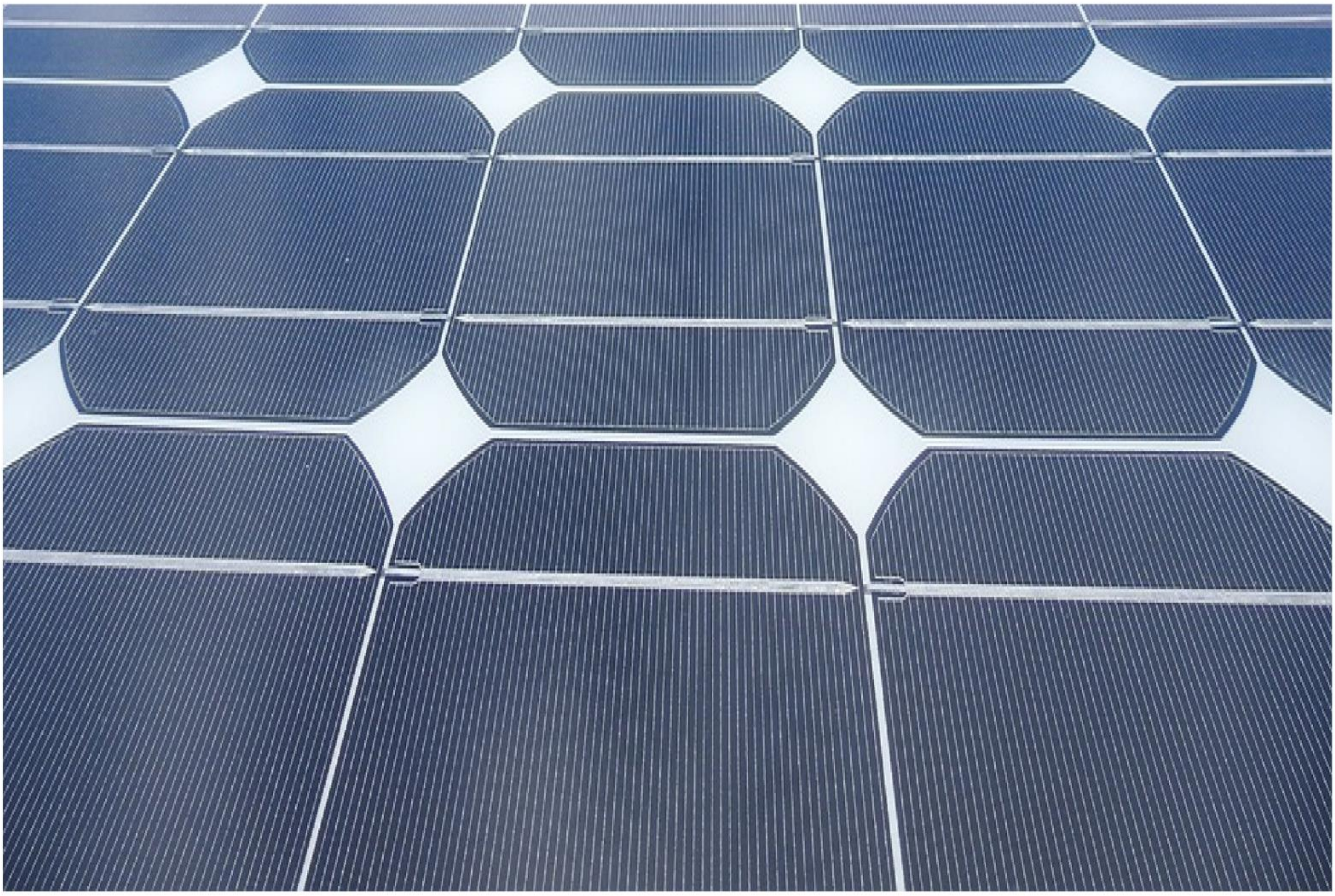
State-level Policy Analysis for PV Module Manufacturing in India



State-level Policy Analysis for PV Module Manufacturing in India

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Executive Summary

The Indian government introduced the National Solar Mission (NSM) in 2010, which aims to make India a global leader, in terms of installed solar energy capacity as well as manufacturing for Photovoltaic (PV) technologies. The installed capacity for solar energy in India stands at ~8.7 GW (2016) up from 2.6 GW in 2014. India has also doubled its module manufacturing capacity from 2.8 GW in 2014 to 5.7 GW in 2015. At present, India has 94 PV module manufacturers. The central government has been encouraging the domestic PV manufacturing industry, by providing incentives, such as exemption from import duties and mandating the deployment of indigenous modules, in some of the projects under NSM. However, very few state-level policy initiatives provide incentives specifically to promote the solar manufacturing industry. Therefore in this report we analyse the potential role of state-level policies in driving the growth of PV manufacturing in India.

India has a reliable manufacturing base for modules, whereas other supply chain components are non-existent. Therefore this analysis is focused on PV module manufacturing. This study examined module manufacturing in 10 selected states: Gujarat, Andhra Pradesh, Jharkhand, Chhattisgarh, Madhya Pradesh, Rajasthan, Odisha, Maharashtra, Karnataka, and Uttar Pradesh. These states were identified as the preferred states for setting up PV module manufacturing, based on certain parameters, which are discussed in detail in the report. Policy incentives given in these states have been compiled and their impact on the final manufacturing cost of a PV module has been examined. Among these states, Chhattisgarh provides a variety of incentives, including capital subsidy, interest rate subsidy, stamp duty exemption, electricity subsidy, etc., whereas, Gujarat provides fewer types of subsidies. These two states provide capital subsidies at different levels.

A financial model was also created to evaluate the current situation of module manufacturing in India, given the current policy scenario. A semi-automated type of module manufacturing facility is selected for the analysis. Several investors have set up module manufacturing plants; however, many of these module-manufacturing facilities are running at very low capacity utilization or have stopped production. The average utilization in India across all facilities is 30%. Development of the model in this study enables assessment of policy options to improve the economics of domestic production.

Because we find that raw materials (70-80%) and the working capital (12-15%) comprise the majority of manufacturing costs, this financial analysis suggests that incentives given on capital investment are not very helpful in lowering the cost of manufacturing. The major components used to manufacture a module include cells, glass, encapsulant, back sheet, interconnect ribbon, sealant, frames, etc. A cell comprises ~60% of the cost of a module. This analysis has determined that the current cost of manufacturing is INR 31.97/W_p[1]. This analysis has identified three major challenges, which need to be addressed to make module manufacturing competitive in India:

- Higher working capital (WC) needs is the hallmark of module manufacturing. Non-availability of WC makes it difficult to compete against the firms from China and South East Asia, who offer better terms.
- Interest rate is one of the major cost components affecting the cost of module manufacturing. The current interest rates are in range of 12-15%, which is high.
- Higher inventory levels of raw materials and finished modules raises the manufacturing costs.
- Falling prices also make inventories extremely costly
- Low utilization factor increases the cost of manufacturing

A sensitivity analysis was performed to see the impact of above mentioned challenges on the final manufacturing cost of a module. The analysis shows;

[1] This cost was analyzed based on FY 2015-16 module manufacturing scenario.

- With lower interest rates of 8% and financing backed by government green bonds, the cost can be brought down by ~1.03 INR/W_p.
- A combination of efficient inventory management and high capacity factor can bring down the manufacturing cost by ~1.45 INR/W_p

To manufacture domestic modules at competitive costs, compared to its global counterparts, the government may choose to incentivize operations of module manufacturers, through combined efforts including offering attractive interest rates, ensuring a good market for domestic modules.

In India the operations vary according to the size of the plant and there are considerable reductions in the cost of manufacturing above 75 MW. Globally 120 MW is the entry barrier for modules; but in India the size varies and most of them are below 120 MW. They can be classified in two categories: >75 MW or < 75 MW, depending on their operations. Bigger plants have lower raw material procurement costs, higher productivity, and moderate inventory cost. Also, they can avail Modified Special Incentive Package Scheme (M-SIPS) capital subsidy.

The raw material prices from Chinese companies vary up to 15%, depending upon track record, payment terms, demand situation, quality etc.

