Analysis of International Policies In The Solar Electricity Sector:

Lessons for India

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आरोग्य, ऊर्जा, शिक्षण आणि पालकत्व
या विषयांतील विशेष प्रयत्न

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Summary for Policy Makers

Although solar costs are dropping rapidly, solar power is still more expensive than conventional and other renewable energy options. The solar sector still needs continuing government policy support. These policies are driven by objectives that go beyond the goal of achieving grid parity. The need to achieve multiple objectives and ensure sufficient political support for solar power makes it difficult for policy makers to design the optimal solar power policy. The dynamic and uncertain nature of the solar industry, combined with the constraints offered by broader economic, political and social conditions further complicates the task of policy making.

This report presents an analysis of solar promotion policies in seven countries - Germany, Spain, the United States, Japan, China, Taiwan, and India – in terms of their outlook, objectives, policy mechanisms and outcomes. The report presents key insights, primarily in qualitative terms, and recommendations for two distinct audiences. The first audience consists of global policy makers who are exploring various mechanisms to increase the penetration of solar power in markets to mitigate climate change. The second audience consists of key Indian policy makers who are developing a long-term implementation plan under the Jawaharlal Nehru National Solar Mission and various state initiatives.

National objectives, policies and outcomes

Government policies are mainly a combination of 'pull' and 'push' policies. 'Pull' policies provide purchase support to increase installed generation capacity and include Renewable Portfolio Standards (or Renewable Purchase Obligations), feed-in tariffs, generation-based subsidies, and capacity-based subsidies. 'Push' policies directly support manufacturing and Research, Development & Demonstration (RD&D) by providing grants or low-cost loans, tax concessions, RD&D grants, training activities, and the provision of reliable and often, subsidized support infrastructure (for example, land, energy, water, communications, and transportation).

The objectives behind these policies include increase in renewable energy generation to mitigate climate change, or boost energy security; develop domestic industry to create jobs and exports; develop technology and intellectual property rights via RD&D; and improve access to electricity where the electric grid is unreliable or absent.

Most countries may prefer to invest significantly more in the deployment of lower cost renewables, such as wind, hydro and biomass, compared to solar power to meet their objectives of achieving higher clean energy penetration and ensuring energy security. Until its cost decreases substantially, the contribution of solar power deployment to achieving those national objectives may continue to remain small in the near future.

In contrast, pull policies for solar have been and will continue to be driven by the objectives of achieving public awareness and political support through 'green' initiatives, as well as providing access to clean electricity and lighting. For example, Germany provides higher feed-in tariffs to encourage smaller rooftop PV systems compared to megawatt scale solar plants. As a result, more than 99 percent of Germany's PV installations from January 2009 to August 2010, accounting for 85 percent of the 8.7 GW installed capacity during that period, were less than 1 MW in size. Until recently, China concentrated mainly on off-grid solar PV deployment through its Brightness Rural Electrification and the Township Electrification Programs to provide energy to its remote communities, while India with its large population without access to electricity stands to benefit greatly from off-grid decentralized solar applications.

Deployment of solar is driven through individual jurisdiction environmental protection regimes, especially since the stalemate in climate change negotiations. Only a few countries have established pull policies that provide significant deployment support, with Germany accounting for more than 40 percent of the annual PV market in 2010. However, deployment support can be severely affected by macro-economic conditions as seen in 2008 when the Spanish government drastically reduced its support for solar PV to cope with the economic recession.

While pull policies create jobs in the installation sector, push policies directly incentivize job creation in the manufacturing and RD&D sectors. According to one estimate, there were 170,000 solar-sector jobs in 2008, with China accounting for the highest, followed by Germany and Japan.

Push policies, but also pull policies to a certain extent result in broader economic development and exports. Pull policies alone may not lead to economic development through industry growth, since they may result in imports of lower cost solar equipment from already developed industries in other countries. To avoid such an outcome that may result in loss of political support, governments may opt to mandate domestic content in their pull policies. Although mandates for domestic content may lead to higher deployment costs in the short term due to the infancy of the domestic industry and a lack of exposure to international competition, these may lead to the development of that country's domestic industry and realize potential cost reductions for the global industry in the future as shown by the outcome of the Chinese policies in the wind sector. However, countries with established industries may oppose such moves, as illustrated by Japan's trade dispute with Canada (Province of Ontario) at the World Trade Organization, and the United States' protest against India.

Most countries support their industries including solar through push policies by subsidizing their costs of inputs. Germany provides incentives to its industry to set up facilities in its eastern region. The US provides loan guarantees and other incentives to its industry. China's currency policy of pegging the yuan to the US dollar arguably has an effect on making China's exports more competitive, as does low-interest finance from state-owned banks. Further, the examples of China and Taiwan that together manufactured 60 percent of the solar PV cells in 2010 illustrate that a combination of push policies and limited pull policies are more than sufficient to develop a thriving solar PV manufacturing industry. Both China and Taiwan have adopted an export-oriented economic growth paradigm similar to that of Germany and Japan. However, unlike Germany and Japan that were early starters in the solar industry and provided significant deployment support, the domestic demand created in China and Taiwan is very limited compared to their solar industry output. The present economic slowdown has led to a tussle between nations to secure the financial and employment gains associated with developing the clean energy industry. An example is the trade case filed by the United Steelworkers Union of the United States in 2010 accusing China of violating the World Trade Organization's free trade rules by subsidizing exports of clean energy equipment.

