APRIL 2009

The Solar PV Landscape in India

An Industry Perspective

INTRODUCTION

This paper attempts to provide an overview of the state of solar photovoltaics (PV) in India. It presents the case for PV in India from a structural, market-opportunity, as well as from a social-benefits perspective. It briefly presents the current play of the Indian PV industry, outlines important challenges, and makes key recommendations that could accelerate the growth, adoption and proliferation of the technology in India.

The report is the first of its kind to represent the 'voice of the Indian PV industry' and to highlight the industry perspective. It is supported by leaders of the Indian PV industry and the SEMI India PV Advisory Committee, and is an attempt towards building consensus and developing a strong collaborative model that could enable the growth of the Indian PV industry.

"In this (India's) strategy, the Sun occupies centre stage, as it should, being literally the original source of all energy. We will pool all our scientific, technical and managerial talents, with financial resources, to develop solar energy as a source of abundant energy to power our economy and to transform the lives of our people. Our success in this endeavor will change the face of India".

—India's Prime Minister, Dr. Manmohan Singh, releasing the National Action Plan on Climate Change in 2008.

EXECUTIVE SUMMARY

The Case for PV in India

India is poised at the threshold of opportunity to grow and expand its role in PV adoption and manufacturing and potentially to become a global leader in this technology.

Specific drivers for PV in India include the country's rapidly rising primary energy and electricity needs, the persistent energy deficit situation, the country's overdependence on coal for electricity generation and on oil and gas imports (amounting to 7% of its GDP). These factors coupled with India's endowment with abundant irradiation, with most parts of the country enjoying 300 sunny days a year, make PV particularly attractive to the country's energy strategy.

There is enormous potential for off-grid PV deployment, in India, based on real needs and benefits, in the areas of rural lighting and electrification, for powering irrigation pump sets, back-up power generation for the expanding network of cellular towers across the country, captive power

generation, urban applications and highway lighting.

A robust PV industry in India would create jobs right across the value chain from R&D to manufacturing, installation, maintenance and opportunities for small entrepreneurs. Sources in India's Ministry of New and Renewable Energy (MNRE) suggest that about 100,000 jobs will be created by the PV industry by 2020 and industry sources believe the figures could be higher once all job linkages are taken into consideration.

PV solutions have the potential to transform lives across India, where 450 million people rely on kerosene and other fuels to light up their homes. The productivity and quality of life benefits of rural home electrification through PV, and kerosene replacement, are dramatic, as case studies illustrate.

Given the persistent supply-demand gap, reliance on captive power generation is likely to continue into the foreseeable future. The enormous investments needed to build required electricity generation capacity as well as very high transmission and distribution losses on India's electricity grid, are factors that will make PV an attractive choice for captive generation as well.

Although wind currently dominates renewable sources of power generation in the country (accounting for 70% of total power generated from renewable sources), solar PV is expected to outpace wind in the longer term as the renewable source of choice. Today, however, PV constitutes a miniscule part India's installed power generation capacity with estimates in the region of 100 MWp, with grid connected solar PV generation at a mere 2.12 MWp.

The India PV Market, Industry and Challenges

The application spread for PV in India today, is very different from the global mix of solar applications, where grid connected PV generation accounts for about 75% of installed capacity and off grid lighting and consumer applications for the rest.

Although grid connected solar generation in India is currently very small, the MNRE is targeting a capacity of 50 MWp by 2012, through its Generation Based Incentives (GBI) program of 2008 (the equivalent of feed-in tariffs) and officials within the ministry expect that this target will be exceeded.

MNRE reports indicate that India has 9 manufacturers of solar cells and about twice as many module makers. There is no current silicon feedstock or significant wafer manufacturing in India although recent proposals have been made to the government to build these lines. Almost all of India's current solar cell production is crystalline silicon based while proposals are in the pipeline to build thin film module production lines. PV cell and module manufacturing capacity in India could see dramatic growth depending on how many of the recent proposals submitted to the government, see fruition.

There are a number of balance-of-system (BOS) manufacturers in India who produce charge controllers, inverters and battery systems. Innovation and improvement in quality, reliability and efficiencies in the PV BOS area are seen by the Indian industry as being important success determinants, going forward.

Key challenges facing the growth and development of PV in India include:

- The need for closer industry-government cooperation - for the technology to achieve scale
- The need for common industry standards
- The need for focused, collaborative and goals-driven R&D - to help India attain technology leadership in PV
- The need for financing infrastructure, models and arrangements - to spur the PV industry and consumption of PV products
- Training and development of human Resources - to drive industry growth and PV adoption
- The need for intra-industry cooperation - in expanding the PV supply chain, in technical information sharing through conferences and workshops, in collaborating with BOS manufacturers and in gathering and publishing accurate market data, trends and projections
- The need to build consumer awareness - about the technology, its economics and right usage

Government Initiatives and Policies on Solar PV

Recent Government Initiatives and Policies have been providing the momentum for PV in India.

India's Action Plan on Climate Change (2008) Articulates a Central Role for Solar Power

The Government of India's National Action Plan on Climate Change released in mid-2008, identifies eight critical missions – one of which is the National Solar Mission. The National Solar Mission aims "for local PV production from integrated facilities at a level of 1000 MW per annum by 2017"

India's 2007 Semiconductor Policy and Special Incentives Package Schemes

The Government of India announced Special Incentives Package Schemes (SIPS) that apply to solar cell and module manufacturing in the country. Given the nature of incentives specified (capital investment and interest subsidies) there has been enormous response to the announcement in the form of proposals to build cell, wafer and module manufacturing capacity.

Incentives for Grid Connected Solar Power Generation
India's MNRE announced Generation Based Incentives (the equivalent of feed-in-tariffs) for Grid Interactive solar PV Generation Projects in January 2008.

Important provisions of the GBI guidelines are:

- Combined MNRE plus state utility feed-in tariffs of Rs 15 (US$ 0.30) per kWh. Tariff guarantees cease at the end of 10 years from the start of generation.
- A capacity cap of 50 MWp by 2012, for the incentives scheme (although, subsequently, the MNRE has clarified that this will be raised)
- Accelerated depreciation on capital investment not allowed simultaneously with GBI

The Indian PV industry while welcoming the announcement of a feed-in tariff scheme for grid connected PV, has expressed its concerns that the scheme, as it stands, needs to be expanded in scale and requires review and rework to make it more attractive to investors.