1. Introduction and Policy Questions

1.1. JNNSM and policy motivations for promoting domestic PV Manufacturing

In the face of climate change and ever-increasing energy demand, the sun is increasingly becoming an important source for meeting energy needs in India and around the world,. To this end, India introduced the National Solar Mission (NSM), which in its initial iteration aimed to add 22 GW of solar generating capacity by 2022 [1, 2]. In 2014, the new administration increased the target to 100 GW [3], enough to cut India's energy poverty in half and to increase the share of solar-based generation, from less than 1% of its total electricity generation in 2014, to over 10% by 2022[2]. But India's policy makers are wary of replacing imported coal with imported solar, so in addition to solar generation, there is also considerable political will to build a robust domestic energy manufacturing industry, in order to attain energy independence and economic benefits, such as jobs and exports [4].

Policymakers are keen to use this push for solving energy poverty to simultaneously develop India's industrial capacity and international competitiveness in solar, which they believe could be a strategic "priority" sector [5]. To achieve this objective, the early implementation of the NSM included Domestic Content Requirements (DCRs). DCRs have not achieved their objective of boosting domestic solar manufacturing; moreover they have increased costs for off-takers [6-8]. Additionally the World Trade Organization, which India is signatory to, has ruled against India's solar DCR. Policy makers, therefore want to explore other means of incentivizing domestic manufacturing, especially in the assembly of modules, which directly supports its solar deployment goals [9]. Policy makers hope to incentivize firms to set up manufacturing facilities, and increase domestic PV manufacturing capacity to 5-10 GW per annum of cells and modules. If successful, India's policy makers hope to 1) grow industrial productivity through sales of domestically manufactured solar cells and modules, 2) create jobs [10], 3) increase local tax base and (4) achieve cost savings through technology learning (by manufacturing, R&D and interaction with developed markets) [11-15]. Another less tangible but important benefit to manufacturing solar, explicitly stated in the mission, is the political desire for international recognition as a player in an emerging industry.

This study quantifies the cost of some of the possible alternative, non-DCR industrial policy measures that governments both at the federal and local and state levels, may employ in supporting domestic manufacturing. The study reviews industrial policies, especially in the solar-rich and business-friendly states, and measures their efficacy in incentivizing firms to invest in manufacturing capacity. Assuming that a firm will only manufacture in Indian states, if it can make a positive economic profit after factoring in incentives and cost of manufacturing in the specific location, at prevailing market prices, the study aims to identify mechanisms and level of support required to incentivize this investment

1.2. Overview of PV manufacturing globally and India's competitive position

This section briefly describes the key solar PV technologies employed, especially in India, towards a better appreciation of the domestic manufacturing challenge and the current state of the manufacturing industry.

Two PV technologies dominate the present commercial solar industry: crystalline silicon (c-Si) and thin-film cells. c-Si is the most common, with close to 80% (cumulative) of the total deployed PV market share.

[2] India's total power generation capacity was 303,118.21 MW as on June 30, 2016. See: http://www.ndtv.com/india-news/indias-total-power-generation-capacity-crosses-300-gw-mark-1438906

c-Si is stable, delivers efficiencies in the range of 15% to 25%[3], relies on established process technologies with an enormous database and in general, has proven to be durable and reliable. Its major disadvantage is that it does not absorb light well, compared to other PV materials, and therefore requires an extra thick layer. On the other hand, thin-film solar cells absorb light better, so they only require a thin layer, making them thinner and lighter. However, they are generally less efficient and less durable. The technology used in thin films is also less mature, and therefore enjoys less support services. Some examples of thin films include: amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium (gallium) selenide (CIS or CIGS), and dye-sensitized solar cells (DSC) and other organic materials [16] [19]. Crystalline Si technology dominates the market for solar, with more than 93% share globally and more than 96% share in India (2015). This trend is expected to continue in the future. Therefore, c-Si modules are expected to take the lion share of India's 100 GW solar deployment target.

Figure 1 below provides a schematic illustration of the PV production chain, which corresponds to the various stages of PV manufacturing. The raw material and casting (ingot) processes represent the material phase; the wafer, cell, and module processes are often referred to as the manufacturing phase; and the system, financing, and installation comprise the development phase.

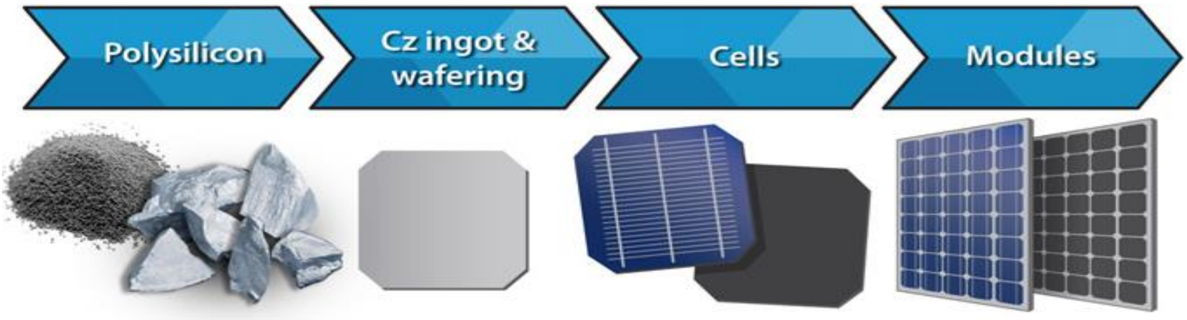

Figure 1: Solar (c-Si) PV Manufacturing Value Chain NREL, 2012

This study focuses on the c-Si production chain, which begins with purification of silicon from quartz (sand), into what is known as Polysilicon. Polysilicon rods created are then moulded into ingots and sliced into wafers. These thin slices of pure silicon are then chemically treated (doping) to form cells. Crystalline silicon cells are thereafter wired together to form modules. Modules are then installed within array to be connected and used in solar farms or on rooftops.

1.3. Global Overview of PV Cell and Module Manufacturing Leaders

Most of the big players in the cell and module markets have existing manufacturing capacity for both. The minimum entry bar in terms of plant capacity and investment for module manufacturing is 120 MW and USD 8-12 million respectively. For cell manufacturing, it is about 400 MW and USD 100-130 million respectively. This implies more opportunities for marginal players in the module market than the cell market. According to NREL, as of 2014, based on the Herfindah–Hirschman index (HHI)[4], there were 59 and 71 effective competitors in the cell and module markets respectively [17].

Nonetheless, only six producers control about 50% of the cell-module market share. These (predominantly Chinese) firms such as - Canadian Solar (Canada), Hanwha Q CELLS (Korea), JA Solar (China), JinkoSolar (China), Trina Solar (China) and Yingli Green (China) – are known now as the 'Silicon Module Super League' [18]. Further information about these firms is given in Table 1.

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[3] For more information on on-going research on solar cell efficiencies, readers may consult Martin Green's solar efficiency tables and regular articles published in the progress in photovoltaics journal [19]

[4] HHI is a measure of market concentration. It is the sum of squares of the market share of each firm competing in a market. Read more: Herfindahl-Hirschman Index (HHI) http://www.investopedia.com/terms/h/hhi.asp#ixzz4nmqpgJgh

Table 1: Global PV Market Leaders (2016)

Locations	Company	Technology	Module Capacity (MW)	Rank
China/ Malaysia/ South Africa	Jinko Solar	c-Si	6,700	1
China/ Netherlands	Trina Solar	c-Si	6,550	2
Canada/ China/ Vietnam	Canadian Solar	c-Si	5,173	3
China/ Germany/ Malaysia/ South Korea	Hanwha Q Cells	c-Si	5,000	4
China	JA Solar	c-Si	5,000	5
China	Yingli	c-Si	4,000	6

Source: PV Tech [19]

India's module makers would need to expand their capacities and consolidate, in order to break into these circles, to grow and evolve as a leader in the highly concentrated solar PV module manufacturing market.

1.4. Solar PV Manufacturing in India

This study focuses on module manufacturing, as this segment of the value chain has seen significant growth in India since the NSM. India's current module manufacturing capacity stands at about 5.7 GW per annum. Domestic manufacturers responded to increased deployment targets, by adding manufacturing capacity, in anticipation of demand. The capacity almost doubled from 2.8 GW in 2014 to 5.8 GW in 2016 [1-6]. Figure 2 shows the trend in capacity addition of module manufacturing in India. However, most of the plants are operating at very low capacity utilization; the average utilization in India stands at 30% across all facilities.

