms. For research, the government has set specific goals to be reached and a very high target of becoming the number 1 research place for PV. For PV in particular there is one policy, the national solar mission, that describes the goals for PV. The aim of the NSM is to install 20 GW of grid-connected solar power and two GW of off-grid solar power by 2022. The objectives of the Mission are numerous: increasing deployed capacity; enforcing regulatory obligations for using renewable energy; creating a manufacturing hub in India; and promoting R&D for new solar technologies. And it has been relatively successful, thus far. (PV-magazine, 2012)

7.4.2 EXPECTATIONS OF STAKEHOLDERS

Due to the governmental vision, policies and actions lots of experts are positive about PV in India but have their doubt about the realistity of the solar mission. An interim report produced by the Council on Energy, Environment and Water and the Natural Resources Defense Council has assessed the first few years of the project. Serious doubts remain as to whether the Mission’s Phase 1 projects will achieve the 20 GW of installed solar capacity by 2022. "The sophistication of solar energy stakeholders is increasing; However, a much greater degree of coordinated stakeholder action is needed to unleash the solar energy market’s potential."

In late 2011, competitive bidding for the Mission's second batch of projects under Phase 1 drove prices for grid-connected solar energy to as low as US$0.15 per kilowatt-hour, approaching grid parity with fossil fuel-powered electricity. This made all expects extremely positive about the future of solar energy.

As the Mission heads into Phase 2, certain questions loom large. How the ministries and government agencies, as well as stakeholders – including developers, financial intermediaries, manufacturers and communities can be more effective in scaling solar energy to power the future of india.

Jamshyd N. Godrej, co-chairperson of the Council on Energy, Environment and Water, said that installed capacity and prices do not complete the picture. "There is a need to understand challenges in installing projects, so that developers are able to do so on time and feed electricity into the grid at committed capacities," he wrote in his foreword to the report. "Solar projects have to be financially viable to attract the levels of investment necessary to meet the Mission's targets.

7.4.3 CONCLUSION

Currently there are high expectations of PV in India, Phase 1 of the solar mission went well and the government fulfilled their promises. Hewer some expects still have their doubts about the future of the PV market. They find that there are still many problems to be solved. One import problem is the lack of awareness and information to address perceived risks. monitoring of the Mission's progress would inspire confidence and investment.

7.5 MARKET FORMATION

A new technology often has difficulties to compete with incumbent technologies since it's more expensive. Therefore, it is important to create protected spaces for new technologies. The indicators for this function are the estimation of market size, the available subsidies, The regulation and tax regime and the cost of the establish electricity supply

7.5.1 MARKET SIZE

With the population of India expected to reach 1.47 billion by 2030 and demand for energy increasing among the burgeoning Middle Class. In 2011, investments in India's renewable energy markets rose to approximately $10.3 billion, with more than one-third of the investments directed to solar projects. These investments are expected to double for Phase 2 starting in 2013. (PV-magazine, 2012)

7.5.2 SUBSIDIES

The Indian Renewable Energy Development Agency provides revolving fund to financing and leasing companies offering affordable credit for the purchase of PV systems in India. 80% accelerated depreciation. Concessional duties on import of raw materials Excise duty exemption on certain devices. a Generation-based subsidy is available up to Rs. 12/kWh in addition to the price paid by the State Utility for 10 years (Indian Renewable Energy Development Agency, 2014)

7.5.3 REGULATION/TAX REGIME

After reforming the energy market and providing funds for PV projects in the rural electrification programs, the government opened up the market for PV. After that, it required energy companies to purchase a percentage of their energy from a renewable source. With this competitive advantage, PV technology could be applied in large scales. This should lead to better institution arrangement, more financial support and a faster learning curve. The 3 regulation systems implemented are RPO, REC and FITs. Renewables Purchase Obligations (RPO) dictate that renewable energy should account for 5% of a state's energy mix in 2010, and should increase by 1%-on-year for the next 10 years, A recent amendment has put a solar specific requirement. States must start have 0.25% of PV by 2013 and go up to 3% by 2022. However the current RPO are very difficult to enforce and many states are not reaching their targets. Renewable energy credit (REC), the CERC introduced RECs, market-tradable commodities generated with renewable energy. The hope is that this system will develop PV and renewable energy more cost efficiently allowing states to trade their REC's. The last piece of the puzzle is the Feed in tariffs (FIT). FIT offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology. (Indian Renewable Energy Development Agency, 2014)