Key Recommendations and Call for Action

Evolve a Common Government-Industry Vision to Make India a World Leader in PV

- Operationalize the National Solar Mission. The National Action Plan for Climate Change could be used as a start point for setting PV goals
- Enact laws and pass mandates for expanding solar PV adoption and generation (both off-grid and grid connected applications)
- Evolve a comprehensive research roadmap, in collaboration with universities and national labs, with clearly defined, time-bound, technology and cost goals, encompassing all aspects of the PV eco-system including materials, cell technologies, process, equipment, packaging, test and characterization, manufacturing engineering and automation, battery/storage technology, inverter and BOS electronics, metering, etc.
- Put a plan in place for achieving and sustaining true manufacturing scale. Create a plan to develop and strengthen the entire PV supply chain from silicon feedstock, wafer manufacturing, materials and equipment to end-systems
- Focus on training and human resource development in collaboration with the college, university and training eco-system
- Consider instituting a PV Technology Development Fund with a substantial corpus to help fund joint industry-government research programs

Develop Financing Infrastructure and Models that will Motivate Large Scale PV Adoption and Investments

- Create awareness in the financing community about PV technology, its promise and prospects, to enable informed project evaluation, to accelerate decision making on proposals and to streamline the flow of funds
- Roll-out financing models and schemes to enable lending to all categories of PV customers and develop appropriate financing arrangements to spur the industry
- Evolve banking guidelines and lending policy measures specifically targeted to lending for PV

Expand Deployment of PV in Off-Grid Applications

- Implement a large program for rural electrification and lighting through solar home electrification systems
- Deploy solar PV Irrigation Pump Sets on a large scale by diverting the diesel, kerosene and electricity subsidies towards solar pumps
- Mandate use of PV in power back-ups for cellular base stations across the country
- Boost urban PV adoption through, a target of 'solarizing' a certain number of rooftops, as has been successful in other parts of the world and set a target of something like, one large BIPV structure in each district of the country. Expand the use of PV in street, traffic, billboard and highway lighting
- Provide a mandate for the use of renewable sources, including solar PV in captive power generation plants and promote PV (over other forms of power back-up) for domestic, industrial and commercial applications

Prioritize Grid-Connected PV Generation on a Large Scale

- Review and rework the current Generation Based Initiative scheme of the MNRE, in consultation and collaboration with industry groups and representatives to expand its size and scope and to generate greater investor interest
- Operationalize a plan to upgrade the power grid to support large scale feed-in from solar farms
- Identify regions and land tracts suitable for the establishment of solar farms to streamline and accelerate land acquisition

THE CASE FOR PV IN INDIA

Primary Drivers of PV in India

India is positioned at a threshold of opportunity to grow and expand its role as a leader in solar PV adoption, technology and manufacturing. Primary drivers for PV in India include:

The country's rising energy needs, proportional to Gross Domestic Product (GDP) growth

- Primary energy demand in India is expected to grow from 400 million tonnes of oil Equivalent (toe) to well over 1200 million toe by 2030.[12]
- Consumption of electrical energy will rise from the current, low, 660 kWh per capita[3] to well over 2000 kWh by 2032. India's per capita electricity consumption is among the lowest in the world at about 7% of that in the OECD countries[4] and 20%-25% of the world average[3]. With economic growth, a sharp rise in consumption is inevitable.
- India's grid-connected power generation capacity will need to scale from the current (2008) figure of about 147 GW to well over 460 GW by 2030, with other estimates projecting even higher needed generation capacity growth.[5]

The persistent energy deficit situation:

- One-third of the population, over 450 million people, have no access to grid electricity today[6]
- India's power supply-demand gap has averaged 8%-10% over the last 10 years where electricity access does exist
- India's National Electricity Policy aims at an availability of 1000 kWh per-capita, per year, by 2012. Provision of power to first time users at this average would suggest that 450 billion kWh of additional energy would have to be made available in that time frame.

Over dependence on Coal for electricity generation

- 52% of India's current installed power generation is from coal[7],[3]
- Life of coal reserves in India are projected to decline alarmingly to between 14 and 43 years, by 2030[8]
- India's carbon dioxide emissions from coal combustion are projected to total 1.4 billion metric tons in 2030, accounting for more than 7 percent of the world total.[9]

Over dependence on oil imports because of very small natural reserves, and corresponding energy security considerations

- India lacks substantive crude oil reserves and most projections suggest that these will deplete completely in 20 years
- Over 100 million rural families rely on kerosene for domestic lighting.[10]
- Extensive usage of diesel and kerosene for captive power generation of all kinds – industrial, commercial, domestic and agricultural

India's abundant endowment with solar radiation

- Irradiation figures range between 4 and 7 kWh per day, per square meter, varying by location, across much of the country and most parts of the peninsula enjoy close to 300 sunny days a year. Approximately 2000 kWh or electricity could be generated per KWp of PV capacity

- PV will progressively become more attractive vis-à-vis other renewable sources of power as its cost curve declines

- Among other renewable sources of electricity generation, wind has seen rapid growth in India in recent years (over 8 GW of installed generation capacity in 2007). However, India being a medium wind profile country, its low plant load factors and the saturation of optimal locations for wind generation are expected make it less attractive than PV in the longer term.

- Approximate calculations, based on irradiation data would suggest that half a percent of India's land area (amounting to about 16500 square kilometers) brought under solar PV could meet all the electricity needs of the country in the year 2030.

Key PV Applications

The Immense Potential for Off-Grid Applications

As much as 70% of India's population is involved in agriculture and lives in rural areas. Upwards of 450 million Indians have no access to grid electricity 6 and an estimated 80,000 villages are not connected to the grid. Those parts of rural India that do have electricity supply suffer chronic power shortages. Rural and remote area electrification needs, therefore, present an enormous opportunity for PV.

<u>Basic Off-grid Lighting and Electrification Systems</u>

Addressing the most basic lighting needs through small standalone home lighting systems would result in very significant kerosene replacement at the national level and amelioration in the quality of lives of millions. Estimates suggest that between Rs 10,000 and 20,000 crores (US$ 2 to 4 billion) are spent by the government every year on subsidizing the price of kerosene. PV lighting systems would greatly improve the quality of lighting and reduce health and safety risks due to inhalation of fumes and from the widespread use of combustible kerosene fuel. Such PV systems could be extended to support add-ons such as a

single electric fan to beat the intense summer heat, and a facility for charging a cell phone. This would be a very compelling solution for millions across the country.

Irrigation Pumps

Solar irrigation pumps potentially are an enormous market. Seventy percent of India's population is involved in agriculture, and small and subsistence farmers are entirely dependent on variable rainfall and ground water for their crop needs. State and regional governments in India, it is estimated, subsidize electricity for irrigation pumps and agricultural use by somewhere between Rs 30,000 and 40,000 crores (US$6 and $8 billion) each year. There are an estimated 21 million irrigation pumps in India out of which over 9 million run on diesel and 12 million are on the electricity grid. Electricity consumption by irrigation pump-sets alone accounts for between 10% and 15% of India's total consumption. India's irrigation pumps are also believed to be far less efficient than those in use in other parts of the world. Besides off-setting this huge consumption of electricity, PV also offers the prospect of diesel and kerosene replacement for the other 9 million pumps.[11] [12] [13] [14]

Power Back-Up for Cellular Towers

Cellular telephone base stations and towers spreading across the country offer a large opportunity for diesel generator replacement. India added 8 million cell phone subscribers a month in 2008 and estimates suggest that there were over 200,000 cell phone towers across the country at the end of the year. 90,000 more towers are expected to be added in 2009[15]. The vast majority of these are powered by diesel generator back-ups. Some leading Indian PV companies have already begun providing solar power solutions for telecom towers in remote, rural and un-electrified areas.

