Domestic Content Requirements and India's Solar Mission

Meera Fickling
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Abstract

Domestic content requirements are widely-used policies that require a specified proportion of a good to be produced within a certain jurisdiction. Applied to solar cells and modules procured through India's national solar power program, this policy is part of India's strategy to build a domestic manufacturing base for solar components and attain energy independence. However, a loophole in the requirement appears to have undermined its effectiveness. This paper uses a conceptual model and a set of probit and logit regressions to determine the effect of India's domestic content requirement for solar cells and modules on domestic manufacturing and technology choice. It finds that the requirement has done much less to spur domestic manufacturing than the Indian government envisioned.

Introduction and Summary

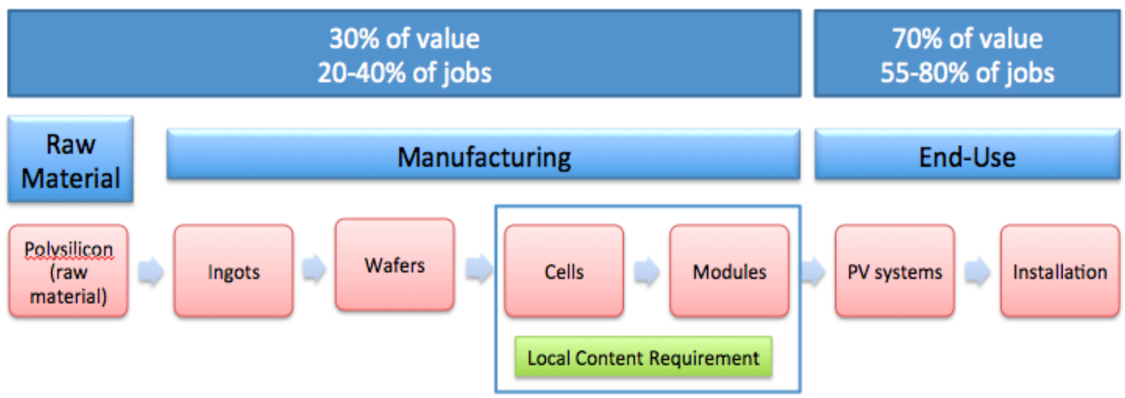
Like many other subsidies for solar electricity, India's Solar Mission seeks to achieve multiple ambitious goals. Official objectives are to promote ecologically sustainable growth and energy security; empower people through decentralized energy generation, especially in rural areas; and establish India as a leader in solar energy.[1] More specifically, India's solar policies aim to increase installed capacity and reduce costs, while also establishing India as a global manufacturing hub for solar panels.

To achieve solar capacity and cost targets, the Jawaharlal Nehru National Solar Mission (JNNSM) auctions power purchase agreements to solar developers at a premium over the cost of coal-fired electricity. To ensure that the installation of capacity creates domestic solar manufacturing, the program includes a domestic content requirement (DCR): developers must use cells and modules manufactured in

[1] Ministry of Natural Resources and Environment, Government of India (MNRE). 2009. "Jawaharlal Nehru Solar Mission: Towards Building Solar India." Available at http://www.mnre.gov.in/file-manager/UserFiles/mission_document_JNNSM.pdf (accessed on January 4, 2013).

India. Cells and modules are the main building blocks of solar PV systems, which are used to generate electricity (Figure 1). However, the DCR requirement makes an exception for solar photovoltaic (PV) developers using thin film technologies, which may be imported. The majority of solar developers in India currently use imported thin film modules.

Figure 1. The Solar PV Value Chain (Crystalline Silicon)



The DCR seems to have substantially distorted the Indian module market compared to the structure in other countries. Ghosh, et al. (2011) point out that globally, only 11 percent of PV deployment is in thin film, while 89 percent is in crystalline silicon (CSi), the dominant technology.[2] By contrast, over 70 percent of Indian PV capacity subsidized through the latest batch of JNNSM auctions was imported thin film.[3] Other commentators, however, argue that this difference is not produced primarily by the JNNSM; rather, generous financing from the US Ex-Im Bank and a hot Indian climate, which favors thin film modules, have been instrumental in biasing India's module toward domestic thin film. It has been pointed out that the India-wide average

[2] Shiao, M.J. 2012. "Thin Film Manufacturing Prospects in the Sub-Dollar-Per-Watt Market." *Greentech Solar.* Available at http://www.greentechmedia.com/articles/read/thin-film-manufacturing-prospects-in-the-sub-dollar-per-watt-market (accessed on November 24, 2012).
[3] Bridge to India. 2012. "The India Solar Handbook: November 2012 Edition." Available at http://bridgetoindia.com/our-reports/the-india-solar-handbook (accessed on December 22, 2012).

(including JNNSM and non-JNNSM) thin film penetration is approximately 50 percent, which is similar to the JNNSM Batch I results (e.g., Sahoo and Shrimali).[4]

This leads us to three questions. One, how has the domestic content requirement affected domestic production and market structure, including developers' choice of module manufacturers and technologies? Two, at what cost are these changes achieved? And three, if India expands its domestic content requirement to include thin film technologies, what effect might this have on module prices, the price of electricity, and the feasibility of the program in subsequent years?

This paper begins by providing an overview of subsidies as a driver of global renewables growth, and of the DCR as a tool often included in subsidies to create a competitive advantage for domestic manufacturing of new renewable technologies. It then provides an explanation of how India's Solar Mission fits into the Indian energy policy environment. Next, the paper reviews the literature on domestic content requirements and suggests a model for understanding the impact of India's DCR on prices and output.

The paper then picks two adjacent Indian states -- Gujarat and Rajasthan – one of which is primarily subject to the JNNSM, and one of which primarily signs power purchase agreements with the state that are not subject to a domestic content requirement. Regression models compare the development of the solar industry in each location, using global price data and fine-grained data on technology and supplier choice in India. The paper concludes that the JNNSM has mostly caused a shift toward thin film technology use, while creating little or no additional domestic manufacturing.

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4 Sahoo, Anshuman, and Gireesh Shrimali. "An Analysis of Industrial Policy Support for the Indian Solar Photovoltaic Manufacturing Sector." Available at http://www.usaee.org/usaee2012/submissions/OnlineProceedings/USAEE%20Proceedings%20Paper_Sahoo%20and%20Shrimali.pdf (accessed on December 21, 2012).

The Global Outlook for Solar Subsidies

Although the high cost of solar power has prevented widespread commercial deployment to date, the industry is rapidly growing in many countries thanks to generous government incentives. Feed-in tariffs for solar power are now available in about 50 countries, along with capital subsidies, production tax credits, and other incentives.[5]

The International Energy Agency (IEA) projects explosive growth (albeit from a very low base) in solar energy and other renewables over the next two decades. Solar photovoltaic (PV) provided 32 terawatt-hours (TWh) of electricity globally in 2010. If current policies are extended, this number will grow nearly nine-fold by the end of the decade and 16-fold by 2035. With more aggressive policies in place, global solar PV generation could grow ten-fold by the end of the decade and 26-fold by 2035. Projections for concentrated solar power (CSP) are even more impressive, with output growing 20-fold over the next decade and 70-fold by 2035 under current policies.[6]

Despite robust growth rates, solar will provide only a modest percentage of renewable generation and total electricity generation over the coming decades. In total, solar provided only 0.8 percent of renewable electricity generation and 0.2 percent of total global electricity generation in 2010. With aggressive policies, solar can provide up to 10 percent of renewable generation and 3.1 percent of total electricity generation by 2035. Under current policies, solar is expected to provide only 6.9 percent of renewable generation and 1.7 percent of total electricity generation in 2035.[7]

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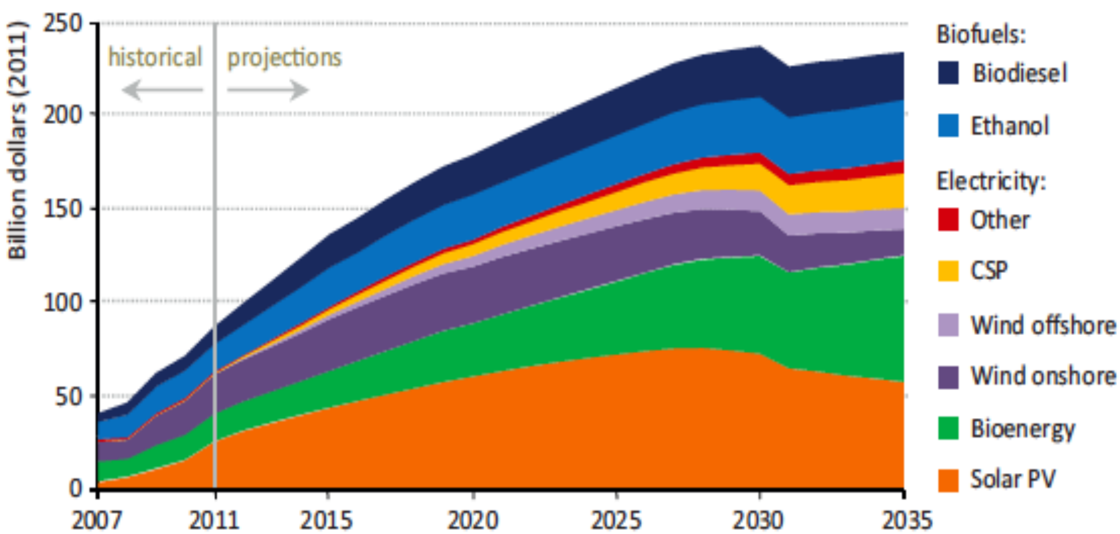
[5] Baziliana, Morgan, Michael Liebreichc IjeomaOnyejia, Ian MacGilld, Jennifer Chasec, Jigar Shahe, Dolf Gielenf, Doug Arentg, Doug Landfearh, and Shi Zhengrongi. 2012. "Re-considering the Economics of Photovoltaic Power." *Blomberg NEF:* New York, USA.