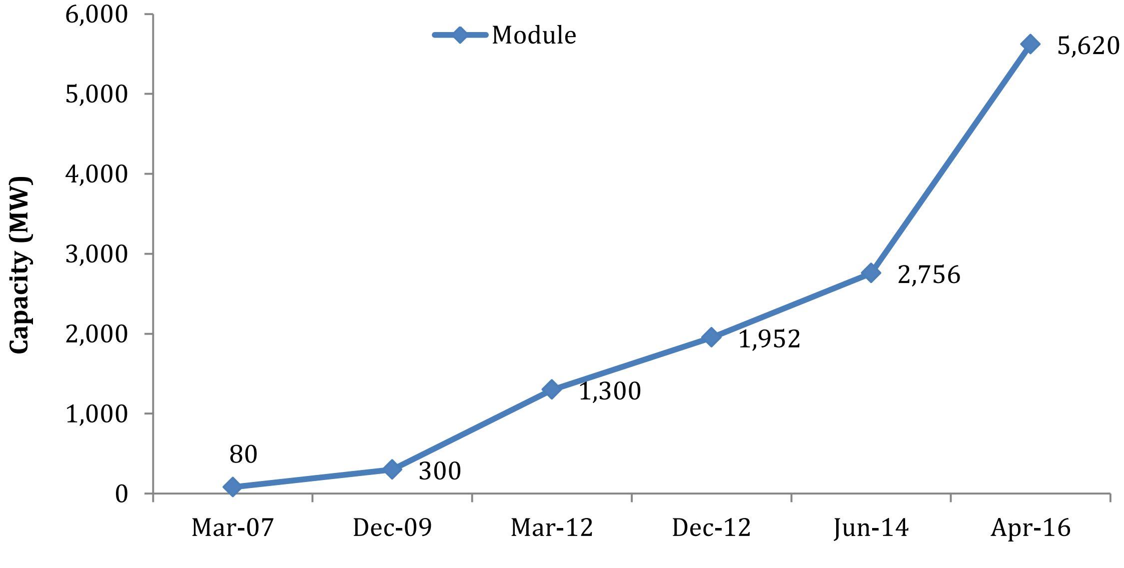

Figure 2: Trend in Module Manufacturing Capacity Addition in India

Currently 90% of the Indian solar PV installations are driven by imported modules, as the domestic modules are not price competitive. The domestic modules are priced around INR 32-34 /W_p, whereas imported ones are 10-15% cheaper. Moreover, China is providing way cheaper modules, at a rate of ~INR 25-26/W_p (PVinsights, 2016).

As on October 25, 2016, India had 20 cell manufacturers with a total production capacity of 1,468 MW/year and 94 module manufacturers, with a total installed production capacity of 5,848 MW/year. Capacity utilisations vary widely, between 20-50%, for most firms interviewed. Fourteen of the 94 companies mentioned above, manufacture both cells and modules. Under the NSM, policy makers have set a goal of manufacturing 4-5 GW of cells and modules domestically, by 2022 [20].

While India is far from its target in the cell segment, it has met its capacity goal in the module segment, However, with the exception of a few leading firms that are expanding their capacities to meet increasing demand, most firms operate below full capacity. Module manufacturing is more diversified than cell manufacturing in India, because it is cheaper and less technology intensive to set up.

In India, the operations vary with the size of the plant. Globally 120 MW/year capacity is the minimum capacity to be competitive for a module facility but in India the size varies and most manufacturing facilities are below 120 MW. They can be classified into two categories: >75 MW or < 75 MW, depending on their operations.

India's leading module manufacturers are Vikram and Waaree, each with 500 MW installed capacity, leads the market in the >75 MW category, followed by Tata (300 MW), Moser Baer (230 MW) and XL Energy (210 MW). The leading cell manufacturers include Jupiter Solar (280 MW), Moser Baer (250 MW) and Indosolar (250 MW); followed by, Tata Power (180 MW). Bigger plants have lower raw material procurement costs, higher productivity, and moderate inventory cost. Also, they can avail MSIPS capital subsidy. There is currently no capacity for manufacturing polysilicon or wafers in India.

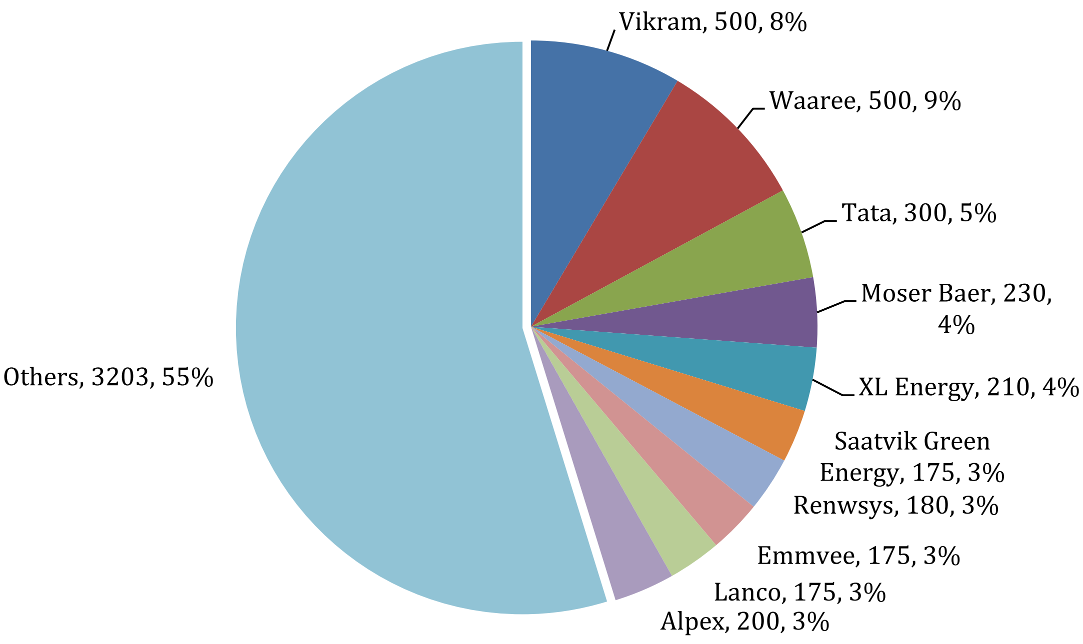

Figure 3: Top Solar Module Manufacturers in India (MW, %) Source: MNRE 2016

75 module manufacturers have their capacities below 75 MW. Some of them are Kotak Urja, Navitas Green Solution etc. However, they are operating at around 50-60% capacity utilisation. These manufacturers face certain disadvantages due to the lack of economies of scale. They generally exhibit higher raw material procurement costs, low productivity and high inventory costs. The benefits of economies of scale are mentioned in the Table 2 below.

Table 2: Benefits of Economies of Scale

	Module Plant < 75MW capacity	**Module Plant >75 MW**
Raw Materials	- Procurement through local agents /local manufacturers - Higher cost	- Direct import from China suppliers (Containers) -Moderate
Product Mix	- Small – Medium size (<150W) Modules dominant - Lower productivity	- Large size (250-320W) dominant - Higher productivity
Marketing	Dealer based	Direct users
Inventory costs	Higher	Moderate
MSIPS capital subsidy	Not available	Available

The Indian market is largely fragmented, despite many players not being able to operate at full capacity, in the face of stiff international competition. Interviews with manufacturers revealed that while manufacturers are optimistic that the industry can be competitive, they are worried about competition, in particular China. The Chinese have an advantage of more active government participation in export promotion, providing capital subsidies, tax credits, cheap finance, land and other incentives which Indian companies lack. Therefore, all the components, across the supply chain, are cheaper in China. Indian manufacturers argue that if the Indian market provided the same advantages, coupled with other intrinsic advantages such as a cheaper, highly skilled labor force and a large domestic demand, the industry could become internationally competitive. Both Indian developers and manufacturers alike agree that the Government's domestic content policy was not sufficient to promote the domestic manufacturing sector or to justify the market distortion it caused. The majority argued for more direct incentives, that target specific market weaknesses in the Indian context [21].