Captive Power Generation

Diesel based captive power generation is used extensively in the country today to bridge power supply deficits and to overcome supply quality problems in industrial, commercial and domestic applications. Estimates suggest that net captive power generation capacity (from all fuel sources) could be as high as between 20 and 25 GW (2007-08) and diesel accounts for a sizable portion of this.

Urban Applications and Highway Lighting

Urban areas present opportunities for street and traffic lighting, the use of PV for billboards, Building Integrated PV (BIPV), PV installations in apartment complexes and private developer properties, where uninterrupted power is currently provisioned for, at prices much higher than grid electricity, through the use of diesel generator sets and uninterruptible power supplies based on battery storage.

Highway lighting, even in selected sections of the national road network, would improve visibility and road safety on India's expanding and increasingly important road transport network.

Grid Connected PV Generation

Although total installed grid connected PV generation capacity in India today is a very small 2.12 MWp[16], it could well become a key growth area, given the persistent power deficit situation and the enormous and growing power generation needs of the country. Most estimates suggest that well over 300 GW of power generation capacity will need to be added by 2030 to meet the country's electricity needs. Grid connected solar farms, PV installations working in conjunction with wind energy installations and the deployment of mini and smart grids present very substantial opportunities.

The Benefits of PV in India

Creating Jobs

Renewable energy technologies generate more jobs per megawatt of installed capacity, per unit of energy produced, and per dollar of investment, than the fossil fuel-based energy sector[17]. Available data and estimates are indicative of the job creation potential of PV, and numbers from the US PV industry are impressive even though the US has not been the world leader in adopting or deploying solar technology, this far.

- The PV industry in the United States today directly employs 20,000 people and indirectly supports 100,000 jobs. These figures are expected to rise to 150,000 by 2020, equaling employment in the US glass industry.[18]

- Various (European as well as US) studies suggest that in the range of 25 and 30 direct jobs are created for every MWp of PV installed.[17]

- 5-15 jobs are created in indirect employment for each person directly employed in producing PV systems.[18]

- Germany today employs over 42,000 people in its PV industry, more than total employment in its nuclear energy industry. Estimates suggest that close to 10 million jobs could be created worldwide in solar power by 2030.[19]

A robust and expanding PV industry in India will create jobs right across the value chain – from specialized high paying, high-technology sector employment in R&D, to employment for manufacturing workers, technicians, construction workers, installers and in field maintenance. A senior official in the MNRE estimates 100,000 jobs in PV by 2020.[20] Industry sources suggest that if all job linkages are considered, PV jobs in India could far exceed this figure.

Wide PV adoption will also spur a whole host of opportunities for smaller businesses and entrepreneurs across the country in the sales, service and maintenance of PV systems, including in the Balance of Systems (BOS) supply chain covering charge control/inverter electronics and battery systems. Such opportunities would be similar to, but on an even larger scale than, those that have been created with cell phone proliferation and the spread of cable and satellite TV in recent years across the country. India's MNRE acknowledges the potential for small entrepreneurship in its own initiative of promoting solar Shops – called "Akshay Urja" Shops – where individuals avail of soft loans and receive monthly support grants for promoting and selling solar products.

Transforming Lives

Key PV industry executives in India who have been committed to this technology for over two decades despite its slow adoption and persistent questions around its viability, speak glowingly of the transformational potential PV possesses in the Indian context.

In a country where over 450 million people live without access to electricity and have to depend on kerosene and other alternatives for whatever little lighting they can get at night, solar PV even in its most basic application in small home lighting systems has the ability to dramatically transform lives.

The extensive dependence on kerosene for basic home lighting, in India's rural areas, leads to a high incidence of fire and asphyxiation accidents and slow, progressive damage to the health of users due to the inhalation of kerosene fumes. Industry sources highlight that this hazard can be eliminated by the deployment of PV solutions financed by diverting the same kerosene subsidies.

The transformational potential of solar energy received mention by India's Prime Minister, in mid 2008 when he released the country's Action Plan on Climate Change. In his own words, "In this strategy, the sun occupies centre stage, as it should, being literally the original source of all energy. We will pool all our scientific, technical and managerial talents, with financial resources, to develop solar energy as a source of abundant energy to power our economy and to transform the lives of our people. Our success in this endeavor will change the face of India".

Industry voices harbor hope that given India's unique natural and circumstantial suitability for solar energy, a PV revolution to match India's much vaunted telecom revolution of the 1990s, will transform its energy sector in the years ahead.

One key India industry executive stated it succinctly when he said, in the context of the country's domestic electrification challenges, "a solar PV revolution could untether the population from the power lines just like the telecom revolution did with the phone lines".

CASE STUDY: SMALL PV SYSTEMS TRANSFORM LIVES AND THE LOCAL ECONOMY IN UTTAR PRADESH

It all began when the Aryavart Gramin bank in the state of Uttar Pradesh needed reliable back up power to run its computerized branches in the rural areas. Uninterrupted power supply was required to run the computers equipped with high speed wireless communication. In 2006, the bank installed PV systems in five of its branches to charge the backup batteries that provide AC power through an inverter, during power outages. Impressed by the reliability and ease of use of solar electricity, the bank realized that PV systems were the most suited answer to the power needs of its rural customers, many of whom had partial or no access to electricity at all.

The Aryavart Gramin bank initiated a program under which it helped the local dealers buy bulk orders of Solar Home Systems (SHS) manufactured by Tata BP Solar, providing them with commercial loans. Under the program a customer could purchase 2 types of SHS – the Venus I and the much larger Venus II package. Both systems are specified to power Compact Fluorescent Lights (CFLs) for between 4 and 8 hours. The systems also support a mobile phone charger, a dc fan and/or a basic television.

The bank offers the SHS program only to its Kisan Credit Card (KCC) customers since they have an established track record of credit payments without default. For example, a Venus I purchaser pays Rs 2520 (US$ 500) upfront and an additional amount of Rs 11000 (US$ 220) is provided as a loan, at a 12% rate of interest, per year. The loan is paid back in equated monthly installments of Rs 245 (US$ 5) over 5 years. The monthly expenditure on the SHS is lower than that for kerosene, which amounts to Rs 280 (US$ 5.60), for average rural household use.

Case Study Reference:
http://www.ashdenawards.org/files/reports/a_graminbank_case_study_2008_0.pdf

The benefits, both on the domestic and commercial front are immediate. School and college going children are able to study for longer hours, under brighter illumination, minus the fumes and fire risk of kerosene lamps. Leisure hours are spent watching television. The community has begun to pool in its PV systems for use during social functions, doing away with diesel generator sets. On the employment front, the main cottage industry is Chikan handicrafts - a form of intricate embroidery requiring bright light. With the installation of PV systems, the workers have extended their working hours, and a family of embroiderers has seen their monthly earnings rise by Rs 450 (US$ 9).