[6] These projections are subject to some uncertainty, as solar power is dependent on subsidies; if countries permanently remove or reduce subsidies due to worsening fiscal crises, the growth of solar power could stall.

[7] Source: International Energy Agency (IEA). 2012. World Energy Outlook. Figure 7.10: "Global Renewable Energy Subsidies By Source in the New Policies Scenario."

Subsidies like those provided by India's JNNSM are the single largest driver of the solar industry's growth. Figure 3 shows that close to 100 percent of expected solar PV generation over the coming decades will be subsidized. Unlike biomass, wind, and hydro, solar is not expected to gain a market foothold without subsidies. The global solar industry receives a disproportionate amount of subsidies given its market share. In 2011, solar received $25 billion (US dollars), more than any other form of renewable electricity. This amounted to nearly 30 percent of total global subsidies for renewable energy and nearly 40 percent of total global subsidies for renewable electricity. Though solar may not continue to receive such an outsize share of subsidies in the future, its total will likely increase in absolute terms. The IEA expects solar subsidies to peak at $77 billion in 2027.

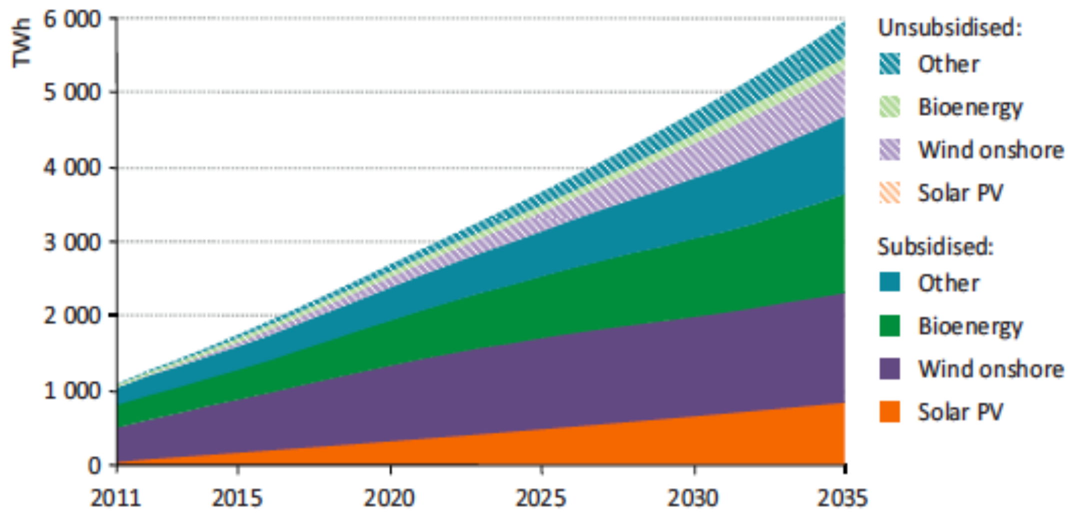
Figure 2. Projected Renewable Energy Subsidies by Source.



Notes: Other includes geothermal, marine and small hydro. CSP = Concentrating solar power.

Source: International Energy Agency (IEA). 2012. World Energy Outlook. Figure 7.10: "Global Renewable Energy Subsidies By Source in the New Policies Scenario."

Figure 3. Subsidized and Unsubsidized Generation By Source



Note: Other includes concentrating solar power, geothermal, marine energy, small hydro and wind offshore.

Source: International Energy Agency (IEA). 2012. World Energy Outlook. Figure 7.11: "Subsidized and Unsubsidized Renewables-Based Electricity Generation By Type in the New Policies Scenario."

The Political Case for Domestic Content Requirements in Solar Subsidies

As solar and other renewable electricity generation has grown, domestic content requirements have proliferated for renewable electricity components such as solar panels and wind turbines. In addition to India, Ontario, China, Brazil, and Spain have embedded domestic content requirements within their support programs for renewable energy. To explain why so many countries have chosen to enact these requirements, we can look to the reasons behind support for renewable electricity as a whole.

Countries are eager to promote renewable electricity for several reasons. One justification is the environmental cost of fossil fuel-based generation. Policies can allow utilities to incorporate the value of positive externalities such as cleaner air, better health, and climate change mitigation into decision-making and price structures.

An equally powerful driver is economic growth and development. Ghosh and Gangania (2012) point out several economic reasons for countries to support renewables. One is industrial policy. Currently, renewable energy sectors have a steep learning curve, creating economies of scale. If a country attains dominance in a sector or an area of the manufacturing chain, it is likely to be able to offer lower prices and remain more competitive into the future. As an example, Ghosh and Gangania (2012) point out that China has received large dividends from its large investment in the solar panel sector. It now accounts for approximately 60 percent of world solar production, 95 percent of which is exported.

A second economic motivator is the push for "green jobs" in the wake of the 2008-09 recession. During this time, most major economies spent billions of dollars in stimulus in order to reverse negative economic growth. The stimulatory effect of such investment would be greater in developing countries like India; because India has a higher price elasticity of demand for energy, subsidies for renewables are likely to stimulate new energy consumption rather than simply induce a switch from fossil fuels to renewable sources. China in particular has pursued an aggressive strategy of subsidizing its domestic solar sector and now employs 1 million people in renewable energy (Ghosh and Gangania 2012).

The third motivator according to Ghosh and Gangania (2012) is mercantilism. Because many countries support renewable energy – China, the United States, Germany, Spain, Brazil – other countries feel that they need subsidies and industrial support of their own in order to play on a level field. Fourth, distributed renewable generation can expand energy access to communities that currently lack it, accelerating economic development.

When renewable subsidies are enacted for economic stimulus or industrial policy, pressures rise to create employment along the full renewable electricity value chain, including manufacturing inputs. Consequently, many countries include a domestic content requirement in renewable energy subsidies.

A domestic content requirement is a requirement to purchase certain components (or a certain percentage of components) of a final product from domestic producers. The subsidy in question is usually denied to any firm in noncompliance with the requirement. Effectively, this forces firms to source all or part of their inputs domestically in order to remain competitive.

DCRs give nascent domestic input manufacturers access to a growing domestic market shielded from international competition. As a result, domestic firms may in time develop economies of scale and technological capacity. As domestic firms become more established, their finance costs may also decrease. Component manufacturers for renewable energy compete primarily on the basis of cost, and economies of scale are crucial to maintaining market share.[8]

DCRs are not without downsides. As explained in the following sections, domestic content requirements have significant potential to distort global markets and increase costs. Another downside is the possibility of countervailing duties imposed by other countries. The World Trade Organization (WTO) dispute settlement panel recently ruled against Ontario's DCR for wind turbines, which requires electricity producers to have up to 60 percent of project costs come from local goods and labor.

[8] Platzer, Michaela. 2012. "US Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support." *Washington, DC: Congressional Research Service* 6.

Solar Power in India

The Indian Energy Context

Despite a fast growing economy, India's electricity infrastructure remains woefully inadequate; 300 million people continue to lack power. Energy supplies from existing resources have failed to keep up with rising demand for electricity; India suffered the largest blackout in its history in the summer of 2012. This is partly due to a rigid tariff structure, which fails to reward new investment, and partly due to exceptionally large line losses.[9] Part of the planned remedy is to establish India as a leader in solar energy manufacturing and deployment. Energy security and expansion of energy access to the rural poor are primary motivators for India's solar program.

The Indian Solar Mission takes place in the context of several recent policies designed to reform the Indian power sector and promote renewable energy. The first component enabling the development of the solar industry in India is limited privatization; a reverse auction scheme like the Solar Mission relies on production by independent generators. In 1991, India's government allowed private investment in generation and distribution for the first time. The 2003 Electricity Act unbundled state electricity utilities into generation, transmission, and distribution companies and, at least in theory, established non-discriminatory access to transmission.

Despite efforts to decentralize and open the market to independent power producers, however, national and state government-owned entities still supply the overwhelming bulk of power in India. The Ministry of Power controls the National Thermal Power Corporation (NTPC), the largest thermal power generation company in India. The NTPC holds 20 percent of India's total generating capacity, the power from which is supplied to states to supplement state utilities. This creates inefficiencies,

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[9] International Energy Agency (IEA). 2012. "Understanding Energy Challenges in India: Policies, Players and Issues." Paris: International Energy Agency.

although it does allow the Indian government sufficient market power to force local utilities to buy solar electricity. [10]

The second component enabling solar generation is support for distributed solar in rural areas, which is a component of India's strategy to achieve universal access to electricity. The 2005 National Electricity Policy and the 2006 Rural Electrification Policy promote rural electrification, including distributed generation. The Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) established in 2005 aimed to electrify 115,000 villages and 23 million households. As of 2011, 91 percent of the villages and 77 percent of the households targeted had been electrified. The program, however, did not achieve its broader goal of electrifying all households by 2009. [11]

The third component is the implementation of renewable purchase obligations. The 2003 Electricity Act calls on state Electricity Regulatory Commissions to establish minimum purchase requirements for all renewable energy, which increased to 6 percent as of 2010.[12] Purchases of renewable electricity do not necessarily have to be direct; renewable electricity credits (RECs) created by renewable generation that is not itself procured, established in 2010, also qualify. Later, a 2011 amendment to the National Tariff Policy established a purchase obligation specifically for solar power, requiring utilities to obtain 0.25 percent of total power generation from solar by 2013 and 3 percent by 2022.