Various countries provide support for RD&D to create intellectual property rights in a future growth industry so that their domestic firms might steadily rise through the value chain of products. Japan, the US and Germany have traditionally invested in RD&D, which is reflected in their combined share of 70 percent of patent applications in the field of solar energy from 2005-2009. The Chinese government is strongly incentivizing patent activity, and Chinese industry is moving from lower-profit manufacturing to higher-margin brand/RD&D and sales/marketing.

Effect on solar cost reduction

Solar PV saw a large price reduction from 1980s through early 2000s, mainly as a result of sustained RD&D. Substantial PV capacity additions began in the early 2000s, with rapid acceleration taking place since 2008, when more than 75 percent of the cumulative PV capacity till 2010 was installed. However, real price remained relatively stable through this growth period of installed capacity till 2007, following which prices resumed their downward trend.

While Japan and Germany dominated solar PV cells manufacturing till 2006, the manufacturing support provided by China and Taiwan has led to their domination of the solar PV cells market, increased competition, and subsequent lowering of input costs for solar PV.

Support from governments in the form of interest subsidies, land allotment, subsidized utility services and currency policies, all play a role in reducing the costs of inputs for the industry. Although these subsidies are by themselves not real cost reductions, they may eventually reduce the costs of solar power by establishing an industry and encouraging its development.

The levelized cost of solar power is directly affected by the quality of the solar resource. For example, the levelized cost of solar electricity generation is much higher in Germany and Japan (countries that account for more than 50 percent of global PV installed capacity) due to their poor solar resource compared to that in Spain or India.

Many leading firms have already achieved 1 GW-plus manufacturing capability at the plant level and the future incremental potential to reduce production costs through economies-of-scale in manufacturing remains to be seen.

Free-field installations are less expensive than small rooftop PV systems. However, most countries encourage smaller scale PV plants by offering higher feed-in tariffs compared to free-field installations, thereby forgoing any cost reductions from economies-of-scale.

Sustained support for the solar industry reduces costs over time through learning-by-doing. According to one study, the average installed cost of 3-5 kW residential PV installations in 2009 was significantly lower in both Germany and Japan (countries with a greater and longer history of support for solar deployment) than in the US.

Countries like Taiwan, Germany and China got an edge in the international PV market by developing industry clusters for learning across such industries as semiconductors and flat displays (TFT-LCD).

Incremental RD&D, especially that pursued by industry to reduce the amount of material and energy inputs, as well as improve efficiencies of the solar modules while lowering costs, has been responsible for a steady decline in solar costs. Economies-of-scale or volumes do provide revenues and profits for industries to invest in such RD&D.

Breakthrough RD&D has a large potential to leapfrog existing technologies and ultimately bring about major reductions in costs of solar power. For example, Cadmium Telluride (CdTe) thin film technology lowered solar costs enough to pose a big challenge to the dominant crystalline-Si technology.

The prices of inputs such as polysilicon, silicon, steel, and glass depend on the status of their demand and supply. The shortage of polysilicon in 2005-2008 was followed by massive investments by the industry in new capacities that led to an oversupply in 2009, sending the spot price down from its maximum of US$500 per kg to approximately US$55 per kg. Continuing oversupply situation and the increasing competition in the solar sector has exerted a downward pressure on the profit margins of all the manufacturers, a key factor in the reduction of PV prices.

Individual countries or regions that exploit their monopolies based on strategic considerations can also affect the price of inputs. This was illustrated when the Chinese government blocked the export of 'rare earth' minerals to Japan over a security incident in 2010. China controls 97 percent of the world's market for 'rare earth' minerals, which are important ingredients in thin film PV amongst several other electronic technologies.

Recommendations

Given the ongoing economic turmoil and scarce ratepayer and taxpayer resources available for solar power, it is important for governments to implement an optimal mix of policies that are effective in balancing national objectives with achieving the long term objective of making solar power competitive with other renewable energy options and subsequently conventional generation.

Although economies-of-scale in terms of global PV demand during the 2000s had a role in the reduction in cost of solar power, they may not have delivered cost reductions commensurate with the subsidies provided. RD&D, both incremental and breakthrough can substantially reduce the cost of solar power. However, resources spent on deployment of solar are comparatively an order of magnitude higher than those spent on RD&D. Further, the industry is likely to under-invest in break-through RD&D and next generation solar technologies, both due to the high capital requirement and spillover effects that may not let them take total advantage of their RD&D investments. Hence, it is critical for governments to provide adequate investment in basic research and innovation. According to a 2010 report of the International Energy Agency, the global budget for RD&D was US$680 million/year, which is a fraction of the subsidy committed for deployment and is estimated to be as less as about one-third of the total required RD&D budget. National efforts and international collaboration on solar energy RD&D need to be expanded based on a systematic assessment of RD&D gaps and funding needs.

Given the various limitations of pull policies in achieving key objectives such as clean energy, energy security, economic development, and others; solar deployment can be done in a more strategic way than is currently being considered in India and elsewhere. While smaller PV installations such as rooftop PV in sub-optimal locations are promoted mainly to garner environmental and political support, it is important for policy makers to assess further opportunities for solar deployment in optimal locations. For developing countries like India with large populations without access to electricity, decentralized PV systems present a viable option for providing access to clean lighting and electricity. CSP technology offers the advantage of thermal storage and subsequently, the potential of dispatchable power. The CSP industry, with just over 1 GW of installations, is relatively nascent compared to PV and may have a large potential for cost reduction, especially in high solar resource countries. Opportunities need to be explored to maximize solar electricity generation, thus reducing costs without losing public support.