The bank identifies and appoints semi-literate youth of each village as “business facilitators”. The local Tata BP Solar dealer trains the facilitator in system installation, maintenance and repair. He is given a basic tool kit and a cell phone to conduct his business. Each facilitator is allocated a hundred SHS customers to service, and in addition helps the dealer install new systems. His earnings are Rs 500 (US$ 10) per month and an additional productivity bonus of Rs 4000 (US$ 80) a year if all systems are found up and working.

By June 2008, 10,103 customers signed up for SHS loans, where 8007 PV systems were installed and fully operational. The bank had targeted lighting up 25000 households by November 2008, a month in which Diwali – the festival of lights - is celebrated across India. In its own one hundred branches, the bank has installed PV powered grid backup systems of 1.32 kWp each. The field is wide open to replicate such a model in rural homes, where use of off-grid PV products could transform the daily sunshine into evenings of brightness and cheer!

Current Sources of Electricity Generation in India

India's current electricity generation is overwhelmingly dependent on coal based thermal power. The other major sources of electricity generation are hydroelectricity, natural gas and, non-hydroelectric renewable sources. The share of renewable energy sources in India's electricity generation mix is higher than the world average of about 5%.[21]

Figure 1: India: Electricity Generation Mix Based on Ministry of Power and Ministry of New and Renewable Energy (MNRE) data

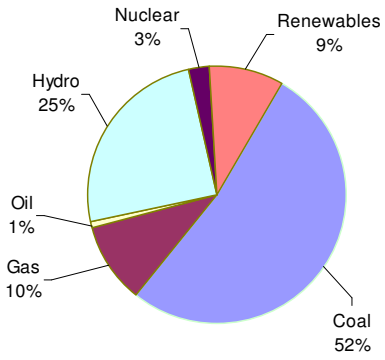


Figure 2: Installed Power Generation Capacity in India, 1997-2008 (in GW)

	1997	2002	2003	2004	2005	2008
Hydroelectric	21.65	26.26	26.76	29.5	30.94	36.7
Nuclear	2.22	2.72	2.72	2.72	2.77	4.12
Solar/Wind/Biomass/Renewables	1.27	1.51	1.74	1.87	3.81	13.45
Conventional Thermal	59.64	74.55	76.65	77.97	80.9	93.4
Total Capacity	85.79	105.05	107.88	112.06	118.42	147.6

Sources: DOE/EIA, Carbon Sequestration Leadership Forum, Ministry of Power, Ministry of New and Renewable Energy (MNRE)

Captive Power Generation Will Continue to Contribute to Electricity Needs

India has seen only modest pace of growth, relative to demand, in electricity generation. This has resulted in persistent supply shortages for both urban and rural customers. The widening deficit, because of the slow rate of growth of generation, plus, the non-availability of grid power to a huge proportion of the population will ensure that off-grid and captive power generation will remain essential to meeting the country's needs.

Estimates suggest that India needs cumulative investments of the order of US$ 1 trillion to build needed power generation capacity by 2030. Given the enormous scale of these investments it seems likely that the country will continue to see a supply-demand gap, at least in the medium term.

Captive power generation capacity in India is estimated to be in the range of 20 to 25 GW[22], a substantial percentage of which is generated from diesel, with costs of energy being about twice the cost of grid power.

Electricity grid transmission and distribution (T&D) losses in India are among the highest in the world (state-wise figures range from 20% to well over 40%[23]). Given this situation, and coupled with the power supply deficit, there is good reason to believe that off-grid and captive power generation will remain attractive options for meeting the country's electricity needs. Captive PV generation and local area distribution through mini-grids, could therefore well become a viable alternative, even as the reach of the power grid expands.

Renewable Sources of Electricity Generation in India and the Promise of PV

Renewable resources account for a respectable 9% of India's power generation capacity. Wind energy currently dominates, accounting for over 9 GW (over 70%) of the total generation from renewable resources, because of a favorable incentive policy that has spurred it on, as well as the very competitive capital costs for wind power generation.

Solar PV constitutes a very small part of India's installed power generation capacity today – with estimates of the total installed PV generation capacity in the region of 100 MWp.

The overwhelming majority of this installed capacity is in distributed, off-grid applications. Grid connected PV generation is estimated at a mere 2.12 MWp.[16] However, larger projects are being announced, almost each month, in various states, indicating rising interest in grid-connected PV generation and a clear recognition of its potential.

Estimated capital costs of setting up a solar PV generation plant in India are about Rs 200 million (US$ 4 million) per MWp. This is in contrast to approximately Rs 40 million (US$ 800,000) per MW for thermal plants and somewhere between Rs 60 to 100 million (US $1.2 million to US$ 2.5 million) per MW for nuclear power plants.

Wind generation capital costs are competitive with those for thermal power and this has been a key reason for the recent, rapid expansion of wind farms in India. However, despite substantially lower capital costs for wind generation, there are good reasons to believe that PV generation will outpace wind in India in the longer term even though the momentum in capacity installation is currently with wind based generation. These include:

The natural endowment of the landmass with abundant irradiation (5000 trillion kWh per year, across the landmass) with tremendous potential to meet the country's long term electricity needs

Technology improvements that will result in the increasing attractiveness and viability of solar PV generation, as efficiencies improve and costs of modules and systems decline

India is a medium wind profile nation and plant load factors are low compared to other wind intensive global locations. Also, saturation of the windiest locations in the country and a wind power cost curve which is expected to decline slower than for PV, in the longer term, will make the latter more attractive

THE INDIA PV MARKET, INDUSTRY AND CHALLENGES

The Current Spread of PV Applications

The application spread for PV in India, today, is very different from the global mix of solar applications, where grid connectivity accounts for about 75% of installed capacity and off grid lighting and consumer applications for the rest.

PV installations in India today almost entirely comprise off-grid and small capacity applications. They are most visibly seen in lighting applications (street lighting, traffic signaling, domestic power back-up) in the cities and towns, and in small electrification systems and solar lanterns in rural areas. PV has also begun to be deployed to a small degree in powering water pump sets running surface/submersible pumps on farms and in small industrial units. The railways, telecom and other government departments and agencies (including the military and space organizations) remain the largest consumers of PV in India.

Accurate data on installed capacity and growth projections need further primary research to validate. The non-government market for small, off-grid PV solutions is fragmented between the major Indian PV system manufacturers and several smaller system integrators, many of whom import their components. Poor consumer awareness of the economics of PV, coupled with a lack of easily available financing schemes from banks and lending agencies has meant that market growth so far has been sluggish.

Estimates of installed PV systems, published by the MNRE, are illustrative of the kinds of applications that are seen deployed across the country today.