1.5. Research Questions

This study aims to inform policy makers and manufacturers. For policy makers, the study intends to clarify the financial effect of national and state policies that are intended to increase solar manufacturing, and potentially recommend policies that could prove more effective in achieving the objective of a thriving domestic industry. For manufacturers the study provides information pertaining to manufacturing policies across various states, which could possibly aid them in making decisions about locating their plants. Specifically the study asks:

1. What policies are employed in key states to promote solar manufacturing?
2. What financial variables can be viably affected by government incentives?
3. What is the feasibility and cost of implementing such incentives?

2. Methodology

The study utilizes a discounted cash flow accounting model to analyse the potential impact of receiving incentives to a hypothetical firm located in various states in India.

Figure 4 shows the logical flow of the study. First a few important states are identified based on their solar potential (based on MNRE data), relative ease-of-doing-business measures, installed solar PV capacity, and level of activity in promoting solar. Next the study evaluates existing non-DCR, policies in each state, such as capital and interest rate subsidies, tax breaks, and other incentives and exemptions. Next it details the essentials of a module manufacturing facility, which is modelled and analysed. Ten states were selected for analysis in the study. To determine the ease of doing business, this study relied on the World Bank's Ease of Doing Business report, 2016 [22]. It considered details such as the ease of establishing business, land allotment and construction permits, compliance with environment protocols, compliance with labor laws, ease of obtaining infrastructure-related utilities, registration and compliance with tax procedures, performance of inspections, and enforcing contracts.

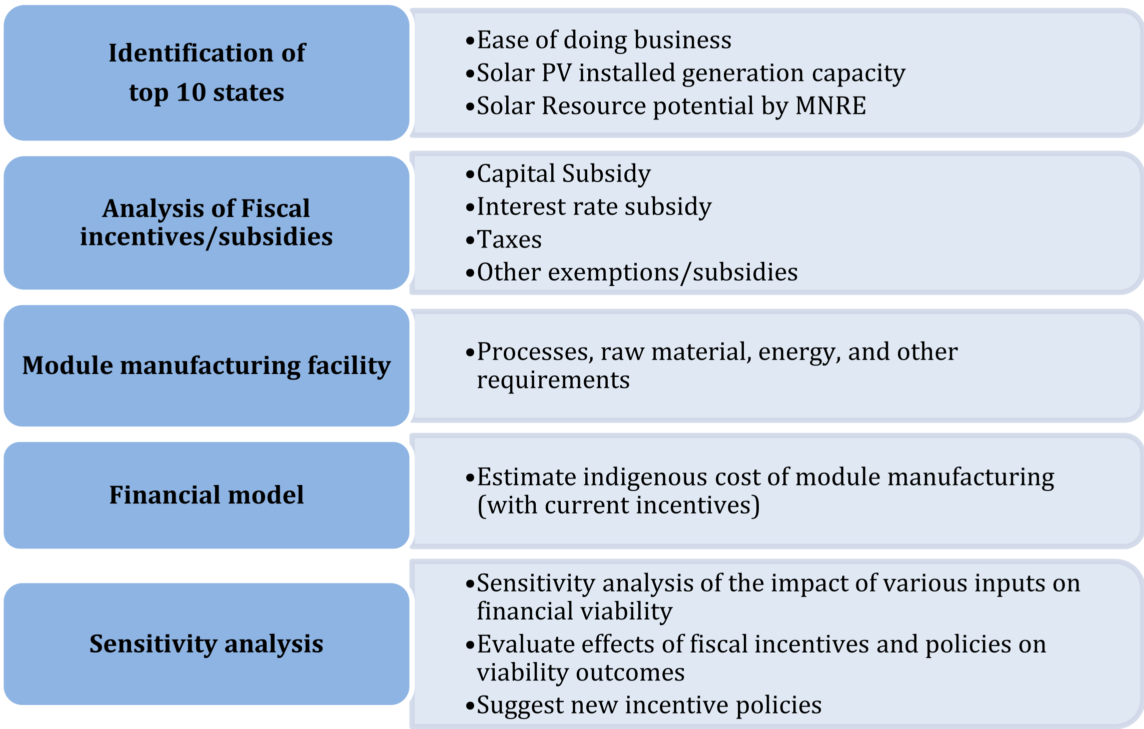

Figure 4: Summary of Methodology and assumptions for State Selection and Financial Analysis

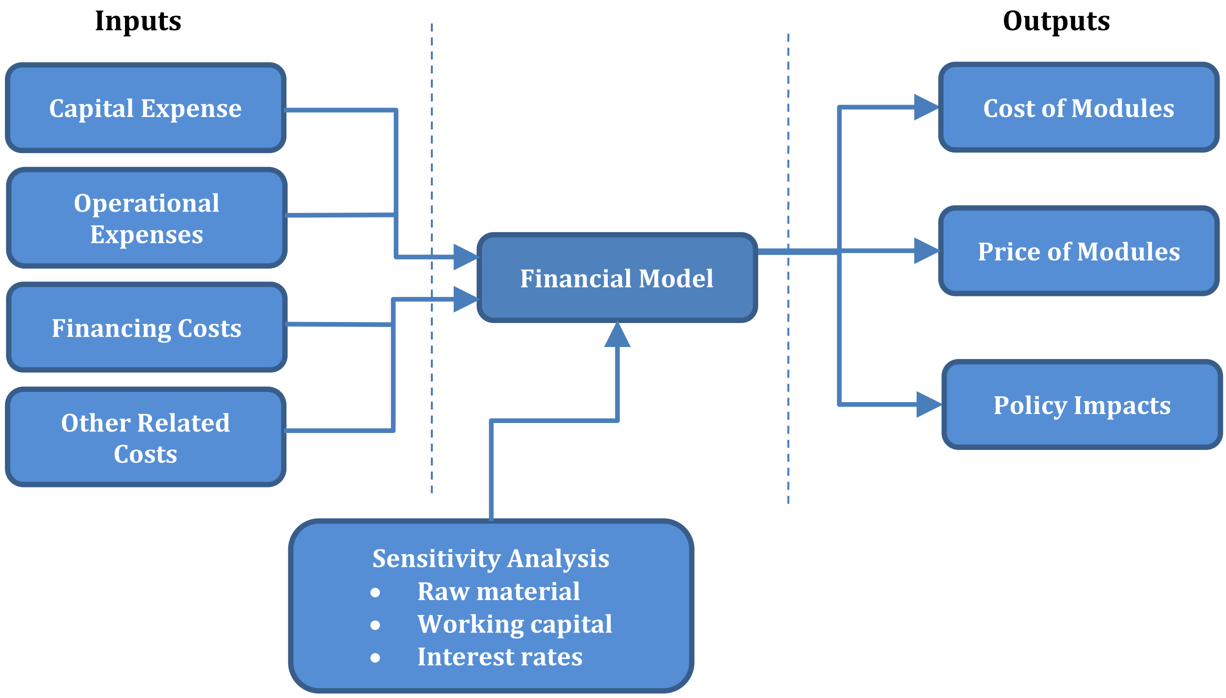

Figure 5: Financial Model Framework

The model is used to estimate how much support is required to bring a domestic manufacturing firm to profitability, in the short run. The model does not address long term effects such as those from entry of new firms, technology obsolescence, or demand volatility. The cost-analytic model follows the schematic shown in Figure 5 to provide an accounting of profitability over the lifespan of the manufacturing plant. The model inputs include capital cost, raw material, electricity, and labor cost, to calculate annual variable costs, cost of debt and repayment, net profit and loss, a balance sheet, and key viability measures such as the sustainable price at which firms can produce under current conditions.

3. States' Support policies for Manufacturers

Based on the methodology described above, the following states were selected for this study:

- Gujarat
- Chhattisgarh
- Odisha
- Uttar Pradesh
- Andhra Pradesh
- Madhya Pradesh
- Maharashtra
- Jharkhand
- Rajasthan
- Karnataka

Figure 6 below shows a map of India, with the key criteria for selecting states used in the analysis. States are colored from red (higher solar potential) to green (lower solar potential). As the figure indicates, Rajasthan (in red) has the highest solar potential at 143 GW. States' installed capacity is also shown in text within the figure; Rajasthan currently has the highest installed solar capacity with over 1300 MW installed solar PV (as of 2016). The grey circles indicate the 10 highest ranked states for doing business, based on the ranking listed in Table 3.