While the examples of China and Taiwan illustrate that significant deployment support is not essential to develop a strong domestic industry, trade disputes are expected to occur, especially in the present economic slowdown. Hence, for long-term sustainability of the solar sector, it is important for countries to balance pull policies (considering the paying capacity of their consumers) along with push policies, so that the burden of providing a market for solar power is not borne by just a handful of nations.

Various governments have enforced domestic content mandate to prevent domestic subsidies from flowing towards imports. For example, India and Canada (Province of Ontario) have mandated domestic content in their solar programs, while the US is enforcing similar mandates for solar projects funded under the American Recovery and Reinvestment Act. Although from a national perspective, the domestic content mandate seems justified, it prevents countries from utilizing each other’s comparative advantages. A transparent assessment of these comparative advantages along with unfair incentives from countries for encouraging exports needs to be undertaken for informed policy choices across countries that would benefit the entire solar industry.

Solar power has become an important and critical renewable energy generation option. It is important for policy makers to optimally design their solar policies by balancing national objectives and paying capacity with the global objective of solar power cost reduction in order to realize its full potential.

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Background and Motivation

"Solar power has become an unlovely adolescent. It used to be a sweet little thing, shiny and new and full of promise. One day it will doubtless grow into a solid citizen, quite possibly a person of substance. At the moment it is stuck in between; no longer a child to be coddled and pampered, but not yet able to pay its own way. This presents a challenge both for the governments who want to see it grow up big and strong and the companies that have been making money out of its progress to date. *No one doubts that it will continue to grow; the question is who will suffer most from the growing pains*." [emphasis added]

– The Economist (April 15, 2010)

This excerpt captures the gist of the conundrum faced by policy makers all over the world regarding solar power policy. Solar power has tremendous potential in terms of resource availability, and its costs have been dropping over the years. However, it is still relatively expensive compared to conventional as well as other renewable energy (RE) generation options. Rapid cost reduction of solar electricity to achieve grid parity is the ultimate societal goal, since this will facilitate widespread deployment of solar.[1] How soon existing and planned solar power policies would advance grid parity is not clear. Neither is it clear what policy interventions are likely to be most effective in achieving grid parity. Further, the recent economic crisis has forced many governments all over the world to adopt austerity measures, thereby reducing their appetite for continuing extensive subsidies for purposes such as solar development.

All segments of the solar power supply chain – installed capacity, manufacturing capability, creation of new ventures, advanced research and development (R&D), etc. – are growing rapidly in response to a variety of policies. These policies can be classified into three broad categories:

1. purchase support to increase the installed generation capacity of solar;
2. manufacturing support to encourage the industry and create jobs; and
3. support for RD&D of technological innovations, and reductions in costs.

These policies are driven by objectives that go beyond the goal of achieving grid parity. Depending on the geographic jurisdiction of the governments involved (ranging from national to local), the policies may be formulated to increase renewable energy generation to mitigate climate change, or boost energy security; develop domestic industry to create jobs and exports; develop technology and intellectual property rights via R&D; and/or improve access to electricity where the electric grid is unreliable or absent.

Policy makers have found that designing the optimal solar power policy is complicated by multiple such objectives, some of which are difficult to quantify. At the same time, the policy must be designed to meet these multiple objectives in order to garner sufficient political support for solar power. The dynamic and uncertain nature of the solar industry (e.g. cost of technology, efficiency, introduction of new technologies, etc.) complicates the task of policy making even further. In addition, policy makers are constrained by broader economic, political and social conditions. Finally, the lessons learnt during the relatively short history of the solar sector offer limited insights for the selection of policies.

1 From a power supplier's perspective, grid parity consists of comparing the cost of solar power with that of the power it would be directly substituting in a specific period of time at a specific location. From a customer's perspective, where the customer is considering replacing grid electricity with a solar generator located on their premises, grid parity is defined as the price of retail grid electricity.

As many factors have influenced solar power policy worldwide, deriving policy principles is substantially difficult. In this paper, we review the experience of various governments to assess the effectiveness of their solar power sector policies, specifically:

- the objectives that the policy was designed to achieve;
- the different policy mechanisms used to achieve those objectives;
- whether the policy mechanisms achieved these objectives, and whether the policy was the most effective way of achieving them; and
- the effectiveness of the policy mechanisms in bringing down the cost of solar.

We review the solar promotion policies in seven countries including Germany, Spain, the United States (specifically, the State of California), Japan, China, Taiwan, and India. Germany has been a leader in solar photovoltaic (PV) installed capacity for most of the second half of the 2000s, and is also a leading exporter of solar technologies. Spain's experience is useful due to its meteoric rise in installed solar PV capacity spurred by generous government support, followed by a bust due to a drastic reduction in that support. However, the nation continues to strongly support its concentrated solar power (CSP) industry and, with the US, is a leader in the industry.

Policies to support solar power vary substantially across states in the US. We have focused on the State of California because it has the maximum installed and planned new capacity, as a result of its ambitious goals for renewable energy production and carbon emission reductions. Japan has been the world leader in solar PV manufacturing and exports as well as installed capacity during the first half of the 2000s. China has the largest PV cell manufacturing capacity in the world, with Taiwan being the second largest manufacturer. Both these countries have focused on exports of solar equipment to markets such as the EU and US, and have not provided any significant purchase support to increase installed capacity at home. The experiences of these countries may offer valuable lessons for India as it designs its solar policies.