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[10] Ibid.

[11] International Energy Agency (IEA). 2012. "Understanding Energy Challenges in India: Policies, Players and Issues." Paris: International Energy Agency.

[12] Gangania, A. G. H. 2012. Governing Clean Energy Subsidies: What, Why, and How Legal? Global Platform on Climate Change, Trade and Sustainable Energy. International Center for Trade and Sustainable Development, ICTSD. Available at http://ictsd.org/i/publications/143945/ (accessed on November 18, 2012).

The Jawaharlal Nehru National Solar Mission

The goal of India's Jawaharlal Nehru National Solar Mission (JNNSM) is to install 20 GW of solar capacity in India by 2022, which is equivalent to about 10 percent of current total power capacity.[13] Utility-scale capacity installation is to occur in three phases:

- Phase 1, 2010-13 (11th Plan): Goal of 1000 MW by the end of 2013.
- Phase 2, 2013-17 (12th Plan): Goal of an additional 3000 MW by the end of 2017
- Phase 3, 2017-22 (13th Plan): Goal of an additional 16,000 MW by the end of 2022.

The JNNSM will implement its goals for utility-scale solar installation through a procurement auction scheme. During each auction period, or batch, the government agrees to support a specified number of MW of solar capacity. There were two batches in Phase 1. Firms submit bids specifying the lowest price at which they are willing to generate. The government awards power purchase agreements to the lowest bidders. This electricity is bundled with conventional generation and sold to utilities. Because the national government is the main procurer of thermal generation in India, it has sufficient market power to force the utilities to buy the bundles at a slight premium.[14]

Two auctions have taken place so far under Phase I of this system. Batch I pledged government support to 140 MW of solar PV capacity and 470 MW of CSP. Batch II supported around 300 MW of PV capacity. To date, 130 MW of 140 MW capacity auctioned during Batch I has already been commissioned.[15]

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[13] International Energy Agency (IEA). 2012. "Understanding Energy Challenges in India: Policies, Players and Issues." Paris: International Energy Agency.

[14] Phone conversation with Arunabha Ghosh, CEO of the Council on Energy, Environment, and Water, New Delhi, India, October 15, 2012.

[15] Government of India. 2012. "Commissioning Status of Solar PV Projects Under Batch I, Phase I of JNNSM." Available at http://mnre.gov.in/file-manager/UserFiles/commissioning_status_spv_batch1_phase1.pdf (accessed on November 17, 2012).

The JNNSM has spawned similar state-level policies in about 13 different states, which either are developing policies or have put them into place. The state programs are motivated by the imperative to meet their own solar and renewable purchase obligations and to sell renewable electricity credits (RECs) to other states. Of these, Gujarat and Karnataka have already accepted more than 200 MW each in bids.[16]

Overall, national and state policies have spurred rapid growth in solar electricity. Indian solar capacity ballooned from 18 MW in 2010 to 507 MW in March 2012. The JNNSM and other central government schemes directly commissioned 203 MW of this capacity, and an additional 800 MW of capacity are expected to come online by 2013 as a direct result of the JNNSM auctions.[17]

State Solar Procurement Programs

Gujarat's Power Procurement Program

Gujarat's power procurement program came online in 2010 and is expected to remain in place until March 2014. In total, it has signed power purchase agreements for 959 MW of solar power projects, with the goal of reaching 500 MW of actual installed capacity (assuming that approximately half of projects would fail). It has blown past this goal, commissioning 709 MW by October 30, 2012. Projects within this program are utility scale; like the JNNSM, it requires a 5 MW minimum capacity.

Unlike the JNNSM, Gujarat's program is a more traditional feed-in tariff with fixed rates for solar power. Contracts last for 25 years. For projects commissioned between

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[16] Prabhu, Raj. 2012. "Project Due Dates Pass – How Many Were Successfully Completed?" Available at http://www.mercomcapital.com/india-its-time-for-results (accessed on November 24, 2012).
[17] Council on Energy, Environment, and Water; Natural Resources Defense Council (2012). "Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1 of India's National Solar Mission."

2010 and 2012, tariffs begin at 15 rupees per kWh for the first 12 years of the contract, dropping to 5 rupees per kWh for the next 13 years. Tariffs are scheduled to drop precipitously for projects commissioned after 2012; whereas the average 25-year tariff, with accelerated depreciation, is 12.5 rupees per kWh for projects commissioned between 2010 and 2012, it will drop to 9.3 cents for projects commissioned between 2012 and 2013, and to 8 cents by 2014. This provides a powerful incentive for projects to commission by their deadlines, as projects that fail to do so must accept the tariff in effect during the next tariff cycle.

Gujarat's feed-in tariff helps it comply with the aforementioned national solar renewable purchase obligation (RPO) of 0.25 percent in FY 2010-11 and 0.5% in FY 2011-13. It has no domestic content requirement.

Summary of Other State Policies

A handful of other Indian states have begun to design solar policies. As of 2011, Karnataka has a solar power target of 350 MW commissioned by 2016. It signed purchase agreements for 60 MW of solar PV bids and 20 MW of solar CSP in August 2011. Projects are required to fall between 5 MW and 10 MW.

Madhya Pradesh, Andhra Pradesh, and Tamil Nadu also have solar procurement policies in development. Madhya Pradesh legislated a goal in 2012 to allocate 800 MW of solar power, but has not published supporting regulations. Andhra Pradesh has enacted a number of tax and surcharge exemptions for solar projects. The most ambitious of the three policies, the 2012 Tamil Nadu Solar Policy aims to install 3 GW of solar power by 2015, including 1500 MW of utility-scale projects. It intends to accomplish part of this goal through Solar Purchase Obligations of 3 to 6 percent imposed on large power consumers such as Special Economic Zones, IT parks, industrial consumers, and universities. It will also offer a generation based incentive for 500 MW of utility-scale power, based on a reverse bidding process similar to the JNNSM (Bridge to India 2012).

Rajasthan, the second largest producer of solar power in the country, has attempted in vain to establish its own state solar policy. (Nearly all of the power commissioned in Rajasthan has been through the federal JNNSM.) The first phase was intended to allocate 100 MW of utility-scale solar PV and CSP projects. However, the Rajasthan Renewable Energy Corporation (RRECL) announced that the allocation would be delayed indefinitely, as the state is already fulfilling its federal Renewable Purchase Obligation (RPO) through federal programs (Bridge to India 2012).

None of these state solar policies to date contains a domestic content requirement.

The JNNSM Domestic Content Requirement

The JNNSM required crystalline silicon-based solar PV projects selected during Batch I (FY 2010-11) to use modules manufactured in India. Batch II (FY 2011-12), all projects requires use of domestic cells in addition to modules. Both batches exempt thin film modules and concentrator PV cells, which may be sourced anywhere.[18] For solar thermal (CSP) projects, 30 percent of equipment must be sourced from India.

There are indications that the DCR will be continued and expanded after Phase I. Officials have explored the possibility of including inverters in the requirement.[19] In

[18] Government of India. (2010 (?)). Guidelines for Selection of New Grid-Connected Solar Power Projects. Ministry of New and Renewable Energy. Available at URL: http://www.mnre.gov.in/solar-mission/jnnsm/introduction-2/ (accessed on October 3, 2012).
[19] Pearson, N. O. (2010). India May Extend Local Equipment Usage Rule for Solar Power Beyond 2013. Bloomberg. Available at http://www.bloomberg.com/news/2010-12-13/india-may-extend-local-equipment-usage-rule-for-solar-power-beyond-2013.html (accessed on November 24, 2012).

addition, the requirement will likely become more technology neutral in the future by prohibiting (or limiting) imports of thin film in addition to CSi.[20]

From India's perspective, DCRs are necessary to maintain a manufacturing capacity in renewables, and some domestic manufacturing is necessary for energy security.[21] India's goal is to start an indigenous solar manufacturing sector, practically from scratch. Before the JNNSM, the Indian manufacturing sector was very small and largely dependent on export markets. Manufacturers exported 70 percent of cells and 80 percent of modules to Europe, the United States, Japan, and Australia.[22]

Several barriers prevent the Indian solar manufacturing sector from being very competitive in international markets. The first is that Indian manufacturers lack economies of scale. Internationally, module manufacturing lines usually produce 75 MW of capacity per line, whereas Indian lines average around 10-20 MW. As a result, Indian firms lack bargaining power for raw materials and have little leeway to increase production without incurring additional investment costs. Anecdotal evidence suggests that this has led to lower quality products at higher costs.[23]

As Choudhury (2011) suggests, Indian firms are limited to cell and module manufacturing. Vertical integration is nearly absent. India lacks upstream production of silicon, wafers, and materials, and downstream production of inverters and storage. Indigenous thin film producers are also notably missing, despite the technology's dominance in Indian solar electricity production downstream.[24] Fragmentation of production leads to higher costs.

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[20] Phone conversation with Arunabha Ghosh, CEO of the Council on Energy, Environment, and Water, New Delhi, India, October 15, 2012.
[21] As an example of this argument, see Jha, Vyomi. 2011. Cutting Both Ways: Climate, Trade, and the Consistency of India's Domestic Policies. CEEW Policy Brief. New Delhi: Council on Energy, Environment, and Water.
[22] Ibid.
[23] Ibid.
[24] "In Conversation: Debasish Paul Choudhury." *Energy Next*, August 2011. Available at www.pvgroup.org/, accessed on November 18, 2012.