7.5.4 Costs of established electricity supply

Prices of PV are dropping drastically. 2012 lowest bid was 7.49 rs/kwh. This means that solar is already fast on its way to the price of coal, currently around 3.5 rs/kwh . The price of coal, India's most used energy source shows indications of constant rise in price. The beautiful thing for PV is that coal is only available where it's not needed. The transport costs are increasing due to the increased intensity of the railway. So a rise in prices of coal is inevitable. The bad thing is that wind is much more competitive that solar and much more energy is being generated by this technology then pv. In recent analysis it is shown that solar will become more viable then diesel.

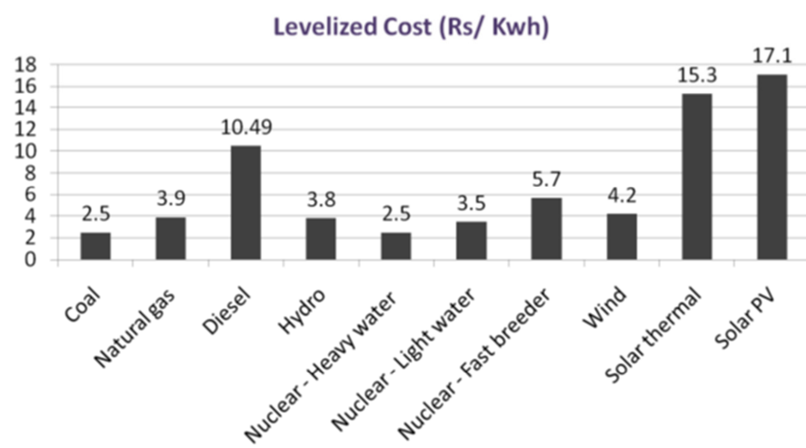


Figure 32: Levelized cost (Bloomberg, 2014)

7.5.5 Conclusion

The Indian government successfully created a subsidized market for PV technology. Now it is the challenge to get the industry and market to take over. This can be done by Launching general public awareness campaigns, facilitating information flows, enacting minimum quality standards, and introducing demonstration projects. Finally, the government also needs to lead by example and use solar systems for new construction.

7.6 Resources mobilization

Resources, financial, material and human, are necessary as a basic input to all the activities within the innovation system to generate a useful output.All resources are needed to get a working system. The allocation of sufficient resources is necessary to make knowledge innovation possible.

7.6.1 HUMAN RESOURCES

For large scale development of the sector, India needs significant amounts of skilled manpower for the execution, operation and maintenance of solar projects. A comprehensive roadmap for solar related vocational training programs that include establishing accreditation standards is required.

The shortage of good quality, industry-ready human resources at different levels of the value chain is a key challenge faced by the manufacturers. The shortage main reason is that experienced professionals are being chased by different sectors. (Chowdhury, 2011)(

To address this critical factor, SEMI India organized 'Solar Workforce Development Programs' in 2011 collaboration with the National Centre for Photovoltaic Research and Education (based at IIT-Bombay, Mumbai in Jaipur, Rajasthan.