In 2010, the Central Government of India announced its Jawaharlal Nehru National Solar Mission (JNNSM), which has a target of 22 GW of installed capacity by 2022. As part of the JNNSM, India is offering a gamut of incentives to support the development of both solar generation and manufacturing capacity. In addition, some Indian state governments have announced their own solar policies, with the state of Gujarat leading the way by signing approximately 1000 MW of power purchase agreements by the middle of 2011.

We analyze the policies of these seven countries (including India) in terms of their outlooks, objectives, mechanisms and outcomes. We scrutinize in depth the specific policy mechanisms under consideration and their effectiveness to achieve the stated objectives of these countries - energy security, climate change mitigation, domestic industry development, access to electricity. Following this, we attempt to draw out key insights in primarily qualitative terms, and provide recommendations from two distinct perspectives. The first consists of key considerations that Indian policy makers should keep in mind as they develop their long-term implementation plan under the JNNSM and various state initiatives. The second offers key considerations for global policy makers as they explore various mechanisms to increase the penetration of solar power in markets to mitigate climate change.

Framework for Analysis

A summary of the underlying framework used in our analysis is shown in Figure 1. We begin by reviewing the key policy objectives adopted by various countries. We then present the different policy mechanisms that are being adopted by governments to fulfill their objectives. Subsequently, we discuss the political-economic contexts, which have influenced policies of individual countries. Finally, we study the outcomes of the policies and their impact on lowering the global cost of solar power through five different cost reduction mechanisms.

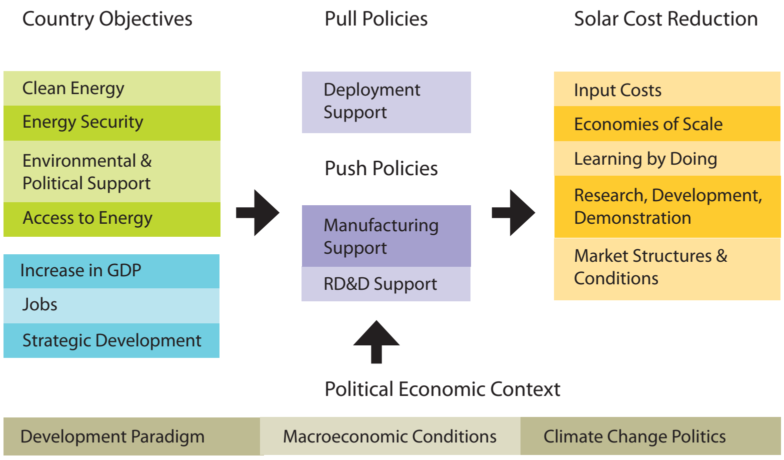


Figure 1: Framework for assessing the effectiveness of solar policies

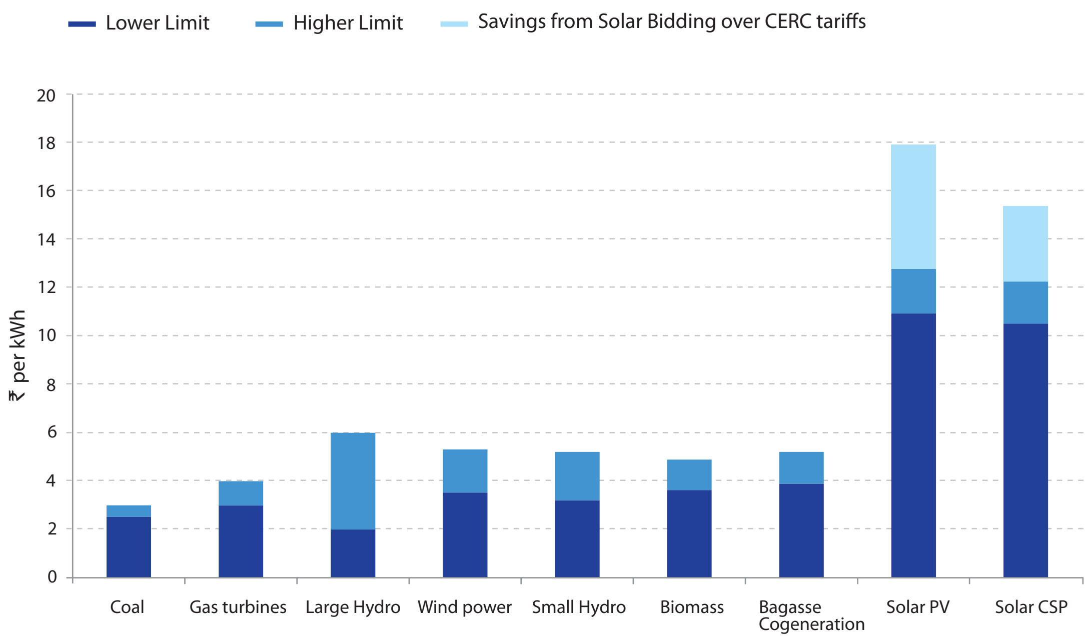
Solar Policy Objectives

In spite of the current, rapid downward trend in solar costs, solar power costs significantly more than conventional fossil-based electricity generation technologies. This is illustrated in Figure 2, which compares the costs of various generation technologies in the India. The lowest bid accepted in the 2010 auction to procure utility-scale solar power under India's National Solar Mission (NSM), approximately US$0.23/kWh (₹11/kWh), was substantially higher than the winning bid of approximately US$0.07/kWh (₹3/kWh) for base-load coal power plants.[2] Such differences make it difficult for solar power to compete in the markets without some policy intervention mainly in the form of subsidies.