PV Based Systems	Total Installations
Solar Street Lighting Systems	54,795
Home Lighting Systems	434,692
Solar Lanterns	697,419
Solar PV pumps	7,148
Solar PV Generation Plants	2.12 MWp

Source: MNRE Website Data, January 2009

India PV industry sources, and other reports, estimate that total installed PV generation capacity is in the region of 100 MWp, over 97% of which is in the form of off-grid applications such as those listed above.

Several recent government announcements and policy measures suggest that PV adoption may be entering a phase of major expansion. The states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Punjab, Rajasthan, Tamil Nadu and West Bengal have announced their own solar PV projects, policies, plans, and incentive packages in recent months including those for grid-connected generation.

India's MNRE has targeted grid connected PV generation capacity of 50 MWp by 2012 which ministry sources expect will be exceeded, and is speaking of much higher targets in the 2012-2017 timeframe.[20]

The India PV Industry

The earliest PV cell manufacturers in India were its 'public sector' enterprises (enterprises that were either fully or partially state owned) and government research laboratories. Some of these organizations entered solar cell play as early as in the mid-1970s and continue, today, in the business as important players.

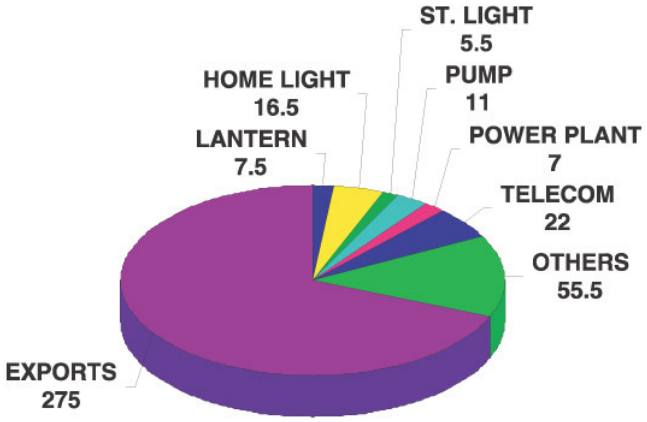
Solar Cell and Module Manufacturing

As of early 2008, India had 9 manufacturers of solar cells and about twice as many module makers.[24] There is no current silicon feedstock or significant wafer manufacturing in India although there are projects at the proposal stage and a few companies have begun to build the needed infrastructure in this direction. Most of the proposals for silicon and wafer manufacturing were motivated by the government's announcement of a Special Incentives Package Scheme (SIPS) under its 2007 Semiconductor Policy. Almost all of India's current solar cell production is crystalline silicon based and the range of proposals that the government has received include plans by some companies to build thin film module production lines.

About 70% of India's solar cell and PV module production has been exported, in recent years, especially as markets for PV have grown in Europe and elsewhere. This is likely to change, in the near future, as government policy provides the push for PV deployment and following the recent release of guidelines for grid connected solar generation in India.

The MNRE provides the chart in Figure 3, to illustrate where most of India's PV production, to date, has been deployed. Figure 4, provides data on annual module and cell production in India.

Figure 3: Cumulative PV Module Production in India and Applications (figures in MWp)



Source: MNRE Annual Report 2007-08

Figure 4: India PV Module and Cell Production (figures in MWp)

	2000	2001	2002	2003	2004	2005	2006	2007
Total PV Module Capacity Manufactured	8	17	20	23	36	45	65	80
Total PV Cell Capacity Manufactured	4.2	14	20	22	25	32	37	45

Source: MNRE Annual Report, 2007-08

PV cell and module manufacturing growth in India, going forward, will depend very strongly on how the industry and its stakeholders deliver on the various proposals for new and expanded manufacturing lines, that have been submitted to the government in response to its SIPS under the 2007, Semiconductor Policy.

Balance of System Manufacturers and System Integrators

There are numerous PV system integrators, in India, who offer end-solutions based on third party PV modules, including imports. The BOS space in India is fragmented with a large number of inverter, charge controller and battery system providers – whose products are, in turn, sourced by the PV system integrators.

India has, for many years, had a thriving industry producing uninterruptible power supplies, consisting of charge controllers, battery back-ups and inverters. These are widely used in urban homes and businesses to tide over power supply cuts, outages and quality problems. Some of these manufacturers are emerging as key players in the solar BOS space. The major manufacturers of cells and modules have also integrated down the supply chain and offer end to end PV solutions, including grid connect sub-systems, today.

While the eco-system for end-to-end PV solutions (cell, module and BOS manufacturing) is in place, in India, and the industry is well positioned to scale up, based on rising market demand, there is an acknowledged need for improvement in the quality, reliability and efficiencies in the PV BOS area. Innovation in this area will be key to delivering better overall system performance, and this could be an important determinant of wider PV adoption.

Challenges of the PV Industry in India

The Need for Closer Industry-Government Cooperation

India's policy makers while clearly acknowledging the central role solar PV will play in the long term energy needs and strategy of the country, also suggest that solar PV is some years away from true cost competitiveness and from being able to compete on the same scale as other energy generation technologies. This is evidenced in the guarded approach taken by the government in announcing Generation Based Initiatives for grid connected solar PV (feed-in tariffs) in 2008, which it views essentially as a pilot program 20.

The interplay between incentives and policy support on the one hand, and technology cost-point reductions, through industry innovations and scale, on the other, will determine

how the PV landscape in India will turn out in the years ahead.

Indian industry executives refer to solar PV, in the country's context, as being both a transition and a transformational solution. PV applications are well suited both for small, off-grid applications, because of India's unique needs and circumstances, as well as at the grid connect level. The proliferation of the former will require financing schemes, mandates and targets, while the latter will ride on technology and cost point improvements, the achievement of scale, and the right policy framework.

Industry trade organizations can play a key role in representing the broader industry position, to the government. In addition to working on policy issues, allied concerns of the industry such as the need to eliminate aberrations in the prevailing tax and duty structure to support local manufacturing over imports, the need for lending guidelines, extension of PV benefits to enable the entire PV supply chain including material and equipment manufacturers, and so on, may be represented more effectively.

The Need for Standards

In technology markets, long-term sustained profitability in the supply chain requires that research and product development costs be concentrated on innovation. In many industries, R&D investments are consumed by product differentiation, such as accommodating special regional or customer-specific requirements. In the PV industry, industry-wide cost reductions, in combination with a sufficiently profitable supply chain, can only be achieved through materials and process innovation, productivity improvements and effective global industry standards.

Industry standards enable innovation through reduced costs on equipment, physical and communications interfaces, product specifications and nomenclature, health and safety requirements, and a host of other aspects. To achieve the growth goals for the industry, standards play an important role by channeling development activities into real innovation, not supporting a fractionated industry with custom sizes, shapes, features, interfaces, quality, and other attributes that are not essential to long term end customer value. A report of the Fraunhofer Institute for Systems and Innovation Research states, "as, for overall economic development, it is not only the potential of existing innovations that is of importance, but also particularly their diffusion. Here, standards play a decisive part. They act as catalysts enabling the diffusion of innovations in the market."