There is need for training and development of human resources to drive industry growth and PV adoption. In this regard, much can be learned from China, which has become the global leader in solar PV manufacturing within a short time period. This has been possible by focusing on talent pool management[4]

7.6.2 PHYSICAL RESOURCES:

One of the objectives of the Jawaharlal Nehru National Solar Mission is to establish a polysilicon plant that can supply cell manufacturing needs of 2000 MW per year by 2020. India's present installed PV module production capacity is about 1 gigawatt (GW) per year or close to 10% of the global production capacity, according to market research firm Frost & Sullivan. The fact that Indian manufacturers depend almost entirely on import of silicon wafers or strips to make PV cells is a key driver for Indian policy makers to encourage investments in the silicon supply chain and especially polysilicon production.

At present levels of polysilicon consumption of 7 grams/watt, a 14,000 tonne-a-year plant would be needed to meet the 2000 MW/year objective. However, with technology improvements, predictions are that polysilicon consumption may reduce to 4-5 grams/watt, by 2020. In this case, a polysilicon plant of 10,000 tonnes-a-year capacity may be sufficient to meet India's present and future needs until 2020. (Rao, 2010)

7.6.3 FINANCIAL RESOURCES:

The funds for the long term R&D of PV technology are made available by the Government of India . Solar projects in India struggle to obtain debt finance. Only a small percentage of projects have attained non-recourse financing. Most have worked with either limited recourse or full recourse finance. Below is shown how a typical project cash flow goes

Banks that provided non-recourse financing are either Indian commercial banks or international lenders with a development mandate. There are several reasons why non-recourse finance is difficult to obtain.

- debt recovery and the legal enforceability of claims in India in general.
- Limited availability of irradiation data, which forms the basis for projecting future revenues.
- the strength of public power purchasing agreements (PPAs) due to the weak financial health of India's public utilities

For small projects Under a scheme, banks may extend subsidized loans to entrepreneurs at interest rates not exceeding five per cent. In addition, exemption of excise duty on procurement of transmission equipment for initial setup of solar power plant are available (Indian Renewable Energy Development Agency, 2014).

For small PV installation in rural areas, people can get a subsidy up to 90% of the total cost + 5 year maintenance cost. This is part of the rural area development plan. To get this subsidy you have to get a special permit, which is not easy to obtain. (Indian Renewable Energy Development Agency, 2014)

7.7 CREATION OF LEGITIMACY

In order to develop well, a new technology has to become part of society. Parties with other interests will often oppose this. This functions will try to find resistance. The indicators for this function are the existence of advocacy coalitions, Public opinion and Political opinion While it is hard to measure these, indications can be found in newspapers.

7.7.1 EXISTENCE OF ADVOCACY COALITIONS

The Government of India has built a lobby for the PV technology by reforming the institutional and regulatory framework of its power sector (Ministry of Power, Ministry of Power, 2014). the Mop and MNRE are the results of reforms that ranged from unbundling of the State Electricity Boards (SEBs), increased involvement of the private sector in generation, transmission and distribution, to liberal setting of electricity tariffs (Asian Development Bank, 2008). In addition, the introduction of National Electrification Policy (of 2005 and the Rural Electrification Policy of 2006 also contribute in the advocacy coalitions of the PV technology development. There are several institutions initiating information campaigns trying to popularize the use of PV systems. The already mentioned ISA is such an institution as well as the Energy Society of India and SESI. The objectives of these institutions include:

- Collecting, compiling and disseminating information on a variety of topical issues of growing interest to the RE community
- Expanding the existing membership base
- Coordination with the regional and local chapters of SESI for possible support and cooperation
- Organizing seminars and conferences, by publishing books, memoirs, journals and proceedings in the field of renewable energy
- Establishing formal education curriculum in collaboration with other institutions
- Establishing renewable Energy Centers in collaboration with Corporates, NGOs, Foundations, individuals and government bodies and
- Collaborating and co-operating with other scientific societies, institutions, and academies in the country and abroad (e.g. International Solar Energy Society) for research, development, and furtherance of renewable energy utilization

7.7.2 *OPINIONS AND EXPECTATIONS.*

Due to the governmental vision, policies and actions lots of experts are positive about PV in India but have their doubt about the realistity of the solar mission. An interim report produced by the Council on Energy, Environment and Water and the Natural Resources Defense Council has assessed the first few years of the project. Serious doubts remain as to whether the Mission’s Phase 1 projects will achieve the 20 GW of installed solar capacity by 2022. "The sophistication of solar energy stakeholders is increasing; However, a much greater degree of coordinated stakeholder action is needed to unleash the solar energy market’s potential."