Third, Indian manufacturers do not employ the best technology. They lag far behind competitors in China, Taiwan, and Malaysia. They require additional training, manpower, and skilled technical workers. And Indian manufacturing in general is plagued by a lack of basic infrastructure – power, water, and roads.[25]

Fourth, Indian manufacturers argue that they are disadvantaged by the subsidies offered by other countries.[26] In addition to domestic content requirements in China, Brazil and South Africa, export financing can play a significant role. The US Export-Import Bank offers US PV exporters such as First Solar an interest rate of 9 percent as opposed to the 13 percent rate offered locally to Indian manufacturers.[27]

The DCR aims to shield domestic solar manufacturers from international competition, allowing them to sell more panels to Indian developers. Through increased domestic sales, manufacturers could acquire better technological expertise and achieve the economies of scale that they currently lack. Ideally, Indian manufacturers would eventually become competitive in domestic and global markets without the crutch of the DCR.

The Effects of Domestic Content Requirements: A review

In general, a domestic content requirement has two effects. It increases derived demand for the domestic input, increasing the price of the domestic input and stimulating domestic manufacturing in the intermediate good compared to a free trade

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25 "Ibid.

26 See, for example, a diplomatically titled article by the Centre for Science and Environment, an Indian think tank: "The US Is Using Climate Finance to Kill the Indian Solar Industry," available at http://www.cseindia.org/content/us-using-climate-finance-kill-indian-solar-panel-industry-cse (accessed on November 24, 2012).

27 Pearson, N. O. (2011). India May Join US-China Trade Spat to Prevent Solar Disaster. Bloomberg Businessweek, Bloomberg News.

case.[28] This direct effect on manufacturing can be partially or fully offset by reductions in demand for the final good resulting from pass-through of the price increase for the input through the value chain.

In the model used by Grossman (1981), the implementation of a DCR, from a situation of free trade, causes domestic output of the intermediate good to increase.[29] For small amounts of intermediate goods, domestic demand remains stable at the international price for intermediates, plus the amount that must be paid as a penalty if a firm does not comply with the domestic content standard (in the Grossman model, there is an option not to comply with the DCR and face a penalty). In other words, firms will refuse to pay domestic producers more than they would pay if they simply imported the intermediate goods and paid the noncompliance penalty. At a certain point, however, the price of compliance becomes less than the price of noncompliance, and firms begin buying domestically. At the end of the consumption curve, when the content requirement is fully met, willingness to pay does not exceed the international price.

The content requirement always increases domestic production of the intermediate good. However, a higher domestic content requirement leads to higher intermediate input prices, which are passed along to the price of the final good. Thus, successive tightening of the requirement, to a higher percentage of intermediate inputs that must be procured from domestic manufacturers, could decrease domestic demand for the intermediate good. In general, the increase in the domestic price for the intermediate good depends on the substitution possibilities for production of the final good, the supply conditions in domestic intermediate good manufacturing, and market structure. Davidson, et al. (1985) finds a similar result for foreign direct investment, and

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[28] Mussa, Michael. 1984. "The Economics of Content Protection." *NBER Working Paper* no. 1457. Cambridge, MA: National Bureau of Economic Research.

[29] Grossman, Gene M. 1981. "The theory of domestic content protection and content preference." *The Quarterly Journal of Economics* 96, no. 4: 583-603.

several authors -- Davidson, et al. (1985), Richardson (1991), and Krishna and Itoh (1988) -- examine the effects of domestic content requirements in the case of market power in the intermediate or final good industries.[30]

Mussa (1984) alters the assumptions in the model used by Grossman (1981) to examine the case of smooth substitution between domestic and imported inputs. As in Grossman (1981), suppliers of the domestic input benefit, provided that elasticity of demand for the final product is below a critical value. The content requirement with smooth substitution also causes efficiency gains to be concentrated in technologies and processes that save imported inputs rather than domestic inputs.

Examples of early empirical study of the effects of DCRs include Beghin and Lovell (1993) and Beghin, Brown, and Zaini (1997), who studied the effect of a domestic content requirements imposed on cigarettes by Australia and the United States.[31] Due to a high elasticity of substitution between domestic and foreign products for cigarettes, they find a large substitution effect and a small output effect. In other words, the policies vastly increased domestic tobacco's share of the cigarette market, without decreasing overall cigarette production very much, as domestic tobacco was easily substituted at relatively low cost. The overall short-run impact for domestic tobacco farmers was positive. In addition, a number of authors have examined the impact of domestic content requirements on the auto industry and computer industries; some have found large effects on domestic production and prices (Frischtak 1986, Tacaks 1994).[32]

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[30] Davidson, Carl, Steven J. Matusz, and Mordechai E. Kreinin. "Analysis of performance standards for direct foreign investments." *Canadian Journal of Economics* (1985): 876-890; Richardson, M. (1991). "The Effects of a Content Requirement on a Foreign Duopsonist." *Journal of International Economics* 31 (1-2): 143-55; Krishna, K. and M. Itoh. 1988. "Content Protection and Oligopolistic Interactions." *The Review of Economic Studies* 55 (1): 107-25.

[31] Beghin, John C., and CA Knox Lovell. "Trade and Efficiency Effects of Domestic Content Protection: The Australian Tobacco and Cigarette Industries." *The Review of Economics and Statistics* (1993): 623-631.

[32] Frischtak, C. 1986. "Brazil." *National Policies for Developing High Tech Industries: International Comparisons.* Boulder: Westview Press. Takacs, W. E. 1994. "Domestic Content and Compensatory

Researchers have begun to study the specific effects of domestic content requirements for renewable electricity. Rivers and Wigle (2011) develop a comparative static model of a domestic content requirement included in a feed-in tariff for renewable power and apply this model to Ontario's feed-in tariff for wind and solar electricity.[33] They assume that the number of plants producing inputs for renewable energy is fixed. Thus, marginal costs of production are rising. Demand consists of two components: a renewable component and a conventional component. The demand for renewables is driven by the feed-in tariff's subsidy for renewable electricity, paid for by a surcharge on all electricity sales.

The theoretical results of this model follow from Grossman (1981) and Mussa (1984). Because the model assumes an upward sloping supply curve for domestic equipment inputs, the domestic content requirement increases the cost of generating renewable energy and increases the price. This increases the supply of conventional electricity and lowers the supply of renewable electricity. As in Grossman (1981), the result of these two effects – an increase in the share of domestic inputs, but a lowering of overall renewable electricity production – in terms of domestic manufacturing depends on demand and supply elasticities and substitution possibilities.

Net creation of "green jobs" from the domestic content requirement depends on what happens in the manufacturing and generating sectors. As explained by Grossman (1981), domestic manufacturing may either increase or decrease as a result of the requirement. Meanwhile, the renewable generation sector in theory experiences two competing effects: (i) an output effect, where the decrease in the supply of renewable

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Export Requirements: Protection of the Motor Vehicle Industry in the Philippines." World Bank Economic Review **8** (1): 127-49.

[33] Rivers, Nicholas, and Randy Wigle. 2011. "Domestic Content Requirements and Renewable Energy Legislation." Available at papers.ssrn.com/sol3/papers.cfm?abstr**act**_id=2129808 (accessed on April 26, 2013).

electricity decreases the number of workers needed for generation, and (ii) a substitution effect, where generators attempt to substitute labor for equipment as much as possible. (The latter effect probably would not be prevalent in the case of renewable electricity.)

Parameterizing the model for Ontario's FIT, the authors find that the positive effects of the DCR for domestic renewable component production and employment far outweigh the negative effects. Employment increases are particularly large in manufacturing; overall, the number of "green jobs" in the province doubles in the short run.

India's Content Requirement: A literature review

There has been very little empirical work on India's DCR to date. Sahoo and Shrimali (2011) examine the effect of India's DCR on feasibility of meeting the JNNSM's targets, on the competitiveness of India's solar manufacturing industry, and on consumer and producer surplus. [34] The authors do not expect a domestic content requirement to constrain solar deployment, although they do not quantify whether unit solar costs would be expected to rise beyond the Solar Mission's current reserve tariffs if the DCR is tightened. However, they present compelling evidence that the DCR has not led Indian manufacturers to improve competitiveness over time.

In fact, over the past five years, Indian solar power has become *less* competitive relative to the rest of the world. Sahoo and Shrimali (2011) calculate a the unit value ratio of India's solar exports – that is, the price charged for India's exports as a proportion of the world price for the same product. The lower the ratio, the more

[34] Sahoo, Anshuman, and Gireesh Shrimali. 2011. "An Analysis of Industrial Policy Support for the Indian Solar Photovoltaic Manufacturing Sector." Available at http://www.usaee.org/usaee2012/submissions/OnlineProceedings/USAEE%20Proceedings%20Paper_Sahoo%20and%20Shrimali.pdf (accessed on December 21, 2012).

competitive the industry is globally. India's ratio relative to the OECD and to China has steadily risen between 2003 and 2011, and is now above 1. At the same time, some domestic manufacturing does appear to occupy the lowest portions of the supply curve in India. For example, the lowest bidder in Batch II of the JNNSM auctions, Solairedirect, intends to use domestic crystalline silicon panels.