Cost reduction of solar is the ultimate societal objective, which would enable solar power to penetrate a large part of the market without needing additional financial or other support to make it financially viable.[3] Statements by several jurisdictions formally acknowledge cost reduction as the

2 Prayas (2011), "India's Solar Mission: Procurement and Auctions", Economic and Political Weekly, Vol XLVI, No 28, pp 22-26; Prayas (2011), "Transition from MoU to Competitive Bidding: Good Take-off but Turbulence Ahead, Review of Thermal Capacity Addition through Competitive Bidding in India".

3 Note that the main alternative to reducing cost of solar or eliminating the gap in the costs of solar and conventional technologies is raising the cost of conventional technologies through policies such as cap-and-trade or carbon taxes.



Note: *Renewable Energy tariffs are as per the CERC regulations.*
Solar PV and CSP tariffs are from the Jawaharlal Nehru National Solar Mission phase I bidding.
Coal, gas and large hydro tariffs are Prayas estimates.

Figure 2: Range of generation tariffs in India

broader objective of their solar power policies, in line with the ultimate objective of the global solar sector.
For example:

- India's National Solar Mission (2009) explicitly states, "The objective of the Solar Mission is to create conditions, through rapid scale-up of capacity and technological innovation to drive down costs towards grid parity. The Mission anticipates achieving grid parity by 2022 and parity with coal-based thermal power by 2030…."
- California SB1 (2006) states, "It is the goal of the state to … establish a self-sufficient solar industry in which solar energy systems are a viable mainstream option for both homes and businesses in 10 years...."
- Germany's Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz or EEG) (2000) states, "The purpose of this Act is to facilitate a sustainable development of energy supply, particularly for the sake of protecting our climate, nature and the environment, to reduce the costs of energy supply to the national economy…."

On the one hand, due to the global nature of both the market for and the supply chain of solar power (e.g. PV), it is unlikely that the policies of one nation or region would unilaterally achieve the required cost reduction. On the other hand, domestic politics usually requires governments to highlight other objectives in order to build and develop political support for solar policies. This is especially important since the political appetite for providing massive ongoing subsidies for solar power within a country, especially in the current economic slowdown, can be limited. Consequently, policy makers have to choose the most effective of various levers to achieve maximum cost reduction, while also maintaining political support. Besides, for a nation, the cost reduction objective is essentially to reduce its own deployment costs as well as to enhance the competitiveness of its solar manufacturing industry.

Here, we present the national objectives behind a nation or jurisdiction's support for solar power. Most of the major countries/regions in the solar sector have aggressively sought political support for their solar policies by highlighting both clean deployment and domestic value addition as key objectives.

Deployment Objectives

Broadly characterized, deployment objectives include (a) increasing the contribution of clean energy to mitigate carbon emissions and other pollution; (b) enhancing energy security by reducing dependence on imports of fuel for energy production; (c) creating political symbols such as rooftop PV installations which provide visible evidence of a society cherishing environment friendly values, and thus sustaining political support for environmental policies; and (d) ensuring access to energy for customers in under-served regions through decentralized and off-grid applications.

A strategy that is likely to achieve one of these deployment objectives will not necessarily work in achieving others. Solar PV being one of the most expensive technologies, countries prefer to push relatively cheaper renewable energy options at the utility scale to achieve their clean energy and energy security objectives, while deploying PV in decentralized applications to increase public awareness and broaden customer access.

Domestic Value Addition Objectives

Domestic value addition objectives consist of (a) job creation, (b) increasing GDP, and (c) strategic development. While employment trends in the solar industry are imprecisely understood, growth in jobs has been visible. Broader economic development is also likely to result from supporting the solar sector. This is an indirect benefit of manufacturing and/or installation, and results from the creation of ancillary industries to support sector growth in tax revenues, human resource capability, infrastructure investments, and so on. The third broader objective in domestic value addition is strategic, that is, creating and owning intellectual property rights in a future growth industry, so that domestic firms can rise steadily through the value chain of products.

While nation-specific policies designed to achieve these objectives have led to cost reduction and brought solar power closer to grid parity, they might not have been the most effective ways to achieve these ends. In the next section, we look at the type of policy support and mechanisms that have been used to promote solar power.

Types of Policies

Policies used to support solar energy across the world are typically classified into two categories – *pull* and *push*. *Pull* policies create a strong demand for solar power, which the industry then meets. *Push* policies create a supply of solar power, which consumers from utilities to homeowners then procure. In general, most governmental jurisdictions don't prefer one category over the other, but some combination of the two.

Our intention is not an in-depth theoretical discussion of all such policy options and their variations. Instead, in this section, we provide a conceptual overview and examples of the policy mechanisms used to support solar power.

Pull Policies

'Pull' policies are intended to stimulate demand and include Renewable Portfolio Standards (or Renewable Purchase Obligations), feed-in tariffs, generation-based subsidies, and capacity-based subsidies.[4] It should be noted that stimulating demand may boost imports from already developed industries in other countries rather than stimulate domestic production, unless the policy includes 'domestic content' requirements.