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Jamshyd N. Godrej, co-chairperson of the Council on Energy, Environment and Water, said that installed capacity and prices do not complete the picture. "There is a need to understand challenges in installing projects, so that developers are able to do so on time and feed electricity into the grid at committed capacities," he wrote in his foreword to the report. "Solar projects have to be financially viable to attract the levels of investment necessary to meet the Mission’s targets

7.7.3 *CONCLUSION.*

While the government has set a good basis for the development of PV it isn’t promoting the technology enough. Most businesses know the advantage of PV but local people, especially in rural areas who would benefit the most, have no awareness. The government should focus on its financial opportunities, possibilities of finance and possible usage for these people

CONCLUSION

Entrepreneurial activity for PV is increasing; however, there is simply too much competition from china and Taiwan who can deliver better products cheaper and there is a big absence of a skilled workforce and an unreliable electricity supply. While India is doing well in the formation of knowledge development it has not done as well in spreading the knowledge. There is a gap between research and companies. The major stakeholders like the government have ambitious goals, however in practice these goals are almost impossible or unrealistic since the resources are simply not available. The market for PV is mainly driven by the government, In time the consumer market has to take over. While the government has set a good basis for the development of PV it isn’t promoting the technology enough. Most businesses know the advantage of PV but local people, especially in rural areas who would benefit the most, have no awareness. The government should focus on its financial opportunities, possibilities of finance and possible usage for these people

8 MOTORS OF INNOVATION

Not only the performance of each function but also the interactions between functions is important. Functions are able to influence each other's performance both positively and negatively. Suurs labeled the interactions between functions 'motors of innovation'. These motors of innovation help to explain interactions around sustainable energy technologies. Suurs Identified 5 motors (Suurs, 2009). It is important to know if these motors create a Positive (virtuous) or negative (vicious) feedback loop, these motors give an indication how far the development of PV currently is.

8.1 SCIENCE AND TECHNOLOGY PUSH MOTOR

This motor is expected to precede the initiation of a project, because a certain knowledge base and a minimal of expectations are required before a project is initiated. This motor is dominated by knowledge development and knowledge exchange. This knowledge is obtained with guidance of search and resource allocation. New knowledge will create entrepreneurial activity which in turn will creation legitimacy. The creation of legitimacy will stimulate the guidance of search and resource allocation. We now have the feedback loop.

For India the creation of knowledge is increasing which can be shown by the number of papers however the knowledge exchange is hampering. There are no legal frameworks for the knowledge to be exchanged to entrepreneurs, there are only a few conferences and researches are not stimulated to share their knowledge. The resulting entrepreneurial activity however is doing well in India, Many companies, both big and small in module and project development have emerged. Creations of legitimacy is also good, Some resistance is still there, but this is not against PV but more pro coal. Until now most of the targets set by the Indian government has been reached The guidance of search is very clear in India, The government has set goals, However there are experts that believe the goals to be unrealistic. The motors is creating a positive feedback loop for the PV innovation system.

8.2 ENTREPRENEURIAL MOTOR

This motor should replace the knowledge development push by an entrepreneurial push and should add to the positive feedback especially to creation of legitimacy and entrepreneurial activity. Action is created by new entrants or diversifying incumbent actors that start experimenting, positive expectations in turn leads to lobby activities for support from other actors to mobilize resources, which in turn leads to more entrepreneurial activities. We now have the feedback loop.