The authors fit logit and probit models to determine whether the module technology used was influenced by inclusion in the JNNSM. The structure they used was similar to the structure of the regression in this paper; they constructed a dummy independent variable for inclusion in the Solar Mission, and included state, capacity, inclusion in Gujarat's solar policy, and year as covariates. At the time the study was conducted, they did not find a statistically significant difference; there were few observations from Batch II of the auctions, and fewer observations overall. Still, the authors acknowledge that "some evidence exists…of shift…may thus be that, without the DCR, cheap foreign crystalline capacity could have further decreased tariffs bid by developers in Batch II." Sahoo and Shrimali (2011) expect the close of the market to foreign crystalline capacity to shift the marginal cost curve for producing solar electricity upwards in the short run, particularly if the DCR causes previously uncompetitive manufacturers to be competitive. This is likely to incentivize greater usage of foreign thin film modules.

Expanding the DCR to cover thin film, rather than increasing the efficiency of the domestic thin film industry, would likely cause an exodus from the foreign thin film technology to domestic crystalline silicon. Sahoo and Shrimali (2011) point out that costs would likely rise substantially, reflected in higher tariff bids and electricity prices. Because electricity demand is inelastic, consumers could lose substantial surplus.[35]

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[35] Ibid.

Modeling India's Domestic Content Requirement

This section provides a simple conceptual model for understanding how the domestic content requirement affects the Indian market for solar panels. The extent to which the domestic content requirement causes solar module procurement to shift from foreign to domestic depends on the elasticity of substitution between thin film and crystalline silicon modules.[36] If foreign thin film is easy to substitute for foreign crystalline silicon, then the shift from foreign to domestic modules will be slight. Rather, developers will simply shift from foreign crystalline to foreign thin film modules. If thin film is less substitutable for crystalline silicon, however, there will be a larger shift from foreign to domestic modules.

These shifts occur in terms of proportions of the total market. To a point, there is no shift in the total number of megawatts of solar panels purchased. Demand for capacity is perfectly inelastic within a certain range, as the Indian government has agreed to purchase a set amount of power within each auction, up to a certain reserve tariff.

There has been some limited study of substitution between thin film and crystalline silicon panels. Evidence suggests that thin film and crystalline modules are relatively close substitutes for utility-scale applications. Crystalline silicon panel manufacturers responding to a US International Trade Commission (USITC) survey report competing head-to-head with thin film panel manufacturers in bids. Respondents reported that thin film prices placed downward pressure on the crystalline silicon market.[37]

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[36] Mussa, Michael. 1984. "The Economics of Content Protection." *NBER Working Paper* no. 1457. Cambridge, MA: National Bureau of Economic Research.

[37] US International Trade Commission (USITC). 2011. "Crystalline Silicon Photovoltaic Cells and Modules from China." Report from Investigation Nos. 701-TA-481 and 731-TA-1190 (Preliminary). Publication no. 4295. Washington, DC: USITC.

In the following graphs, for simplicity's sake, we assume that thin film and crystalline silicon panels are perfectly substitutable – but that one can be more expensive to install, on a per-MW basis, than the other. Thin film panels are generally slightly cheaper than crystalline silicon, but they are also less efficient. Wesoff and Shiao (2012) describe a "balance of systems" penalty that thin film's lower efficiency imposes on developers.[38] The "balance of system" refers to non-module system costs such as land, installation, and inverters, which fall with rising efficiency. Even with a lower module price per kWh, thin-film modules may impose a higher overall cost when their lower efficiencies are taken into account. The "balance of system penalty" reflects how much cheaper thin film modules must be than CSi modules in order to compete in the global market.

Figures 4 and 5 provide a simple model to capture how this might play out in the Indian market once a DCR is imposed. Figure 5 depicts the market under free trade conditions. P*[CSi] is the world price of crystalline silicon modules, and P*[TF] is the world price of thin film modules. The line marked "P*[TF] + BOS penalty" essentially shows demand for non-thin film modules (i.e., either foreign CSi or domestic modules), which are demanded at any price equal to or lower than the real cost of using imported thin film modules. As such, the demand for non-thin film modules is equal to the world price of thin film plus a unique balance of systems penalty added for each firm. Firms on the left side of the curve have higher balance of systems penalties, and firms on the right have lower penalties.

The bolded lines in Figure 4 show demand for domestic modules. From quantity 0 to quantity B – that is, for firms that experience balance of systems costs that cause the cost of imported thin film panels to exceed the cost of imported crystalline silicon panels - demand for domestic modules is perfectly elastic and equal to P[CSi]. For firms

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[38] Wesoff, Eric, and M.J. Shiao. 2012. "Thin Film 2012–2016: Technologies, Markets and Strategies for Survival." *Greentech Media*. Available at http://www.greentechmedia.com/research/report/thin-film-2012-2016/ (accessed on December 5, 2012).

whose balance of systems costs do not cause the cost of thin film panels to exceed the cost of crystalline silicon – that is, from quantity B to quantity C - demand equals the (perfectly elastic) price of foreign thin film panels plus the balance of systems costs. The number of solar panels produced domestically is equal to A; B-A foreign crystalline silicon panels are imported, and C-B foreign thin film panels are imported. The vertical line marked “Total Demand” represents the total capacity commissioned by the JNNSM program, which is perfectly inelastic.

With the domestic content requirement applied, crystalline silicon imports disappear from the market, and domestic modules are the only alternative to foreign thin film. Thus, the demand curve for domestic modules is equal to the price of foreign thin film panels plus balance of systems costs (Figure 5). The domestic supply curve intersects with this curve at price P[2] and quantity A’. The domestic content requirement therefore causes domestic module production to increase from A to A’. The remainder of the modules demanded for the program, equal to the quantity C-A’, are supplied by foreign thin film manufacturers.

Figure 4.

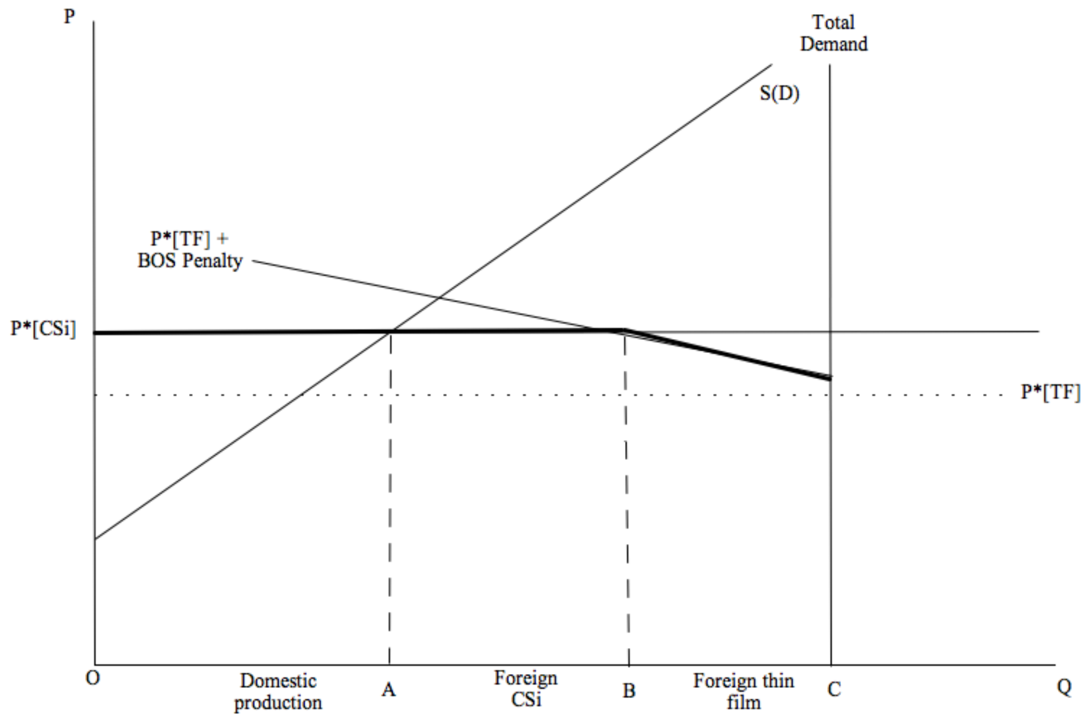
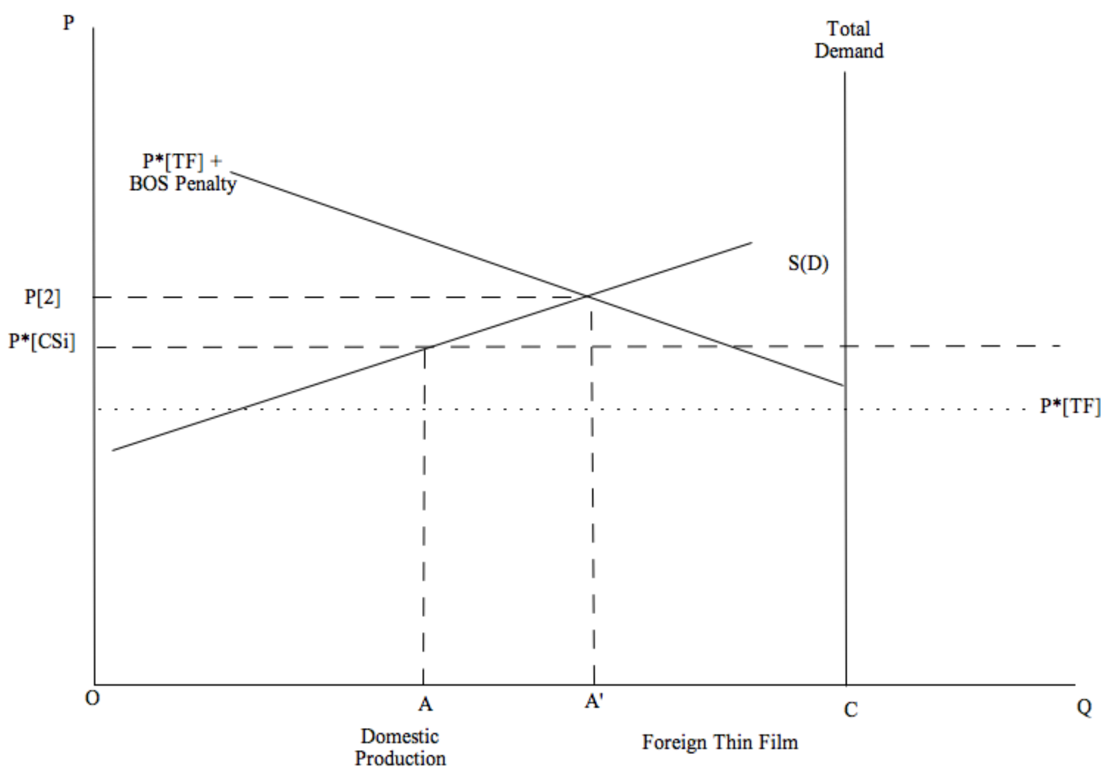


Figure 5.