Feed-in Tariff (FiT), a generation-based incentive, is by far the most popular pull policy, with more than 40 countries having adopted solar-specific FiTs.[5] FiTs are higher electricity purchase prices based on the cost of renewable energy generation, often levelized over the life of the project. FiTs are usually accompanied by long-term contracts and guaranteed grid access. Higher electricity purchase prices for renewable energy are also offered in the form of premiums that are paid to the producer on top of the current electricity market price.

The other popular pull policy is the Renewable Purchase Obligation (RPO) or Renewable Portfolio Standard (RPS). A RPO/RPS is a legislated quota obligation or a binding renewable energy target which requires that a minimum percentage of electricity generation installed capacity or electricity generated or sold be provided by renewable

4 Carbon mitigation policies (e.g. cap-and-trade, carbon tax, etc.) would also come under the 'pull' category since they raise the cost of carbon-emitting power sources relative to the cost of solar power.

5 European Photovoltaic Industry Association and Greenpeace (2011), "Solar Generation 6 – Solar Photovoltaic Electricity Empowering the World".

energy. Renewable Energy Certificates (REC) can work in tandem with an RPO/RPS policy. An REC, also known as a green tag or a renewable energy credit, represents the environmental or green credit of renewable electricity and can be traded to meet renewable energy targets.

Other pull policy mechanisms include capital-based (i.e. per watt of installed capacity) incentives or rebates, tax incentives (investment tax credits and production tax credits), grants, interest subsidies or low-cost financing, and loan guarantees. Most of these and other forms of subsidies are financed from either electricity ratepayer charges and/or taxpayers monies.

Push Policies

'Push' policies support the creation of businesses in the solar supply chain, especially those that manufacture solar power components and systems. This support is usually in the form of grants or low-cost loans, tax concessions, RD&D grants, training activities, and the provision of reliable and often, subsidized support infrastructure (e.g. land, energy, water, communications, and transportation). Policy makers also support the development of capacity-creating networks/clusters. Such supplemental support can lower some of the non-monetary barriers that can impede the growth of the solar sector, including lack of skilled personnel and research facilities, inadequate means of information sharing, and inadequate infrastructure for pilot projects and development.

In general, most jurisdictions prefer some combination of push and pull policies. Both the financial and infrastructure incentives can be offered by various levels of governments.

Political-Economic Context

The adoption of both specific solar power objectives and policies to implement them depends on the local political and economic context at the time. Three major context factors are:

1. macroeconomic conditions;
2. the economic development paradigm; and
3. international and local climate change politics.

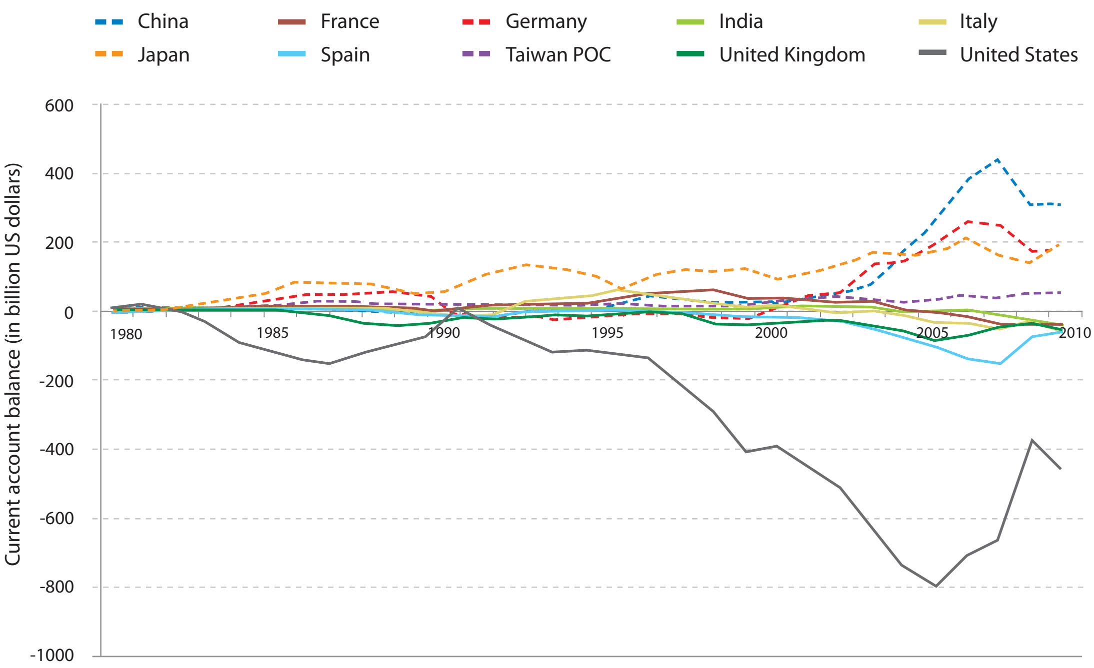
Macroeconomic Conditions

Global and national macroeconomic conditions impact the level and duration of solar support policies significantly. The main financial support provided for solar power consists of ratepayer funds (i.e. those collected from electricity customers through a surcharge on their bills) and taxpayer funds allocated from government budgets. Local economic conditions – recession, unemployment, budget and trade deficits, and competing social and political priorities – have a strong influence on both the level of support and its long-term sustainability.