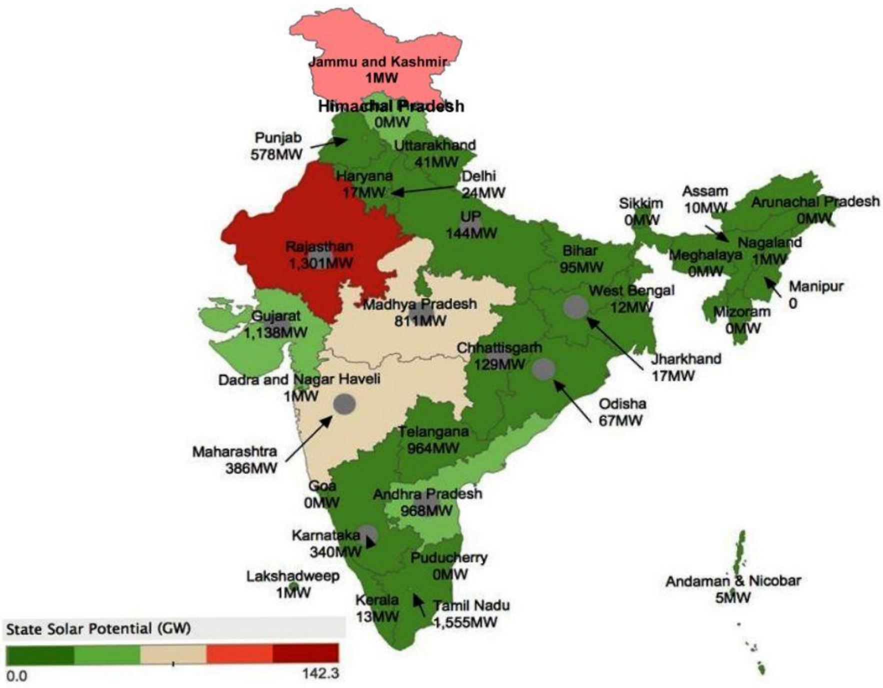

Figure 6: India's State Wise Solar Potential and Installed PV Capacity*

* Solar Potential is presented in colors and installed capacity is mentioned in numbers

Table 3: Top 10 States Ranked by Ease of Doing Business/Solar Capacity

Ease-of-Doing Business Rank	State	Ease-of-Doing Business Score	Installed Capacity (MW)
1	Gujarat	71.14	1138.19
2	Andhra Pradesh	70.12	968.05
3.	Jharkhand	63.09	16.84
4	Chhattisgarh	62.45	128.56
5	Madhya Pradesh	62.00	811.38
6	Rajasthan	61.04	1301.16
7	Odisha	52.12	66.92
8	Maharashtra	49.43	386.06
9	Karnataka	48.50	340.08
10	Uttar Pradesh	47.37	143.50

Source: India Briefing [22], MNRE 2016

The states highlighted in Table 3 also tend to have the highest cumulative solar installed. In addition, these states have all defined manufacturing incentives/ industrial policy programs that target the solar industry among many others. Therefore the analysis going forward examines these states' policies in addition to central government policies.

3.1. Overview of State Industrial Policies

This section illustrates the existing policy mechanisms available in the selected states that produce the required incentives discussed above. Table 4 below shows the industrial policy incentives, available to solar manufacturers, in the top ten states identified for analysis.

Table 4: Industrial Policy Incentives in 10 Most Active States

	Capital Subsidy (%)	Capital Subsidy Limit (Lakhs)	Interest Rate subsidy	VAT Exemption	Land Incentive	Stamp duty exemption	Electricity duty exemption
Gujarat	10%	INR 15 Lakh	7% for 5 years	-	-	-	- Power Tariff INR 7.50 for industries
Andhra Pradesh	25%	-	-	50% for 7 years	-	100%	-
Jharkhand	20%	-	5% for 5 years	80%	-	-	-
Chhattisgarh	35%	INR 110 Lakh	50% for 5 years	100 %	20% on land premium	100%	100% up to 7 years (also special tariff of INR 3.50/kwh for Renewable Energy Equipment Manufacturing Industries)
Madhya Pradesh	50%	-	5%	75% for 10 years		100%	-
Rajasthan	30%	-	-	50% on plant and machinery	50% on land tax	50%	50%
Odisha	-		5% for 5 years	100% for 7 years	-	100%	100% for 5 years
Maharashtra	-	-	5%	-	-	100%	

	Capital Subsidy (%)	Capital Subsidy Limit (Lakhs)	Interest Rate subsidy	VAT Exemption	Land Incentive	Stamp duty exemption	Electricity duty exemption
Karnataka	-	-	Full VAT & CST (7-9 years)	50% on plant and machinery	-	75-100 %	100 % for 6 years Power Tariff INR 7.50 for industries
Uttar Pradesh	-	-	5%	-	-	-	100% for 7 years

Source: Industrial policy document of each state [23-31]

4. Financial assessment of module manufacturing plant

This section describes the financial forecast model used to evaluate a hypothetical c-Si PV module manufacturing facility in India in various states. The financial schematic of the model was shown above in Figure 5. The assumptions used for this analysis are taken from a commercially viable plant after our discussions with prominent industry experts.

4.1. Assumptions

A detailed financial forecasting model provides insight into the current situation of module manufacturing in India. For the analysis, a semi-automated type of module manufacturing facility was selected. This facility is less capital-intensive, but requires more labor for operations. The assumptions constitute to a base case of analysis where the cost has been derived without considering any incentives. Further, to study the impact of state-level policies, incentives were fed into the model and costs were determined. Table 5 provides a summary of assumptions used in the analysis.

Table 5: Key Assumptions Used in Deriving Module Manufacturing Costs in India for Semi-Automatic Module Manufacturing Multi-crystalline Silicon PV Plant Type

Model Parameters	Base Case Assumptions
Capacity	200 MW_p/annum
Construction Period	9 months
Life of Plant	15 years
Plant and Machinery Cost	INR 2/W_p
Debt to Equity Ratio	70:30
Electricity Cost	INR 0.275/W_p
Labor	INR 0.50/W_p
Land	1 Acre
Income Tax Rate	34%

We studied the impact of changing assumptions by performing a sensitivity analysis on several additional variables; these parameters are given in Table 6. The impact of these parameters was analyzed in the form of final manufacturing cost in each of the selected states.

Table 6: Base Values of Variable Inputs Used in Sensitivity Analysis

<table>
<tr><th colspan="2">Additional Parameters</th><th>Values</th></tr>
<tr><td colspan="2">c-Si Cell</td><td>INR 19.89/W_p</td></tr>
<tr><td colspan="2">Total raw material cost</td><td>INR 28.69/W_p</td></tr>
<tr><td colspan="2">Interest rate</td><td>15%</td></tr>
<tr><td rowspan="2">Inventory</td><td>Raw material</td><td>2.0 months</td></tr>
<tr><td>Finished product</td><td>2.0 months</td></tr>
<tr><td colspan="2">Capacity Factor(CF)</td><td>70%</td></tr>
</table>

Raw materials for a module primarily include solar cell, glass, encapsulant, backsheet; interconnect ribbons, sealants, junction box, etc. The cost of each component is given in Table 7.

Table 7: Important Raw Materials and their Costs per W_p

Component	INR/W_p
c-Si Cell	19.89
Glass	2.24
Aluminium Frame	1.77
Backsheet	1.53
Encapsulant	1.11
Junction Box	1
Interconnect Ribbon	0.81
Edge tape	0.3
Sealant	0.04

As the table shows, the solar cell constitutes the biggest share of raw materials cost required for the c-Si PV module manufacturing. The impact of the various cost components is seen in detail in the further sections.