For India new entrepreneurs are entering the PV business. New project are being developed, and government has set clear goals and allocated some resources. However, the PV module manufactures in India have a hard time due to the competition from outside India. Papers have occurred trying to influence the government to improve PV innovations in many ways, analyzing the current solar mission and giving recommendations for improvement. The expectation of PV is very high, Many experts are interested how the seconds phase of the solar mission will go. If this will go as expects it will create a very positive feedback to creation of legitimacy. Some Lobby groups are currently formed by PV industry leaders but not many exist yet. The motors is creating a positive feedback loop for the PV innovation system.

8.3 SYSTEM BUILDING MOTOR

This motor resembles the entrepreneurial motor with some changes; it includes a more important role of market formation. The main difference lies in the connection between creation of legitimacy , on the one hand, and market formation and guidance of the search on the other. Outsiders are increasingly involved in networks by enacting new entrants, governments, intermediaries and stakeholders in their system. From this network, outsiders attempt to develop the innovation system by enhancing the motors virtuous cycles.

For India the market formation, the most important part of this motor, is mainly governmentally subsided. It is expected that in between 2017 to 2022 this might changes because then PV is to become economically competitive with the regime. Currently not many activity is seen in outsiders attempting to develop the innovation system.

8.4 MARKET MOTOR

The market motor is characterized by a strong fulfillment of all functions, except the creation of legitimacy is not strongly fulfilled. This function is not as important for this motor because market formation is no longer a political issue. The market environment has been created as the result of formal regulations. Market formation is taken up as part of regular business activities (i.e. marketing activities and promoting strategies) that are directly connected to entrepreneurial activities .

For India, This motor is not visible at all. No development have been found in this motor.

9 CONCLUSION

The purpose of this research is to find the factors that hamper or boost photovoltaic energy development India. For that purpose, a set of research questions where predefined as guidance that leads to the research objective. In this section, the conclusions are presented using the sub research questions discussed in the first chapter.

<u>What theoretical framework can be best applied to the innovation system in order to give adequate answers on the main research question?</u>

Photovoltaic technology is a newly explored technology with a high potential of technical development that would influence and would be influenced by the diffusion of the technology in the market. This requires the analysis to take into account the research and development activities as well as the situation of photovoltaic technology market. Furthermore, photovoltaic technology is connecting many sectors in the country and the applications as well as the activities of the Technology are crossing the boundary of the country. This brings the framework of technology Specific Innovation System to fit the analysis of the research.

The development and the environment of photovoltaic technology are very dynamic and high pace. Thus, the framework that is utilized needs to be able to capture the dynamic of events and activities around the technology. The Functions of Innovation System is therefore suitable as the framework for the analysis.

<u>What is photovoltaic technology?</u>

Photovoltaic technology is a process in which electricity is generated in the boundary layers of certain semiconductor materials when they are illuminated. Today's photovoltaic semiconductor materials include silicon, gallium arsenide, copper indium dieseline, cadmium sulfide, and cadmium telluride. 3 major PV technologies are emerging today, namely Crystalline, Polycrystalline and Thin-film. From these materials, a variety of commercial products is produced, like consumer electronics, remote electric power systems, grid-connected power systems and building integrated systems. The PV material that is mostly used today is silicon, due to being abundant in nature and thus cheap. Silicon solar technologies can be grouped in three basic areas namely, single-crystal silicon, polycrystalline silicon and thin-film amorphous silicon.

The primary distinctions among the three technologies are their sunlight-to-electricity conversion efficiency rates, the methods by which they are manufactured, and their associated manufacturing costs.

<u>What are the currently available types of photovoltaic technology in India?</u>

As shown in the answer above the primary distinction between different Photovoltaic energy technology is are their sunlight-to-electricity conversion efficiency rates, the methods by which they are manufactured, and their associated manufacturing costs.

In India there are many types of solar technology available according to CERC. The most popular two are the single and multi-crystal technologies falling under the crystalline Si cells, the reason that they are so popular are there efficiency to cost ration. Other typed of available technology are single junction gaAs, Multi-junction cells, thin film(cdte, cigs, si film) , dye sensitized and organic cells, However these are highly experimental.