The International Monetary Fund's October 2010 World Economic Outlook finds that the global financial crisis affected all major macroeconomic indicators in 2008-09. Developing countries such as China and India (referred to by the IMF as 'emerging economies') are making a rapid recovery, but many of the developed countries (referred to as 'advanced economies') are not. As most of the large investments in solar deployment over the last decade had been committed to in the advanced economies (especially Germany, Spain, UK, Italy, France and parts of the US), governments there have been forced to reconsider their generous support for solar in light of their respective macroeconomic priorities (e.g. debt reduction).

Economic Development Paradigm

The economic development paradigm also affects the nature and extent of the support for solar. Since the end of the Second World War, the US has invested heavily in the development of advanced technologies, emphasizing not only export-led growth but also domestic consumption, as was evidenced by the rapid growth in home and automobile ownership in the country, as well as the rapid adoption by the public of advanced consumer technology such as television. Germany and Japan also invested heavily in their manufacturing sector after the war, and over time made the transition from low-value products to state-of-the-art high-value products whose output in some cases now routinely surpasses that of the US. Unlike the US, both Germany and Japan focused substantially on increasing their exports, especially to markets such as the US.



Source: *International Monetary Fund's World Economic Outlook database April 2011*

Figure 3: Trend (1980 - 2010) in current account balances (in billion US dollars)

Starting substantially later, the four Asian Tigers (Taiwan, Korea, Singapore, and Hong Kong) and then China emulated the German and Japanese export-oriented growth models. Each of these countries has also systematically shifted to the manufacturing of higher value-added products. Figure 3 illustrates the results in current account balances of the different economic development paradigms shaping growth in two sets of countries – China, Japan, Germany, and Taiwan versus the US, UK, France, Spain, Italy, and India.[6] The first set of countries have been net exporters, while the second set have been net importers over the past three decades, a distinction that has grown more marked over the last decade. In some ways, the focus of the solar policies in Taiwan and China on exclusively push policies as opposed to pull policies reflects their economic development paradigm of exporting high-value products to the rest of the world.[7]

International and Local Climate Change Politics

Efforts to establish a new global climate change mitigation treaty have so far failed, as was evident from the Copenhagen meet. However, the individual jurisdiction environmental protection regimes (especially climate change mitigation) are a crucial driver for supporting policies targeting renewables. For example, Germany was forced to rapidly expand its renewable energy portfolio including solar due to the adoption of ambitious EU-wide targets for contributing renewable energy, coupled with Germany's own planned phase-out of its substantial carbon-free nuclear generation plants.[8] While international

6 Current account is all transactions other than those in financial and capital items. The major classifications are goods and services, income and current transfers. The focus of the balance of payment is on transactions (between an economy and the rest of the world) in goods, services, and income.

7 The rapid GDP growth observed in China over recent years coincides with the rapid growth in its current account balance, suggesting that a large portion of the Chinese industrial output has been exported to the rest of the world. An IMF Working Paper estimates that over 2000-2008, the net exports and investments linked with it in China accounted for approximately 60 percent of the country's growth, which was substantially higher than the approximately 40 percent growth observed in 1990-2000 (Guo, K. and N'Diaye, P. (2009), "Is China's export-oriented growth sustainable?", International Monetary Fund Working Paper).

8 After the Fukushima nuclear disaster in Japan due to the March 11, 2011 earthquake and tsunami, the German government pledged to shut down its last nuclear reactor by 2022.

negotiations continue, several other major GHG emitters have also initiated programs to support solar, both to show their willingness to take up some responsibility for mitigation, and to grow a business sector that might capture future exports. However, till an international treaty with binding targets is not enforced, efforts to mitigate climate change will remain unilateral.

Solar Cost Reduction Factors

Most cost reduction theories present learning curves, a black box approach that tries to explain cost reductions observed over time for many technologies by quantifying the cost reduction (or some other characteristic of the technology such as efficiency) achieved in relation to the level of experience with that technology (e.g. production or installed capacity).[9] A learning curve has been the primary tool to justify and assess cost reduction policies. However, some researchers such as Nemet find that learning-by-doing as defined in the learning curves theory only weakly explains the cost reductions achieved in solar PV.[10]

In this study, we have broken down cost reduction into five mechanisms that include costs of inputs, learning-by-doing, economies-of-scale, RD&D, and market structure. Fundamentally, all cost reduction policies - implicitly and/or explicitly – intend to influence one or more of these underlying mechanisms. It should be emphasized that all these mechanisms do not necessarily operate independently of each other.

When making policy, it is critical to assess – at least in relative terms – the contribution of each of these fundamental mechanisms to cost reductions in solar technology. Ideally, policy makers choose an optimal mix of interventions that can achieve maximum cost reductions in the shortest time for the lowest cost.

Inputs

The key inputs in the production of solar power include basic materials such as silicon for PV cells, steel, and glass, land, utility infrastructure, labor, capital, and intellectual property. Substitution of cheaper inputs for more expensive inputs (e.g. automation of product lines to reduce labor costs), use of lesser quantity of inputs (e.g. reducing wastage of materials, etc.), and more efficient processes throughout the solar power value chain can contribute to the cost reduction objective.

Some factors that play a major role in determining the availability of inputs and their costs include, but are not limited to,

- geographic distribution of source of inputs (e.g. 'rare' earth elements necessary for thin-film solar PV are currently available mainly in China; while the solar resource is relatively better in Spain, California and India compared to Germany and Japan, leading to more solar power output for the same installed capacity),
- geographic variability in cost of inputs (e.g. comparative advantage of certain countries with weaker currencies leads to lower labor costs, government subsidies for utilities, infrastructure and capital), and
- market supply-demand equilibrium status (i.e. over-supply results in lower prices while under-supply results in higher prices as compared with actual costs).