Industry standards activities are desperately needed in the PV industry to reduce cost and accelerate investment in innovation. Although some standards are applicable, the PV industry has been dominated by de-facto standards from dominant players or by no standards at all.[25]

These concerns are echoed by Indian industry executives who cite the urgent need for standards in the local context.

- No common PV specifications (for tolerances, test standards, etc) exist between different government departments such as the railways, telecom, the MNRE and defence establishments leading to fragmentation within and across manufacturers and suppliers and a loss of scale. Common specifications for PV need to be evolved, involving all stakeholders, that will become part of those published by the Bureau of Indian Standards (BIS)

- Standards for quality, inspection, safety, testing and certification are central to continuous improvement and to the success and wider adoption of PV. These need to be set and the necessary infrastructure put in place to handle industry needs locally and improve turnaround time.

- Environmental, health and safety standards need to be established and monitored if PV has to deliver on its promise of being a clean energy solution to India's needs. Compliance with environmental standards will be extremely important if India is to play the leading role being envisaged for it, in the PV world.

The Need for Focused, Collaborative, Goals-Driven R&D

Indian PV experts emphasize that given the size and potential of the larger PV opportunity in India, a coordinated effort is required from the industry to put in place a comprehensive research and development plan that will leverage the large, existing network of research institutes and laboratories.

A comprehensive industry research roadmap needs to be evolved, in collaboration with universities and national labs, with clear, time bound, technology and cost goals. The research roadmap needs to encompass all aspects of the PV eco-system including materials, cell technologies, process, equipment, packaging, test and characterization, manufacturing engineering and automation, battery/storage technology, inverter and BOS electronics, metering and so on.

For India to seize the opportunity to become a world leader in PV technology a program of coordinated, sponsored, collaborative, goals-driven research is a critical need.

The Need for Financing Infrastructure, Models and Arrangements to Spur the PV Industry and Consumption of PV products

There is a pressing need to put in place the required financing infrastructure that will motivate and enable large scale PV adoption among consumers as well as investments in PV by the industry.

Financing models need to cover the entire spectrum of users from small rural homes to enterprises implementing PV in power back-up applications and larger grid connected deployments. Expanding PV manufacturing across the supply chain, from silicon and wafer production to end systems, including allied components, equipment and materials, requires the availability of robust and attractive financial arrangements.

Banking institutions and lending agencies need to be familiarized with the promise and prospects of PV technology, manufacturing, its economics and social benefits. Such training and exposure would lead to informed evaluation of project proposals and streamline the flow of funds. Banking guidelines and policy measures, to encourage lending for PV, would boost the flow of funding to the industry.

Loan and financing schemes for end customers have been key enablers in the widespread adoption of solar water heating all across India. Under these schemes, end customers benefited from low interest rates for purchasing and installing solar water heaters, with the MNRE bridging the rate difference with lending institutions. Similar models need to be rolled out to boost PV, until scale is achieved.

Training and Human Resource Development

MNRE sources suggest that PV could create 100,000 jobs in India by 2020. Key industry executives emphasize that human resource training and development is an area that needs immediate attention.

There is a pressing need to scale up the level of technical education in all aspects of PV from materials and cell technology to manufacturing, PV systems engineering, installation and maintenance.

For the Indian industry to scale up in PV technology and manufacturing, technical institutes, colleges and universities will need to develop PV curricula, build infrastructure, and create the right courseware in cooperation with the industry. Certification programs will need to be created in PV technology, systems, applications, installation and maintenance at industrial training institutes and through private training centers to meet projected needs for trained personnel.

Intra-industry Cooperation

Expanding the Industry's Play in the PV Supply Chain

India has no current silicon feedstock or wafer manufacturing capability. PV experts emphasize the need for the Indian PV industry to collaborate to build such capability and expertise, in order to have a real chance at innovation and cost-reduction through ownership and access to the entire supply chain.

Industry experts also emphasize the importance of collaboratively putting in place a materials and equipment supply chain, covering glass, special gasses, ethylene vinyl acetate (EVA) film, etc. to create the expertise and leverage needed to enable game-changing innovations in PV technology.

Information Sharing and Conferences

There is a widely acknowledged need for a platform, via a regular calendar of PV technical conferences and workshops to share and diffuse new findings, best practices, technical problem resolutions and to pave the way for collaborative work in the industry.

Collaboration with Balance of Systems Manufacturers

Industry collaboration is required in order to go beyond cell and module development and manufacturing and to enable and work with BOS manufacturers and developers to innovate, set targets, improve quality and reliability and enhance the overall efficiency of PV systems.

Market Data, Trends, Projections

A critical need, in the Indian PV context, is a source for reliable market data, projections and trends, as well as to track production, sales, adoption and effectiveness of PV products and solutions.

An industry or trade organization can serve as a credible common clearinghouse for collection of accurate industry/market data and statistics; also, as a single window for the dissemination of accurate consumer information and collateral about new technologies, applications, right-usage, economics and so on.

Trade Shows and Expositions

Trade shows are essential to accelerate adoption and diffusion of technologies and solutions and to announce and share new products and information. There is a need to organize a regular calendar of trade shows centered upon the Indian PV industry bringing together the entire eco-system of suppliers and potential customers.

Consumer Awareness

Creating consumer and public awareness has been identified as one of the challenges to wider PV adoption, worldwide. In India this need is further accentuated by the diverse socio-economic context and diversity of living conditions.

In the words of the US National Renewable Energy Laboratory's PV industry Roadmap document, "consumers must become better educated about using solar energy —

not just for water heating but for their electricity needs. They will need to be firmly convinced of the practicality and performance of PV systems over time."

Outreach, training and greater public awareness about solar electricity, the basics of installation, right usage, maintenance and its larger benefits, is needed. Facts and figures about solar electricity need to be consistent, accurate, unbiased and clearly presented. Pervasive misconceptions about PV and its viability and cost-competitiveness, need to be addressed. Comparisons of the cost of PV versus the use of diesel, gas and other conventional fuels, especially for captive and back-up power generation, need to be publicized.

GOVERNMENT INITIATIVES AND POLICIES ON SOLAR PV

Recent policy and planning announcements by the Government of India suggest a clear recognition that PV is likely to play an increasingly dominant role in India's energy strategy, in the future.

India's National Action Plan on Climate Change (2008) Articulates a Central Role for Solar Power

The Government of India's National Action Plan on Climate Change released in mid-2008, by the Prime Minister's Council on Climate Change identifies eight critical missions, one of which is the National Solar Mission.

In the words of the report, solar energy "has great potential as a future energy source. It also has the advantage of permitting a decentralized distribution of energy, thereby empowering people at the grass roots level".