We can use this model to determine a range of possible outcomes. These outcomes depend on the effective price difference between crystalline silicon and thin film, and also on the shape of the domestic supply curve. A steep domestic supply curve or a low balance of system penalty at the margin, both of which are shown in Figure 6, causes most demand to shift from foreign CSi to foreign thin film when the DCR is applied. A shallow supply curve or a higher balance of system penalty at the margin, which are shown in Figure 7, causes most demand to shift from foreign CSi to domestic modules. This gives us a testable hypothesis. Substituting numbers for the price difference and the supply elasticity will allow us to determine which effect is likely to predominate.

Figure 6.

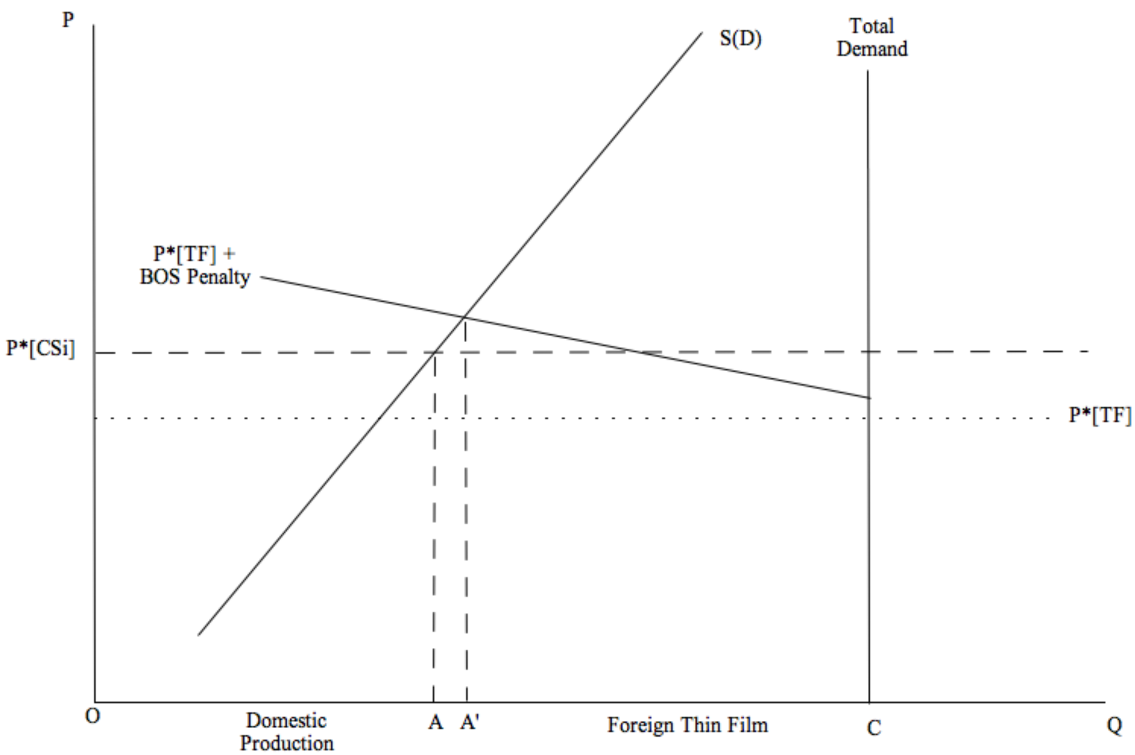
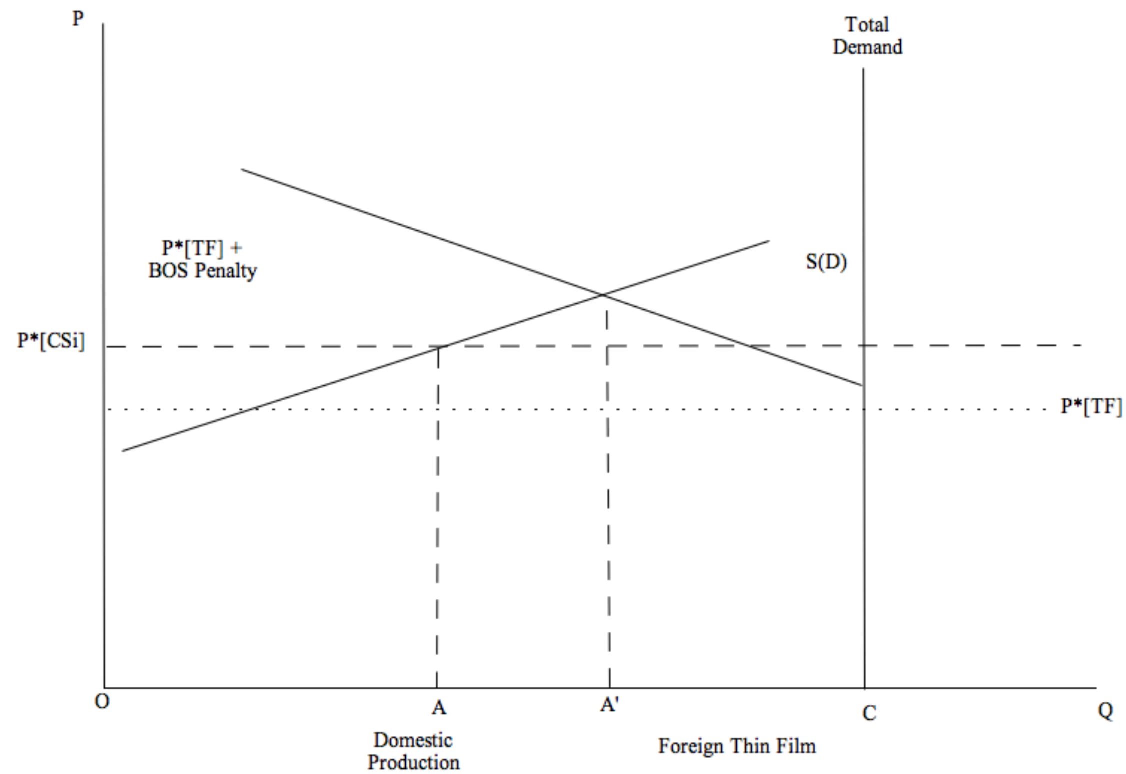


Figure 7.

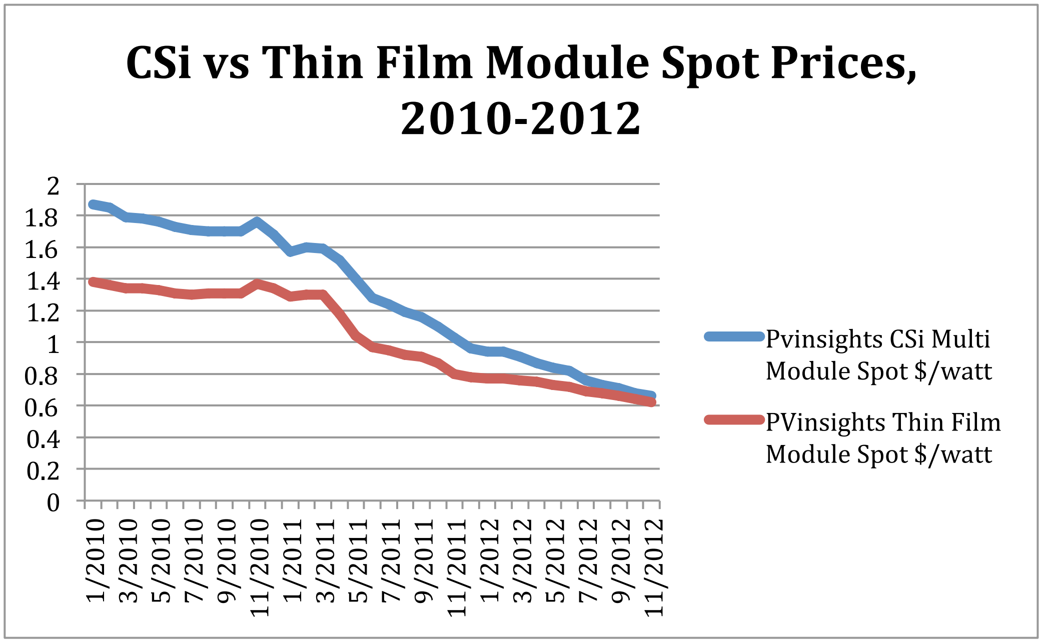


Empirical Results

Predictions Using Recent Module Prices

Figure 8 shows crystalline silicon versus thin film module price movements over the past three years. Thin film modules have historically been slightly cheaper on a per-watt basis, but crystalline silicon modules have nearly closed the price gap over the past year, and forecasters expect the price of CSi modules to continue to decline.