What are the current major energy generating technologies for the Indian energy system?

For photovoltaic technology to defuse into the current energy system it must have an advantage over the existing energy generating technologies. This can be both technical, economic, environment and even social.

The electricity sector in India has an installed capacity of 238.000 GW as of February 2014. The major electricity generating technology for the India electricity consumption is coal with 59%, the main reason for this is the abundance of coal and its cheap price. The last 5 years the installed capacity of coal has been doubled. Second, is hydro which accounts for 17% . Hydro only grew with few percent in de last 5 years because resources are limited, then followed by gas, which accounts for about 9% and grew with about 50% in the last 5 years. India's electricity sector is amongst the world's most active players in renewable energy utilization, especially wind energy. Wind almost has the same share as gas.

What are the factors that hamper or boost the photovoltaic technology development in India?

The function that boosted the development of photovoltaic technology in India are entrepreneurial activity, creation of legitimacy and the guidance of search. These functions positively influence other functions such as Market Formation, and knowledge development. The functions that hampered the development of photovoltaic technology in India is knowledge diffusion and resource mobilization with regards to capital and human resources. Market mobilization might also be considers a hampering function since it is almost fully governmentally subsided.

The enablers derived from both the MLP and FIS analysis are the economic growth of India, which in return needs for electricity. The grid losses are enablers for off grid PV. However big actions are taken to decrease the grid losses, since many can be solved by decreasing illegal tapping and improving metering. Another enabled is the need for energy security, For the government it is important to be as self-reliant as possible. There are good expectations for PV by experts since the government is very clear and many people are waiting to see what happens in the second phase of the solar mission. Many new entrepreneurs have joined in the PV innovation system and the since the creation of legitimacy is going good a positive feedback loop occurs. Another enabler is the awareness of the pollution of current energy generation technologies like coal. Since most of the electricity generation is done by coal a big market share can be won by sustainable technologies like solar.

The barriers derived from both the MLP and FIS analysis are the high-levelized production cost of PV in comparisons to other technologies. However, The levelized production cost of PV is still decreasing while most others are increasing. The limited human resources is a big problem for India, Not many knowledgeable human resources are available to supply future needs. A big disadvantage for India is that they are generating allot of knowledge with regards to PV but most of it is not shared due to the fact that there is no legal framework available and because researchers are not encouraged to share their knowledge. Knowledge sharing between the research organizations and the industry is minimal. There are also some unneeded bureaucracy rules which, if these would be removed might make it a bit easier for entrepreneurs. An example is the unrealistic long waiting periods for permits. And last is the awareness between the population of the possibilities of PV, both financially and technically. Another barrier is the uncertainty of data when investing in PV. There are no reliable information available which makes investors demand more return for their investments, which in turn makes money lending expensive.

10 Recommendations

Recommendations can be derived from the conclusions regarding photovoltaic technology development in India. Since all actors are able to influence the development of photovoltaic technology in India the recommendations will be addressed to all main actors around the technology.

10.1 Recommendations to companies

These recommendations are to the industry along the whole supply chain, including, converters, modules, epcs. It is very important to increase the collaborations between companies since inventing the wheel twice is a waste of resources. Working together might increase the total market share of PV and will thus benefit all stakeholders. An important investment to ensure the development of PV in the near future is the training and development of human resources.

10.2 Recommendations to the government

These recommendations are for the governmental organizations influencing the development of PV. Both locally and nationally. Many developers struggle with the process of land acquisition since it takes a long time and adds uncertainty. It is recommended to try and make the process easier. Another important recommendation is to reducing the cost of capital by reducing investment risks. This could be done by supplying and monitoring accurate radiation data. Two other important recommendations are the creation of standards which will fight unfair competition between module suppliers, and establishing grid standards so it will become easier to connect to a the grid. The last recommendation would be to create more consumer awareness, especially focused on technology, its financial opportunities and possible usage

10.3 Recommendations to scientists and researchers

The main recommendation for scientists would be to make their knowledge more easily accessible. This should be part of your job since it is financed mainly with public money. It would also be beneficial to work to a closer cooperation between scientists and the industry.