4.2. Estimation of manufacturing cost

Based on the above-mentioned assumptions, the cost of manufacturing modules in India is calculated around INR 31.97/W_p. As shown in Figure 7, the biggest cost component in module manufacturing is raw material cost, which makes up approximately 90% of the cost share. Subsequently, interest rate related cost is the second largest cost component, especially interest on working capital. Currently, the Indian domestic module manufacturing industry faces intermittent demand; therefore, they maintain a higher amount of inventory for modules than their optimal level of inventory. This, in turn, results in higher requirement of working capital, which in turn increases the financing costs related to the working capital.

The financial analysis suggests that the incentives given on capital investment do not sufficiently lower the cost of manufacturing. This is because the raw material (70-80%) and the working capital (12-15%) comprise the majority of manufacturing costs. Raw material and the working capital are components of the operating cost, and hence the manufacturing cost is not impacted much with the capital subsidy.

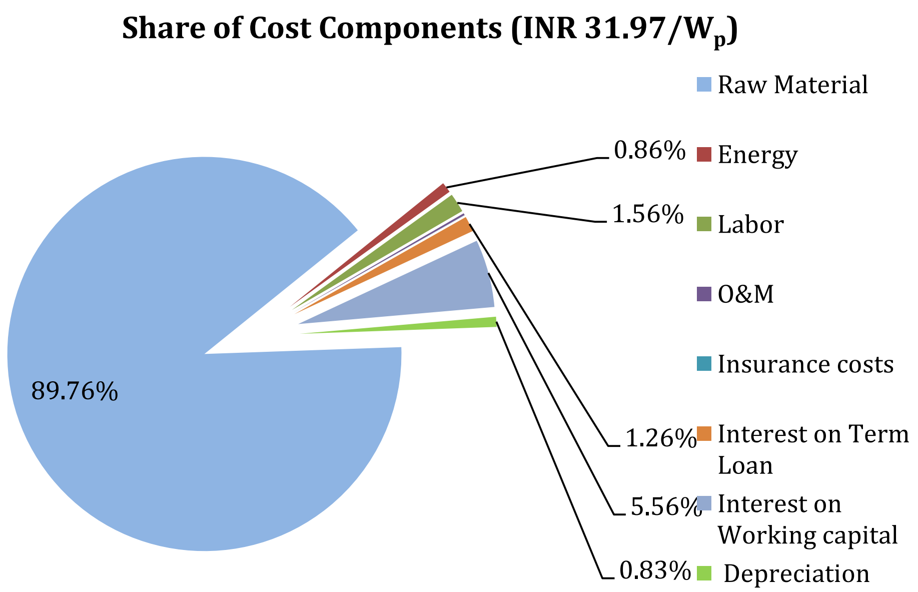

Figure 7: Share of Cost Components in a PV Module Manufacturing Plant

4.3. Impact of current policy incentives through analysis of manufacturing cost

A comprehensive examination of the state policies was completed and incentives given in all the selected states are listed in Table 3. These incentives are given in the form of capital subsidies, interest rate subsidies, stamp duty exemptions and electricity subsidies, etc. Incentives vary from state to state and also the limit of incentives is different in all the states. Among the 10 states, Chhattisgarh provides a variety of incentives in the form of capital subsidy, interest rate subsidy, stamp duty exemption, electricity subsidy, etc. Gujarat provides fewer types of subsidies, which includes interest rate subsidy without a cap.

These state-specific incentives were fed in the financial model and their impact on the manufacturing cost was analyzed. Gujarat was found to have the lowest cost of manufacturing at INR 31.29/W_p owing to interest rate subsidy without a cap. In contrast, Karnataka has the highest cost of manufacturing at INR 31.91/W_p as it provides only capital subsidy and an exemption on stamp duty.

Table 8 provides results from the financial analysis of various incentives and the change in manufacturing cost.

Table 8: Impact of State Level Policies on PV Module Manufacturing Cost

State	INR/W_p
Gujarat	31.29
Andhra Pradesh	31.79
Jharkhand	31.81
Chhattisgarh	31.43
Madhya Pradesh	31.57
Rajasthan	31.69
Odisha	31.60
Maharashtra	31.73
Karnataka	31.91
Uttar Pradesh	31.66

These states have a potentially important role to play in the 100 GW solar PV generation target and resource potential for solar PV generation. With a base of tier-I and tier-II[5] Original Equipment Manufacturers (OEMs), not only is procurement of raw material easy, but transportation costs are reduced as well. There are very good opportunities to attract investors; the state policies are performing well by enabling new capacity additions. However, it would be even better, if necessary incentives are provided specifically to support the operations of the manufacturing industry.

[5]OEM: These companies primarily engage in designing/assembling solar modules/components
Tier-I companies are direct suppliers to OEMs. Hence, major component manufacturers are Tier-I suppliers.
Tier-II: Raw material and small component suppliers represent this segment. These suppliers do not produce raw materials or components only for the renewable industry; they have a large industrial consumer base.

4.4. Sensitivity analysis

4.4.1. Impact of GST on final manufacturing cost

Figure 8 shows the impact of the Goods and Services Tax (GST) on manufacturing cost of modules. With the announcement of GST being implemented in India, the cost of solar manufacturing will be impacted. Currently, the import of raw material to manufacture a module is being exempted from import duties and taxes. However, all the taxes and duties levied at state central levels will be replaced by GST, which means the import of raw material will also be subjected to it. Therefore, we examined a scenario to analyse the impact of GST on the raw material costs and its effect on the final module cost. We assumed two cases: the first case assumes GST of 5% on the import of raw material and it increases the cost of final module by INR 1.48. The second case assumes 18% GST on the raw material imported and this increases the cost of module manufacturing by INR 5.33.

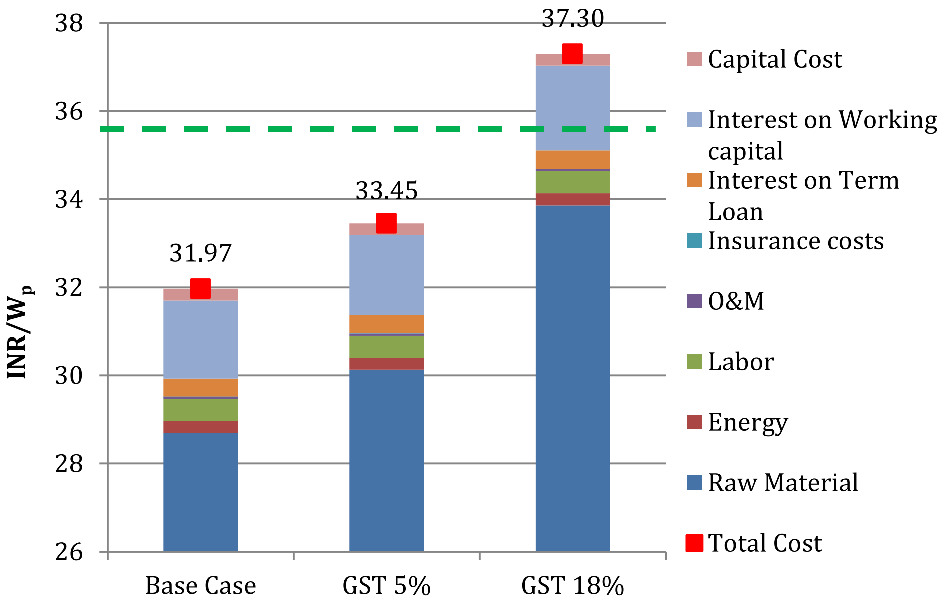

Figure 8: Impact of GST (on raw material) on the Cost of Module Manufacturing in India

4.4.2. Impact of interest rates on final module costs

Interest rate is the second major cost component for module manufacturing. The current interest rates are in range of 12-15%, which is high, compared to other countries that are leaders in solar manufacturing. In our base case of analysis, the interest rate of 15% is considered. We assumed two scenarios to examine the impact of interest rates on the overall manufacturing cost. The first case assumes government facilitates financing at an interest rate of 10%, which will bring down the cost of modules by ~INR 0.74/W_p. In the second case, we assume an interest rate of 8% and the cost can be reduced by ~INR 1.03/W_p. So, if the industry is provided with lower interest rates of 8% and financing backed by government green bonds[6], the cost will be brought down by ~INR 1.03/W_p. Figure 9 shows the impact of interest rates on raw material on the final module manufacturing cost.