Figure 8.



Source: Bloomberg New Energy Finance, 2012, accessed through the Bloomberg Professional database, Perkins Library, Duke University.

Though the balance of system cost associated with using thin film panels varies according to the installation, average balance of systems costs have been calculated. According to analysis by Wesoff and Shiao (2012), the balance of system penalty for thin film panels varies by the type used: $0.12 per watt for CIGS, $0.18 per watt for CdTe, and up to $0.91 per watt for a-Si panels.[39] Given the global mix of panels produced, this works out to a weighted average of about $0.21 for all thin film panels sold. With this balance of system penalty imposed, the effective thin film spot price approached the CSi spot price at the end of 2010, as thin film's share plummeted, and overtook the price of CSi in late 2011.

Sub-tropical countries such as India, however, have an advantage when it comes to thin film because thin film attains higher efficiencies in hot weather. Moreover, thin

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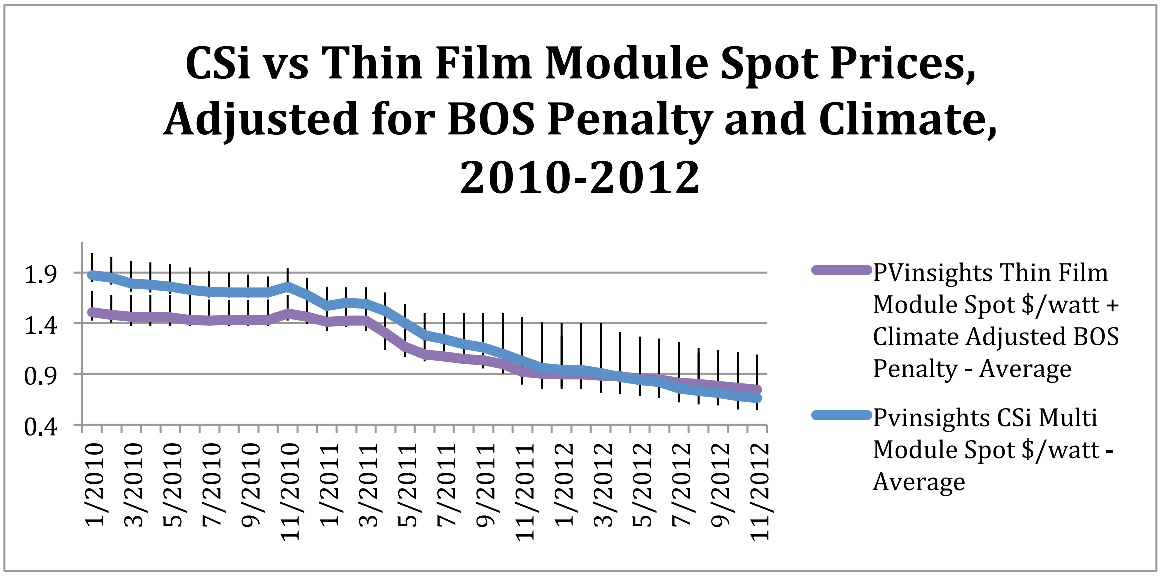
[39] Wesoff, Eric, and M.J. Shiao. 2012. "Is Thin Film Already Dead?" *Greentech Media,* April 27. Available at http://www.greentechmedia.com/articles/read/Slide-Show-Is-Thin-Film-Solar-Dead (accessed on December 5, 2012).

film performs better in low-light conditions. Figure 9 adjusts the balance of system penalty to account for both of these factors, imposing a balance of systems penalty of $0.12 per watt, a weighted average of balance of system penalties calculated by Wesoff and Shiao (2012) for hot and humid climates. In this graph, thin film maintains a small price advantage until 2012, when crystalline silicon's spot price falls below thin film.

Figure 9.



Source: Author's calculations based on data from Shiao, M.J. and Eric Wesoff, 2012, "Is Thin Film Solar Dead?" Greentech Solar, April 27; and Bloomberg New Energy Finance, 2012, accessed through the Bloomberg Professional database, Perkins Library, Duke University.

Adjusted for efficiency and performance, thin film has been around 3 cents per watt more expensive than CSi, on average, in 2012 – or 3 percent of average total module cost.[40] If we substitute this average value for the balance of system penalty experienced in Figure 5 – making a broad assumption that the marginal balance of system penalty is close to the observed average in the literature - we can use supply elasticities derived from empirical literature on renewables to estimate the increase in domestic module production that one would expect as a result of this policy. I apply this

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[40] Thin film was actually less expensive in 2011.

price elasticity to the price difference between P*[CSi] and P[2] to obtain the change in output from A to A' (Figure 5).

Assuming a price elasticity of supply of 1 for PV modules, domestic manufacturing of PV modules in 2012 was at most 3 percent higher than it would have been without the domestic content requirement in 2012, assuming no shift from the non-JNNSM market.[41] Assuming a higher price elasticity of 2.7 – the price elasticity of supply for renewable energy estimated by Johnson (2011) – domestic manufacturing of PV modules might have been up to 8 percent higher than it would be without the domestic content requirement in 2012.[42] Because the market share of domestic panels was low to begin with, however, this does not correspond to a large increase in absolute terms. According to this estimate, one would predict that the DCR has allowed domestic manufacturers to capture an additional 1 to 3 percent of the overall domestic solar market, given an approximate 30 percent share of domestic modules in Batch II. The rest of the market would be occupied by foreign thin film.

Regression Analysis

As explained in the section above, total module demand from the JNNSM does not change as a result of the DCR; this demand is fixed by the JNNSM policy. Rather, the result of the policy is a switch from one module type to another. Developers who would have used foreign CSi modules under free trade conditions have two options:

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[41] A study of Chinese solar tariffs by the Brattle Group also uses 1 as a lower bound and 2.7 as an upper bound for the price elasticity of supply of PV modules. See Berkman, Mark, Lisa Cameron, and Judy Chang, "The Employment Impacts of Proposed Tariffs on Chinese Manufactured Photovoltaic Cells and Modules," study commissioned for the Coalition for Affordable Solar Energy, available at http://coalition4affordablesolar.org/wp-content/uploads/2012/01/TBG_Solar-Trade-Impact-Report.pdf (accessed on January 4, 2013).

[42] Johnson, Erik. 2011. The Price Elasticity of Supply of Renewable Electricity Generation: Evidence from State Renewable Portfolio Standard. Georgia Tech School of Economics, Working Paper #WP2011-001. Available at www.econ.gtech.edu/research/workingpapers (accessed on December 13, 2012).

1. Use domestic modules, or
2. Use foreign thin film.

The objective of this section is to use fine-grained real-world data to determine whether the content requirement has actually accomplished its goal of stimulating domestic manufacturing, or whether it has simply shifted developers' module procurement from foreign crystalline silicon to foreign thin-film modules. Depending on which choice predominates, we should observe one of the following in the data:

1. If most developers who would have otherwise used foreign CSi switch to thin film, we should see a large, significant increase in foreign thin film usage and a small increase in domestic modules, compared with a counterfactual.
2. If most developers who would have otherwise used foreign CSi switch to domestic modules, we should see a large, significant increase in usage of domestic modules instead of foreign modules and a small increase in thin film usage, compared with a counterfactual.
3. If the response is mixed, the increase in domestic module and thin film module usage will be roughly equally significant, compared with a counterfactual.

This paper obtains most of its data from Bloomberg New Energy Finance databases. Bloomberg keeps a record of solar power plants throughout the world, including records of the module technology used, the location of the project, dates that the project was financed and commissioned, the power purchase agreement associated with the project, and (if available) the manufacturer of module inputs. In total, 140 records of commissioned or in-progress utility-scale projects were available for India. Of these, 118 records were associated with a module technology, and 102 records provided the names of the module manufacturers. I coded the latter records as using a domestic module if any of the module manufacturers for the project were domestic; the vast majority of projects had only one module supplier.

Chi-squared tests were run on this data to determine, at first glance, whether inclusion in the Solar Mission had a significant impact on technology choice or nationality of the module supplier. The Pearson chi squared value for thin film choice vs. inclusion in the JNNSM was 5.25, with a p-value of 0.02, indicating significance. Meanwhile, the Pearson chi squared value for domestic module choice vs. inclusion in the JNNSM was 0.06, with a p-value of 0.81; inclusion in the JNNSM was an insignificant predictor of domestic module usage. Table 4 shows that market share for domestic modules is only 2 percent greater for projects within the JNNSM than for eligible projects outside the JNNSM. By contrast, Table 2 shows that thin film module usage is 22 percent greater for projects within the JNNSM.