Going further the report says, "Solar based power technologies are an extremely clean form of generation with absolutely no form of emissions at the point of generation. They would lead to energy security through displacement of coal and petroleum. T&D losses are very low in decentralized systems. Deployment can be done independently of the national grid and integrated with the national grid when needed"

On targets, the document states that the National Solar Mission, "would aim for local PV production from integrated facilities at a level of 1000 MW per annum" by 2017. "In the longer term the Mission would direct Indian solar research initiatives to deliver truly disruptive innovations that cut across any one approach or technology. The ultimate objective of the mission would be to deliver a solar industry in India that is capable of delivering solar energy competitively against fossil options from the Kilowatt range of distributed solar thermal and solar-PV to the Gigawatt scale of base-load priced and dispatchable CSP (concentrated solar power) within the next 20 to 25 years".

India's 2007 Semiconductor Policy and Special Incentives Package Schemes

The Government of India formalized its Semiconductor Policy in March 2007. Under this policy the government issued formal guidelines, in September 2007, for what are called Special Incentives Package Schemes (SIPS) for setting up and operating semiconductor fabrication and eco-system manufacturing units in the country. Solar cells and PV were explicitly included under the definition of 'eco-system' units.

Given the nature of incentives specified (capital investment subsidies of 20% to 25% through grants and interest subsidy or, alternatively, through government equity participation) there was enormous response to the announcement. Major existing PV players as well as several large industrial groups submitted proposals, with the solar/PV component of them amounting to US$ 18 billion (out of a total US$ 23 billion of proposed investments). A related, but parallel, government policy on Special Economic Zones where manufacturing facilities exclusively for exports (including PV/solar type units) are given a host of incentives including tax and duty wavers, further enhanced investor interest.

Incentives for Grid Connected Solar Power Generation

India's Ministry of New and Renewable Energy (MNRE) announced Generation Based Incentives (the equivalent of feed-in-tariffs) for Grid Interactive solar PV Generation Projects in January 2008.

Important provisions under the Generation Based Incentives (GBI) scheme are:

- A cap of 50 MWp of cumulative installations, by 2012, claiming benefits under the scheme
  (More recent indications from the MNRE suggest that this cap almost certainly will be raised, perhaps doubled, in order to allow for bigger investments and to boost grid connected PV generation in the country)
- Incentives are applicable only to non-captive solar PV plants with a minimum generation capacity of 1 MWp, in a given location
- Accelerated depreciation on capital investment is not allowed in conjunction with tariffs claimed under the GBI scheme
- Tariffs, for projects completed before Dec 31, 2009:
  - Rs 12 (US$ 0.24) per kWh in addition to any power purchase rate agreed upon with the state utility company (in the power purchase agreement – or PPA), subject to a maximum combined price of Rs 15 (US$ 0.30) per kWh

- Tariff decreases in accordance with any power purchase rate increase agreed to with the state utility company
- This tariff arrangement ceases at the end of 10 years from the start of generation, even though power generation from the plants continue well beyond this time frame

The Indian PV industry, while welcoming the announcement of a feed-in tariff scheme for grid connected PV, has expressed its concerns that the scheme, as it stands, needs to be expanded in scale and requires review and rework to make it more attractive to investors.

Some states have announced their own feed-in tariffs and incentive packages for grid connected PV generation in recent months, independently of the MNRE's GBI scheme. These benefits are available to projects to be set up in the respective state, and the project has the option of claiming benefits either under the state scheme or the MNRE's GBI scheme.

Other Policies Guiding India's Push towards Renewable Sources of Power

Electricity generation policies in recent years reflect a focus on shifting to renewable sources in India's power generation mix. Key policy directives that are guiding the move to wider renewable energy adoption in power generation are:

The Electricity Act, 2003
Provides a directive to states to promote co-generation and primary generation of electricity from renewable sources and to take measures to enable connectivity with the grid. It also articulates the need to specify a minimum percentage that will be purchased from such sources.

The National Electricity Policy, 2005
Stipulates that the share of electricity from non-conventional sources will need to progressively increase. It also notes that since non-conventional sources are not immediately going to be cost competitive with established power generation technologies that state commissions determine differential pricing to promote these.

The National Tariff Policy, 2006
Mandates state electricity commissions to specify their Renewable Energy Purchase Obligations (RPO).

The National Rural Electrification Policy, 2006
Along with goals to provide access to electrification to all households in the country by 2009 and to provide a minimum 'lifeline' level of consumption of 1 unit (kWh) per household per day, the policy also mentions that off-grid solar PV solutions may be deployed where the supply of grid electricity is infeasible.

RECOMMENDATIONS AND CALL FOR ACTION

Evolve a Common Government-Industry Vision to Make India a World Leader in PV

Given India's geographic advantage in harnessing the power of the sun, the enormous potential of its domestic market, the existence of a strong research and industry eco-system, the job creation and transformational potential of PV, India must aim to become the global leader in this clean, revolutionary energy technology, with the right vision, commitment and policy drive.

As one leading PV industry executive stated it, "India needs to write the future, and become the voice of the world in this people-centric technology"

- The National Solar Mission needs to be operationalized. The National Action Plan for Climate Change could be used as a start point for setting PV goals

- Enact laws and mandates to expand solar PV adoption and generation (both off-grid and grid connected)

- Evolve a comprehensive research roadmap, in collaboration with universities and national labs, with clearly defined, time-bound, technology and cost goals.

  The research roadmap needs to encompass all aspects of the PV eco-system including materials, cell technologies, process, equipment, packaging, test and characterization, manufacturing engineering and automation, battery/storage technology, inverter and BOS electronics, metering, etc.

  India must aim to set, not follow, technology leadership in solar PV.

- Put a plan in place for achieving and sustaining true manufacturing scale. Create a plan to develop and strengthen the entire PV supply chain from silicon feedstock, wafer manufacturing, materials and equipment to end-systems.

- Focus on training and human resource development in collaboration with the college, university and training eco-system

- Consider instituting a PV Technology Development Fund with a substantial corpus to help fund joint industry-government research programs

Develop Financing Infrastructure and Models that will Motivate Large Scale PV Adoption and Investments

- Create awareness in the financing community about PV technology, its promise and prospects, to enable informed project evaluation, in accelerating decision making on proposals and in streamlining the flow of funds

- Roll-out financing models and schemes to enable lending to all categories of PV customers and develop appropriate financing arrangements to spur the industry

- Evolve banking guidelines and lending policy measures specifically targeted to lending for PV

Expand Deployment of PV in Off-Grid Applications

Off-grid applications for PV in India need to be promoted aggressively. The following are key areas where a combination of subsidies and incentives along with targets and a mandate for deployment are the need.

- Expand PV based rural electrification and lighting
  A large program needs to be implemented through respective state utilities, with funding support from organizations such as the Power Finance Corporation, or by diversion of kerosene subsidies.

  One industry source recommends an approach along the following lines:
  The government could start by withdrawing 25% of the Rs 20,000 crore (US$ 4 billion) on kerosene subsidies every year and use it to create a solar light fund. This amount should provide the first 10% of finance required for a home lighting system costing Rs 15,000 (US$ 300), with the remaining coming from a regional rural bank of the area. If this is applied, every year 33.3 million families can be provided solar home lighting systems, assuming that the rest of the cost is pre-financed by regional rural banks and paid back by the beneficiary family over the next 4 or 5 years in monthly installments of approximately Rs 300 (US$ 6). Over 4 years, this scheme would reach 133.3 million families.