[6] These are tax-exempt bonds, which support environment friendly businesses.

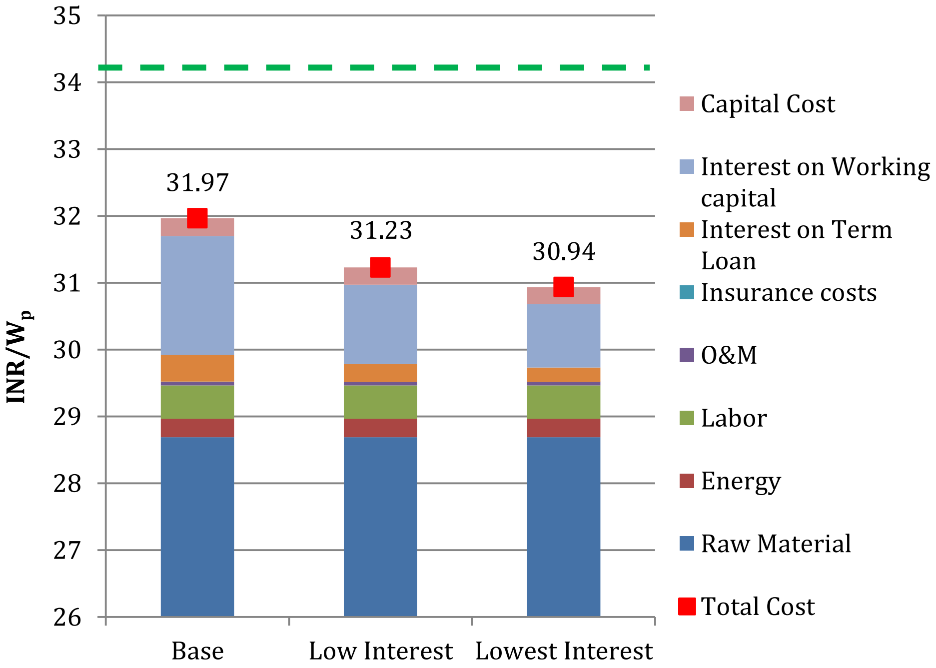

Figure 9: Impact of Interest Rates on the Cost of Module Manufacturing in India

4.4.3. Impact of Inventory and Plant capacity utilization on final module cost

The existing installed capacity of module manufacturing in India is operating at low capacity utilization (30%) because of lower demand for domestically manufactured PV modules and the absence of domestic raw material manufacturing. Therefore, to at least keep the plants running, raw materials need to be stored in the warehouse. Also, the finished modules need to be kept in the warehouse because of intermittent demand in the market. Higher inventory levels of raw materials and finished modules raise the manufacturing costs. In the base case, the inventory level is assumed as 3 months, at a capacity factor of 70%. Further, we assume two scenarios of Inventory levels and how they affect cost reduction. In the first case inventories are assumed at very low level (1 month time) and the cost decreases by ~1.35 INR/W_p. However if the inventories are high, i.e., 5 months' time, the cost increases by ~ 1.35 INR/W_p from the base case. These calculations are made by assuming a capacity factor of 70%. Efficient inventory management with less lead time in procuring raw material and selling the modules would keep the inventory flowing and reduce the module manufacturing cost. This reduction is attributed to the decrease in interest on working capital.

Capacity factor alone doesn't impact the module manufacturing industry much, because capital cost has a small share in final manufacturing cost. We analyzed two cases to see the impact of capacity factor on module manufacturing cost. In case of low capacity factor (30%) the cost increases by ~INR 0.64/W_p, whereas a relatively high capacity factor will reduce the cost by ~INR 0.11/W_p only. A combination of efficient inventory management and high capacity factor (95%) can bring down the manufacturing cost by ~INR 1.46/W_p compared to the average cost of manufacturing. Figure 10 shows the impact of low and high inventory levels and capacity factor on the module manufacturing cost in India.

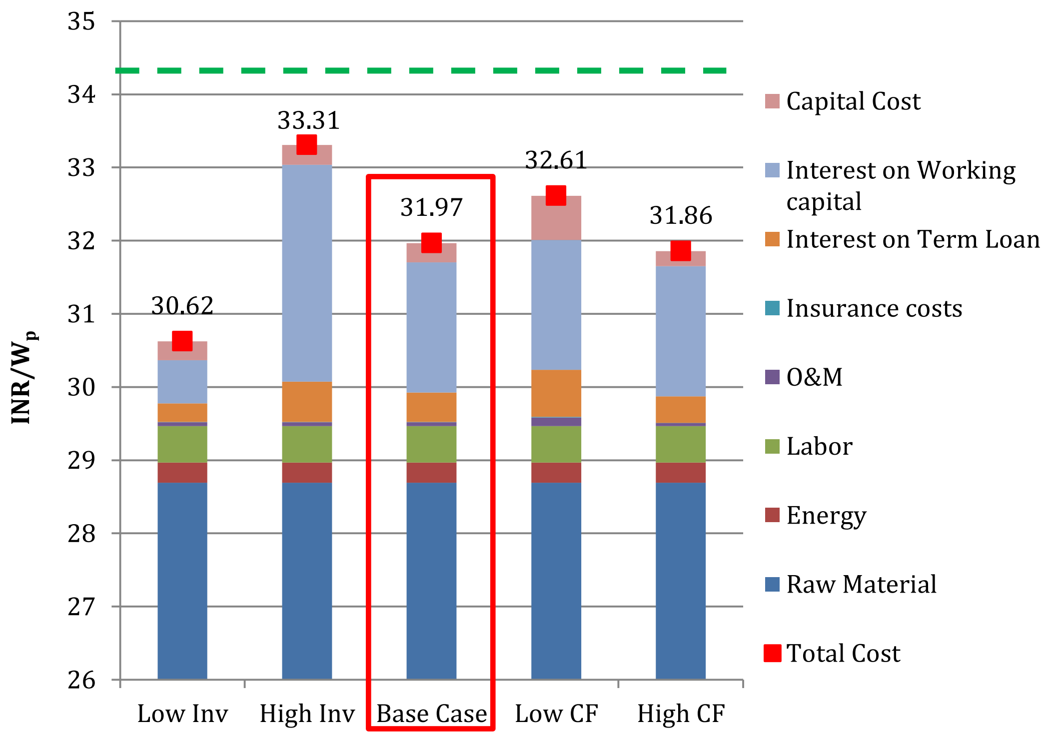

Figure 10: Impact of Level of Inventory and Capacity Utilization Factor on the Cost of Module Manufacturing in India

4.5. Impact on power generation cost

This section, addresses the impact of module costs, estimated in all scenarios of sensitivity analysis, on the power generation cost. Table 9 shows the module prices, capital cost of a 1 MW plant using the same module and power generation cost (Levelized Cost of Electricity, LCOE). The percentage change in power generation costs for each scenario is also shown in the Table 8. Module prices are determined by adding equity returns and economic profits in the module costs. The CSTEP's Solar Techno Economic Model (CSTEM)-PV tool is used to determine the LCOE numbers.[7]

Table 9: Impact of Module Manufacturing Costs from Sensitivity Analysis on Power Generation Costs

Scenarios	Module Price (INR/W_p)	Module Price (INR/W_p)	Capital Cost (Crore INR/MW)	LCOE (INR/kWh)
Base case	31.97	-	5.89	5.65
		% Change in Values over Base case*		
5% GST	33.45	-4.63%	-2.57%	-2.68%
18% GST	37.30	-16.67%	-9.09%	-10.20%

[7] This tool can be accessed here: http://cstem.cstep.in/cstem/

Low Inv & High CF	30.51	4.57%	2.40%	2.86%
High Inv & Low CF	33.95	-6.19%	-3.43%	-3.76%
Low Interest Rate	31.23	2.31%	1.20%	1.43%
Lowest Interest Rate	30.94	3.22%	1.72%	1.97%

5. Way forward and recommendations

5.1. Challenges affecting module manufacturing

There are several factors which contribute to the higher cost of Indian modules, including limited or no access to raw materials, lack of economies of scale, and inverted duty structure. However the GST bill is expected to create a more level playing field for both domestic manufacturers and global suppliers.