Table 1. Observations in Data Set: Module Technology

	Eligible Projects Outside the JNNSM	**JNNSM**	**Total**
CSi	35	20	55
Thin Film	23	32	55
Total	58	52	110

Pearson Chi2 = 5.25; P=0.02

Table 2. Percent of Total: Module Technology

	JNNSM-Eligible	**JNNSM**	**Total**
CSi	60%	38%	50%
Thin Film	40%	62%	50%

Table 3. Observations in Data Set: Domestic vs. Foreign Module Usage

	JNNSM-Eligible	**JNNSM**	**Total**
Foreign	29	31	60
Domestic	16	19	35
Total	45	50	95

Pearson Chi2 = 0.06; P=0.805

Table 4. Percent of Total: Module Technology

	JNNSM-Eligible	JNNSM	Total
Foreign	64%	62%	63%
Domestic	36%	38%	37%

Selection bias might be present in the results above. It could be the case that projects choose to be included in the JNNSM based on an intangible factor not controlled for in the regression that leads developers to prefer a certain module type. In this case, comparing the two groups would produce a biased estimate of the program's impact on module choice.

To reduce the possibility of endogeneity and increase robustness, subsequent tests were run using a geographic explanatory variable.[43] Projects in Gujarat were used as a control group, and projects in Rajasthan were used as an experimental group. This approach assumes that geographic location of facilities is randomly determined and is therefore exogenous to module choice.

Location in one of these states provides an ideal way to define treatment and control groups to determine the treatment effect of the JNNSM, as there is a nearly perfect correlation between location and acceptance of the treatment. Utility-scale solar developers in Rajasthan rely primarily on the Solar Mission for power purchase agreements; all but two projects over 5 MW receive funds from this source (Table 5). Gujarat, on the other hand, has a robust state solar procurement policy – with no domestic content requirement -- that is attractive to developers in this area. All of Gujarat's developers have signed power purchase agreements directly with Gujarat's state utility, bypassing the Solar Mission.

These two states provide a natural experiment through which to assess the effect of the domestic content requirement. They are geographically proximate, reducing the

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[43] As a robustness check, similar tests were run using a dummy variable for inclusion in the JNNSM as the explanatory variable. These tests produced similar results to the tests shown in this paper.

chance that module choice is due to climate-related factors. The Thar Desert dominates the landscape in Rajasthan and northern Gujarat; both areas are arid and hot. A majority of solar installations in both areas are installed in dry desert regions (Appendix I). Both programs signed purchase agreements for projects that were financed in 2011 and 2012, although projects in the Gujarat program are skewed toward being financed in 2011 (Table 6).

In order to control for other variables that could affect technology choice -- commissioning status, capacity of projects, and commissioning year – I ran logit and probit, regressions. The results are shown in Table 7 below. The Rajasthan dummy variable has a positive effect on whether thin film modules are chosen; it is significant at the 5 percent level in one of the four formulations shown and significant at the 10 percent level in three of the four formulations. The treatment effect is estimated to lie between 0.16 and 0.22; in other words, the best guess is that the domestic content requirement has expanded foreign thin film's market share by 16 to 22 percent. The 95 percent confidence interval for this estimate is between 0 and 45 percent.

By contrast, the Rajasthan dummy variable is not significant in determining whether domestic modules are chosen (Table 8). The model's best guess is that the treatment has increased domestic module share by 2 percent, but a wide range is plausible. This estimate fits closely with the increase in market share that we would have guessed based on demand elasticities (see previous section).

Complicating the estimates, the two regions draw from the same domestic manufacturing base. If the domestic content requirement caused developers in Rajasthan to buy additional domestic modules, we would expect a price increase in Rajasthan. This would cause some domestic module manufacturers to abandon Gujarat's market for Rajasthan's. Thus, an increase in domestic module use in Rajasthan should be accompanied by a commensurate decrease in domestic module use in

Gujarat, amplifying the perceived effect of the domestic content requirement in the data. Even with this amplification, however, the data showed a very insignificant increase in domestic module usage from Gujarat to Rajasthan. This gives us additional confidence that the domestic content requirement was ineffective.

The conclusion to be drawn from the data is that the majority of developers that would have otherwise chosen foreign crystalline silicon panels have chosen foreign thin film, not domestic modules. The domestic content requirement has likely created little, if any, domestic manufacturing in India.

Table 5.

	Rajasthan Projects By Financing Date 5MW or Greater	
	2012	2011
JNNSM Migration[44]	0	8
JNNSM Batch I	0	20
JNNSM Batch II	24	0
Non-JNNSM	0	2

Table 6.

	Projects Financed 2011-2012	
	JNNSM Projects	Non-JNNSM Projects > 5 MW
Gujarat	0	59
Rajasthan	52	2

[44] Migration projects were projects moved from other solar programs into the JNNSM fold; that is, the power purchase agreements were shifted from local utilities to the national power corporation, NVVN/NTPC.

Table 7

	Probit Results: Marginal effect of Independent Variable on choice of thin film (dy/dx) (Z-score) (95 percent confidence interval)			
	(I)	**(II)**	**(III)**	**(IV)**
Location in Rajasthan (Treatment = 1)	.19 (1.90) (-0.00-0.39)	.16 (1.51) (-0.05-0.37)	.22 (1.95) (-.00-.45)	.21 (1.83) (-.02-.44)
Year dummy (2012)	--	.14 (1.04) (-.12-.39)	.09 (0.66) (-.18-.36)	-.03 (-0.16) (-.36-.31)
Capacity in MW	--	--	.01 (1.42) (-.00-.03)	.01 (1.40) (-.00-.03)
Commissioning Status	--	--	--	-.20 (-1.31) (-.50-.10)

Table 8

	Probit Results: Marginal effect of Independent Variable on choice of domestic module (dy/dx) (Z-score) (95 percent confidence interval)			
	(I)	**(II)**	**(III)**	**(IV)**
Location in Rajasthan (Treatment = 1)	.03 (0.31) (-.17-.24)	.05 (0.51) (-.15-.26)	.007 (0.06) (-.23-.24)	.01 (0.08) (-.22-.24)
Year dummy (2012)	--	-.09 (-0.80) (-.34-.14)	-.07 (-0.52) (-.32-.19)	-.05 (-0.30) (-.37-.27)
Capacity in MW	--	--	-.008 (-1.03) (-.02-.01)	-.008 (-0.99) (-.02-.01)
Commissioning Status	--	--	--	.03 (0.19) (-.29-.36)

The DCR: What Could Happen Going Forward?

The Government of India will likely make its content requirement more technology-neutral going forward. Several options exist. One alternative is to remove the DCR entirely. Based on the results found in this paper, this option would not affect domestic module manufacturers very much; mainly, it would shift market share back from foreign thin film into foreign CSi. This option preserves the status quo – it does not harm the domestic industry. If current market trends continue, however, India may not find itself with the robust domestic solar manufacturing sector it desires. Rather, it will likely continue to rely on imported components. Scrapping the DCR would be desirable for solar developers, however, allowing them to choose the technologies and suppliers best suited to their project needs.

The opposite extreme would be to expand the DCR to cover 100 percent of cells and modules used in installations, regardless of technology. If this occurred, assuming an upward-sloping supply curve, the domestic module market would likely shift from non-JNNSM developers (e.g., Gujarat) to JNNSM developers. Non-JNNSM developers would instead use imported modules. It appears there is a great deal of slack manufacturing capacity nationwide. 314 MW of projects using domestic modules were financed in 2011, vs. 61 in 2012. The next auction, in 2013, is expected to supply 165 MW, and based on the experience in 2011, Indian manufacturers should have sufficient capacity to fill this demand. Prices may increase from current levels, however.

Conclusion

India's subsidy program for solar electricity provides a powerful driver for the growth of solar generation. The DCR is motivated by pressures to achieve similar growth in India's domestic solar manufacturing. So far, it has failed to meet this goal.

Because the DCR places no limit on imported thin film, the DCR has stimulated far less domestic manufacturing than the Indian government envisioned. Instead, it has mainly shifted the market from one imported technology to another. Any price increases in electricity as a result of switching from imported crystalline silicon to imported thin film modules are likely very low; on average, the estimated balance of system penalty made thin film approximately 3 cents per watt more expensive than crystalline silicon in 2012. Using two different methods, it is estimated that domestic manufacturing might have captured between 0 and 3 percent of additional market share as a result of the DCR.

Future changes to the DCR likely will not jeopardize India's ability to meet its targets, at least in the short term. However, prices could increase if the DCR is expanded. The DCR also introduces the threat of retaliation from other exporters of renewable energy components such as the United States, Germany and Japan. The latter two countries pressed a World Trade Organization (WTO) dispute settlement case against a renewable energy domestic content requirement in Ontario, and the WTO recently ruled against this content requirement. The United States has indicated that it may pursue a similar case against India's content requirement, requesting formal consultations in February 2013.[45]

Thus, the domestic content requirement may not be the best policy for India's solar sector. India's current DCR produces few benefits for manufacturing, and will likely lead to trade disputes that could jeopardize India's ability to grow its solar manufacturing industries. An expanded DCR could help create domestic manufacturing in the short run, but risks increasing the cost of meeting solar installation targets – and trade disputes, again, could prevent Indian solar manufacturers from establishing a presence in global markets. A better alternative could be to enact targeted policies to

[45] Levine, David J., and Pamela Walther. 2013. "Wave of Trade Disputes Complicates Global Market for Renewable Energy Firms, Particularly Solar Sector." *Bloomberg Law.* Available at http://about.bloomberglaw.com/practitioner-contributions/wave-of-trade-disputes-complicates-global-market-for-renewable-energy-firms-particularly-solar-sector/ (Accessed on April 16, 2013).

increase technological capacity in solar manufacturing and provide attractive financial options for buyers of solar panels to compete with US and Chinese export-import banks.

Appendix I. Climate Map of India

Source: Carver, Ben, et al. 2003. "Renewable Lighting for the Developing World: Briefing Book." Available at http://cee45q.stanford.edu/2003/briefing_book/india.html (accessed on April 16, 2013).