- Deploy solar PV irrigation pump sets on a large scale
  Offset both the huge diesel/kerosene uptake by the estimated 9 million irrigation pumps and the enormous electricity consumption by the estimated 12 million electric pumps, using PV.

  Given the huge quantum of money involved in irrigation subsidies, key PV industry executives believe there may be a good case for free solar pump set distribution in parts of the country where the need

is the greatest. For example, some parts of the state of Uttar Pradesh that lie in the Gangetic plain have a high water table and also the highest density of diesel pump sets in the country.

- Issue mandates and guidelines for the use of PV in power back-ups for cellular base stations across the country

- Increase maintenance budgets for government PV deployments to ensure that projects do not end up failing through poor upkeep. Create clusters of PV projects in an area to achieve better, more efficient monitoring and improved delivery of technical support.

- Boost urban PV adoption through, a target of a 'solarizing' a certain number of rooftops, as has been successful in other parts of the world and set a target of something like one large BIPV structure in each district.

  This may even start with targets for government buildings across the country as a demonstrator. Industry sources believe that stand alone, roof top power generation installations, in urban areas are affordable today. If favorable financing schemes are provided to users directly, through commercial banks, this can be the launch pad for exponential growth in roof top PV, in the years to come.

- Mandate the use of renewable sources, including solar PV, in captive power generation plants

- Expand the use of PV in street, traffic, billboard and highway lighting across the country

- Promote and incentivize the use of PV in power supply back-ups for domestic and commercial use

Prioritize Grid-Connected PV Generation on a Large Scale

Grid connected PV needs to be prioritized with a far reaching, full fledged tariff scheme that provides attractive rates of return on investment.

- Review and rework the current Generation Based Initiative Scheme of the MNRE, in consultation and collaboration with industry groups and representatives to motivate greater investor interest

- Operationalize a plan to upgrade the power grid to support large scale feed-in from solar farms

- Identify regions and land tracts suitable for the establishment of solar farms to streamline and accelerate land acquisition

Next Steps

As a part of SEMI, a global association with a focused interest in PV through its PV Group, SEMI India is committed to creating a constructive and collaborative platform, bringing together stakeholders from the government, industry, academia and other sections, to discuss and debate issues that will lead to an action plan to help grow the local PV industry.

SEMI India intends to follow up on the recommendations and calls for action highlighted in this paper in order to convert them into meaningful action plans.

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K. Subramanya	Tata-BP Solar
Dr. Madhusudan V. Atre	Applied Materials
Rao S.Y.S Chodagam	Titan Energy Systems

The SEMI India PV Advisory Committee:

Dr. V. S. Gangadhara Rao	Velankani Renewable Energy
Dr. J. Gururaja	Renewable Energy Action Forum
Dr. Keshav Prasad	Signet Solar
Dr. Madhusudan V. Atre	Applied Materials
S.S.N. Prasad	Solar Semiconductor
Rabindra Satpathy	Reliance Industries, Solar Energy
G. Rajeswaran	Moser Baer Photo Voltaic
Rao S.Y.S. Chodagam	Titan Energy Systems
Seshagiri Rao Meka	Oerlikon Solar India
K. Subramanya	Tata-BP Solar

Feedback and Comments

SEMI India, welcomes comments, feedback and suggestions on any aspect of this paper. Comments may be sent to: semiindia@semi.org

ADDENDUM

The Worldwide PV Scenario

Global installed PV power generation capacity has been buoyed by rising conventional energy costs, strategic national and energy security concerns, the threat posed by climate change, better financial incentives, the decreasing cost of solar cells, panels and systems, and a favorable policy climate in several parts of the world. This is particularly the case in Europe (notably, Germany, Spain and Italy), Japan and the US, that have shown strong growth in PV deployment in recent years.

Worldwide PV manufacturing capacity is expected to scale in order to meet this demand, although dynamics of supply-demand mismatches, as capacity ramps up, may result in intermediate price and cost fluctuations of PV generated electricity.

Annual installed (new) PV generation capacity worldwide has been growing at an average annual rate of 35% since 1998 surpassing 6.5 GWp of cumulative capacity in 2006.[26] In 2007 alone 2.6 GWp of new solar PV generation capacity was added, worldwide.[27]

While PV power today constitutes only a small percentage of global electric power consumption (much < 1%), some scenarios suggest that it could rise to between 6% and 9% by 2030.[26] Upside estimates suggest that by 2040, PV power generation could account for between 20 and 28% of the world's electricity generation. Far term projections predict a dominant role for solar electricity in the world's net energy consumption.[28]

Costs per kWh (unit) of PV electricity will continue to decline continuously, driven by improving solar cell technology and system cost improvements and are expected to result in grid parity, in several regions of the world as early as within the next 10 years. Some analyses suggest that solar electricity is already cost competitive, at the utility level, with intermediate and peak-power generation, in certain parts of the world, such as in Japan and parts of Europe, when more expensive sources of generation (such as natural gas generators, for example) are used to supply the grid.

Besides grid connected solutions, in very large parts of the developing world PV presents tremendous possibilities and potential for meeting electricity needs in highly dispersed rural markets. Such regions in many parts of the world are currently extremely electricity deficient or completely off the grid. In the words of the 'Fund for Renewable Energy Everywhere', for billions of "people without access to electricity, it would be cheaper to install solar panels than to extend the electrical grid".

Rapid PV Growth: The Case of Germany

Total installed PV power generation capacity in Germany, in 1991, was 3 MWp, when feed-in-tariffs (FITs) were first introduced. By 2007, the cumulative installed PV capacity had reached 3,834 MWp.[27] The government's support programs are widely credited for this rapid growth, and FITs have proved to be the most powerful of these.

Other government schemes have resulted in augmenting commercial power production based on solar PV. These programs offer depreciation benefits, VAT exemption and tax credits on investments.

PV power is projected to achieve grid parity in Germany between 2012 and 2015, when costs are expected to be between 23.81 to 24.70 euro cents per kWh.[27] The FIT is widely considered to be the most effective instrument that has driven the dramatic growth of solar PV in Germany.

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Notes on Terminology and Style

- The term photovoltaic is shortened to PV throughout this paper.
- The terms PV and solar PV are used interchangeably and are intended to be synonymous.
- The term R&D is an abbreviation of 'research and development'
- Costs and prices are quoted both in Indian Rupees (abbreviated to Rs) and US dollars (US$)
- Costs in Indian rupees are quoted in 'crores', a unit widely used in India: 1 crore = 10 million
- The term 'off-grid' is used synonymously, or in conjunction with, 'standalone' and 'distributed', in the context of non grid connected PV applications.
- References are listed in the foot notes on each page in the main text of the paper, and are not provided in the Executive Summary.