10.4 Recommendations for further research

Since India is a huge country, it is recommended to take a closer look and do an analysis per region. In my opinion India is too big to draw conclusions for the whole country. There is too much diversity (culture, climate etc). For PV it would be interesting to look especial at the regions with high solar radiation and activity like Gujarat and Rajasthan. Also more indicators could be taking into account for the FIS and MLP perspective and all data sources should be verified with al least two others sources.

11 REFLECTION

11.1 THEORETICAL REFLECTION

There are tree theoretical frameworks that are used in this thesis: Multilevel Perspective (MLP), Functions of Innovation System (FIS) and the combined framework of MLP. The utilization of the three frameworks will be analyzed to see some strengths and weaknesses of each framework.

11.1.1 MULTILEVEL PERSPECTIVE

Multilevel Perspective has been very useful to analyze the position of PV in its socio-technical perspective

The strength of this framework is that it gives a complete overview, from landscape to regime and niches. The Multilevel Perspective framework helps researchers in taking into account the social and cultural aspects in the landscape settings, actors' networks and interactions and level of technological entrenchment in the regime settings, as well as dynamics in the technological niches.

However, in the application of Multilevel Perspective, it is rather hard to determine the level of technology development. This is mainly the case regarding when a technology development is dynamics. It would be highly beneficial to develop a standardized list of indicators that can give a better estimation regarding the development level of a technology in the view of Multilevel Perspective.

11.1.2 FUNCTIONS OF INNOVATION SYSTEM

Using this framework, researchers can understand how the performance of each function can influence the development of the technology. Furthermore, the concept of virtuous and vicious cycle provide a better analytical tool on how the functions are interacting to each other, which also influence the technology development.

The strength of the FIS analysis is it provides a tool to analyze the performance of factors that can influence the development of a certain technology.

11.1.3 COMBINATION OF MLP AND FIS

The combination of MLP and FIS provides frameworks to clearly analyze the dynamics of an Innovation System in each level of socio-technical system, with emphasize on the niche level. The combination enabled researchers to determine how functions can impact each levels and also how the dynamics in each levels can impact functions. Analyzing FIS without combining it with MLP is viewing the issue from a closer distance. When using the combination of FIS and MLP, researchers can get a larger point of view regarding the technology development.

The weakness of this framework is that it is still hard to measure the strengths of functions that influence technology development in each level. Researchers can see that functions have influences to the niches development or technology entrenchment in the regimes. However, how significances of the influences and how big the functions change the situations in each level are still hard to determine.

11.2 PRACTICAL REFLECTION

Some practical reflections that can be derived from the experience when conducting this research. In general, learning about any aspects, such as social, cultural, and political, related to the unit analysis is very useful. The knowledge about these aspects can give researchers more insight to the content and will help the data collection process. In this research, some aspects regarding India that need to be highlighted are:

Data gathering is a complicated process since the governmental structure is complicated and India has a large geographical spread. It would be best to analyze every region separately. The reason for this is that there is a big variety in culture, language, government and development. At first I tried to analyze all regions separately but this simply is too much work for 1 person. In the end I focused more on the active regions and less on the inactive. I also tried to figure out why regions where more or less active.

Many people claim to be experts, Do your homework before setting up a meeting and make sure you are talking with a real expert.

Although the situations are getting better, the complicated bureaucracy systems are still exercised by some government officials.