A module manufacturing facility is not very capital intensive; therefore, raising capital cost is not a big challenge to set up such a facility. Governments, both at central and state levels, provide incentives to subsidize the capital investment for module manufacturers. This analysis however, found that these capital subsidies are insufficient to make domestic manufacturing viable, as its impact is outsized by the other factors responsible for high prices. Three major challenges identified are:

- Raw material cost
- High interest rate
- Inventory management and capacity utilization

Raw material cost

A significant share (80-90%) of module manufacturing cost is attributed to raw material alone. Raw material for a module mainly comprises cell, glass, encapsulant, backsheet, interconnect ribbon, sealant, junction box, etc. Among these, cell has the biggest cost share of ~70% whereas the rest have a ~30% share. Also, the falling prices make inventories extremely costly.

High interest rate

The other challenge for a module manufacturing industry is high interest rate on capital, comprising 12-15% of the total module manufacturing cost. The current interest rates in India are in the range of 12-15%, which are way higher compared to other countries. This analysis observes that high interest rate on working capital increases manufacturing costs. Access to cheaper working capital loans would help reduce costs.

Inventory management and capacity utilization

As mentioned above, Indian module manufacturers are operating at very low capacity utilization; however the capacity is currently sufficient to cater to the demand. The major reason for this is lack of demand for domestic PV modules and unavailability and limited access to raw material. Therefore, to at least keep their plants running, raw materials are stored in the warehouse. Also, the finished modules need to be kept in the warehouse because of intermittent demand in the market. Therefore, higher inventory levels for raw materials and finished modules increase the operating cost and puts upward pressure on manufacturing costs. More long term contracts with manufacturers could assist in this regard, allowing firms to procure raw material just in time to meet demand. Access to working capital is important for Indian companies to compete against the firms from China/ South East Asia, who offer better terms.

5.2. Potential policy modifications and new policy interventions

The analysis shows why existing state-level incentives are proving to be insufficient in promoting the domestic PV module manufacturing industry. The analysis also identifies challenges that could be addressed to increase effectiveness. This is in addition to central policies which alone are inadequate in bringing down the production cost of modules to competitive levels. The current incentives only support the capital cost, which ultimately has negligible impact on the final module manufacturing cost. Therefore, government and private-sector policy makers should understand the implications of these incentives and may want to redirect support towards raw material procurement and interest rates, if the goal is to support the development of a domestic industry, across the full value-chain of c-Si PV manufacture. The following incentives and policy interventions may be appropriate to help in lowering the cost of production of modules:

- Assured market demand (at least till 2022) for new manufacturers to keep inventory flowing – a continuous demand will help to reduce the operational cost because of higher inventories. Therefore, there should be purchase agreements with the manufacturers keeping the 100 GW solar target in mind.
- Working capital could be made available at lower rates with government backed loans such as green bonds- the industry could be provided with lower interest rates finances backed by government green bonds to further reduce the costs.
- Indian certifications may create a more level playing field for Indian companies to compete in domestic market, as Chinese manufacturers will have added expenditure of getting their modules certified in India.
- State government could promote DCR for Public Sector Units consumption to ensure module demand and to help in local employment generation.

In addition the states with good resource potential and an established manufacturing base, might decide to build solar equipment manufacturing clusters, so that all the necessary components can be manufactured in close proximity. This would help reduce the transportation cost and also overcome losses/damages, which occur in transit. Also, testing facilities to test and rate the modules should be part of such a cluster, so that manufacturers need not to travel far to get quality tests.

In the current policy regime, the state with highest cost of module manufacturing, Karnataka, is providing a subsidy worth INR 60,000 per MW of modules and the state with lowest cost, Gujarat, is providing subsidy worth INR 6,80,000 per MW. Additionally incentives of INR 5 Lacs – 40 Lacs per MW would be needed to support the operations of module manufacturing facility and make indigenous modules cost competitive

This study has identified challenges in the current policy regime and steps India might take to better position itself to become a global leader in the PV module manufacturing. Given India's abundant human resource, solar potential, solar demand, and political will, India has the potential to be more competitive in global solar module manufacturing, but this is not likely to occur under the current policies.

References

1. MNRE Ministry of New and Renewable Energy, Government of India. , 2010.
2. Huberty, M. and G. Zachmann, *Green exports and the global product space: prospects for EU industrial policy*. 2011, Bruegel working paper.
3. PIB, *Press Information Bureau, Government of India*. 2015.
4. GOI, *Make in India*. 2015.
5. DIPP, *Government of India, Ministry of Commerce and Industry, Department of Industrial Policy & Promotion*. 2015.
6. Sahoo, A. and G. Shrimali, *The Effectiveness of Domestic Content Criteria in India's Solar Mission.* 2013.
7. Shrimali, G. and V. Nekkalapudi, *How Effective Has India's Solar Mission Been in Reaching Its Deployment Targets?* Economic and Political Weekly, 2014. **49**(42).
8. Johnson, O., *Exploring the effectiveness of local content requirements in promoting solar pv manufacturing in India.* 2013.
9. *WTO ruling aside, India's DCR was a badly designed policy tool*. PV-Tech.org, 2016.
10. CEEW 2015.
11. Lewis, J.I. and R.H. Wiser, *Fostering a renewable energy technology industry: An international comparison of wind industry policy support mechanisms.* Energy Policy, 2007. **35**(3): p. 1844-1857.
12. Fudenberg, D. and J. Tirole, *Learning-by-Doing and Market Performance.* The Bell Journal of Economics, 1983. **14**(2): p. 522-530.
13. Junginger, M., W. van Sark, and A. Faaij, *Technological learning in the energy sector: lessons for policy, industry and science*. 2010: Edward Elgar Publishing.
14. Kobos, P.H., J.D. Erickson, and T.E. Drennen, *Technological learning and renewable energy costs: implications for US renewable energy policy.* Energy policy, 2006. **34**(13): p. 1645-1658.
15. Qiu, Y. and L.D. Anadon, *The price of wind power in China during its expansion: Technology adoption, learning-by-doing, economies of scale, and manufacturing localization.* Energy Economics, 2012. **34**(3): p. 772-785.
16. Luque, A. and S. Hegedus, *Handbook of photovoltaic science and engineering*. 2011: John Wiley & Sons.
17. Goodrich, A., et al., *A wafer-based monocrystalline silicon photovoltaics road map: Utilizing known technology improvement opportunities for further reductions in manufacturing costs.* Solar Energy Materials and Solar Cells, 2013. **114**: p. 110-135.
18. *'Silicon Module Super League' big-six to reach 50% global market share in 2016*. PVTECH, 2015.
19. PVTech. *Top 5 solar module manufacturers in 2016*. 2016 [cited 2017 Mar 1]; Available from: http://www.pv-tech.org/editors-blog/top-5-solar-module-manufacturers-in-2016.
20. *Solar Cells/Modules manufacturing capacities*. Ministry of New and Renewable Energy, 2016.
21. Oluwatola, T.A., *Let There Be Light: Green Industrial Policy and Energy Access in India*, in *Public Policy*. 2017, Pardee RAND Graduate School: California. p. 162.
22. IndiaBriefing, *Ease of Doing Business.* 2016.
23. Rajasthan, G.o., *Rajasthan MSME Policy 2015*. 2015.
24. Pradesh, G.o.U., *Key Fiscal Incentives under Uttar Pradesh Infrastructure & Industrial Investment Policy (IIIP) 2012*. 2012, Government of Uttar Pradesh.
25. Pradesh, G.o.M., *Industrial Promotion Policy*. 2014.
26. Pradesh, G.o.A., *Industrial Development Policy 2015-20* 2014.
27. KPMG, *Karnataka Industrial Policy 2014-19*. 2014.
28. KPMG, *Maharashtra Industrial Policy* 2013.
29. Jharkhand, G.o., *Jharkhand Industrial And Investment Promotion Policy 2016*. 2016, Government of Jharkhand.
30. Gujarat, G.o., *New Industrial Policy Scheme for MSME Assistance*. 2015.
31. Chhattisgarh, G.o., *Industrial Policy 2014-19*. 2013.

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