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Abbreviations

BEE Bureau of Energy Efficiency

CEA Central Electricity Authority

CERC Central Electricity Regulatory Commission

MNRE Ministry of New and Renewable Energy (India)

MoF Ministry of Finance (India)

MoP Ministry of Power (India)

MPNG Ministry of Petroleum and Natural Gas (India)

NEP National Electricity Policy (India)

NTP National Tariff Policy (India)

NTPC National Thermal Power Corporation (India)

PV photovoltaic

R&D research and development

REC renewable electricity certificate

REP Rural Electrification Policy

RPO renewable purchase obligation

SEB State Electricity Board (India)

SERC State Electricity Regulatory Commission (India)

T&D transmission and distribution

TERI The Energy and Resources Institute (India)

Units

INR Indian rupee

Mtoe million tonne of oil equivalent = 10 ^6 tonne of oil equivalent

Interview

<u>Hemant Kumar singh (IIT Mombay), August 2012</u>

Do you expect to have enough skilled manpower available for the governmental targets?

We have enough manpower for the simple tasks, It will be harder in the future to obtain the right people with the right knowledge, that's why we are training them here at NCPRE.

Can NPCRE be the main PV development leader within 10 years?

With current budgets, I doubt it.

Currently the lowest price is 7.5 rupee. It this realistic for the future?

It must be mention that this was an optimal location and I doubt if they will make a profit, however technology is improving and our knowledge on how to use it too.

Why are some solar producers shutting down.

Mainly because of the cheap solar panels from china

Do you expect more base silicon and wafer companies

I think the government is trying hard to get the industry to India, But I have my doubts if they will succeed.

Do you think India can become competitive with Taiwan and china?

If we would heavily subsidize our PV industries, like they do we might

Are rural areas (people) informed of the possibilities of solar

Most rural people do not know the existents of this technology or do not have the knowledge to obtain subsidies to buy them, there are some remote regiins where they are informed and my hope is that the knowledge will spread.

Would it help companies if it had less paperwork (permits) to request for building a plant.

Many EPC companies complain about the long permit time and the unfair rules of the government, It would help allot if there would be a transparent and fair buraurocracy.

Do you think the solar mission is realistic?

Some of the goals we will reach easily.

Is the government effective with their polices. What would you like to see changed

- *Lower interest rate to 2%*
- *Decrease electricity price and make reliable for production*
- *Remove burocracy*

Map of India


INDIA
States and Union Territories
N
TAJIKISTAN
AFGHANISTAN
PAKISTAN
CHINA
TIBET
NEPAL
BHUTAN
BANGLADESH
MYANMAR
SRI LANKA
JAMMU & KASHMIR
Srinagar
Jammu
HIMACHAL PRADESH
Shimla
Chandigarh
PUNJAB
HARYANA
DELHI
Dehradun
UTTARAKHAND
UTTAR PRADESH
Lucknow
Jaipur
RAJASTHAN
SIKKIM
Gangtok
ARUNACHAL PRADESH
Itanagar
Dispur
ASOM
NAGALAND
Kohima
Shillong
MEGHALAYA
Imphal
MANIPUR
Agartala
TRIPURA
Aizawl
MIZORAM
BIHAR
Patna
JHARKHAND
Ranchi
WEST BENGAL
Kolkata
Gandhinagar
GUJARAT
Bhojpal
MADHYA PRADESH
Raipur
CHHATTISGARH
(ODISHA) ORISSA
Bhubaneshwar
Diu
Daman
Silvassa
DADRA & NAGAR HAVELI
Mumbai
MAHARASHTRA
Hyderabad
Yanam (Puducherry)
ANDHRA PRADESH
ARABIAN SEA
BAY OF BENGAL
Panaji
GOA
KARNATAKA
Bengaluru
Chennai
Puducherry
Mahe (Puducherry)
TAMIL NADU
Karaikal (Puducherry)
KERALA
LAKSHADWEEP (INDIA)
Kavaratti
Thiruvananthapuram
ANDAMAN & NICOBAR ISLANDS (INDIA)
Port Blair
INDIAN OCEAN