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10 Nemet, G.F. (2006), "Beyond the learning curve: factors influencing cost reductions in photovoltaics", Energy Policy 34(17), pp. 3218-3232.

Economies-of-scale

The efficiency of large-scale production results in 'economies-of-scale' which reduce the average cost of producing one item, even though the total cost of producing all the items increases as more items are produced.

The potential for cost reductions through large economies-of-scale varies across different components of the solar power supply chain. For example, on the one hand, a capital-intensive manufacturing process may be able to achieve large cost reductions through economies-of-scale. On the other hand, the installation of solar PV on residential rooftops is less likely to yield such results.

The marginal decrease in costs may diminish even though the scale of the enterprise continues to grow. For example, some solar PV manufacturers have already achieved more than 1 GW production capacities at individual facilities. Hence, it may be potentially problematic for policy makers to continue to expect further cost reductions due to the economies-of-scale effect as these production facilities grow in size or number.

Learning-by-doing

'Learning-by-doing' refers to improvements in performance, efficiency, costs, etc. achieved as a worker or business gains experience that enhances expertise and reduces errors. Costs tend to drop as manufacturers gain more experience in producing certain products. At least in the short term, a firm that is able to restrict the benefits of learning-by-doing from becoming known to its competitors will improve only its own profitability through reduced costs, assuming the market price of the product doesn't change. If the benefit of learning-by-doing spills over to other firms, then the market price of the product is likely to decrease through competition, ensuring that at least some of the benefits of learning-by-doing are shared with consumers.

'Cross-learning' between firms making different products can also lower costs. This effect has been seen in the PV sector between semiconductor and Si-based solar PV industries, and between thin film transistor liquid crystal display (TFT-LCD) and thin film PV industries. Policy makers can increase cross-learning opportunities by providing an environment where knowledge sharing is explicitly encouraged. This can be done through support for industry clusters (as in Germany and Taiwan) and knowledge-sharing infrastructure such as communication, libraries, and experimental facilities.

Research Development and Demonstration

RD&D activities leading to both incremental and 'leapfrog' improvements are crucial for reducing costs. Leapfrog RD&D consists of discovering or inventing fundamentally new materials, processes, or techniques that can create a radically better technology by raising its efficiencies and/or lowering its costs of production. For example, CdTe thin film, which competes with crystalline Si PV, promises lower costs as a result of leapfrog RD&D. The 'tower' and compact linear Fresnel reflector technologies in the CSP sector are other examples.

Figure 4 shows the state of efficiency improvements of the main solar PV technologies. Incremental RD&D efforts will continue to push the production-level efficiencies closer to those observed in laboratories and in theory.

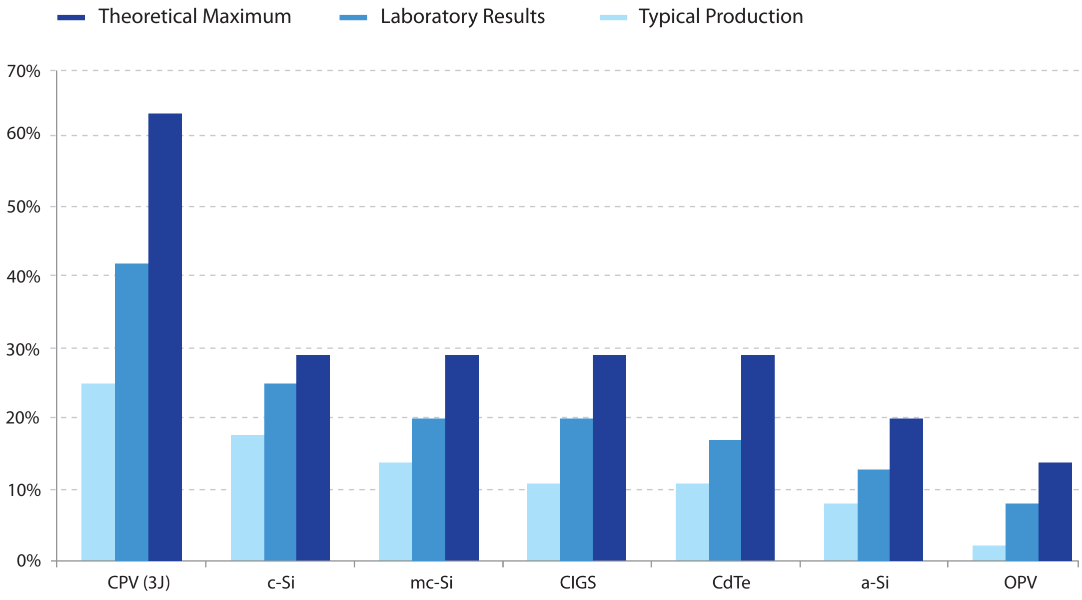
The private sector is likely to under-invest in RD&D as long as there is a risk of knowledge spillover when intellectual property rights (IPR) are not protected, and the return on investment is uncertain without long-term policy incentives. It is critical, therefore, for governments to provide adequate additional investment in RD&D. This investment can be in the form of government-sponsored laboratories or direct funding to the private sector.

Market Structure

Unlike conventional power generation technologies that have been operational for several decades, many solar technologies have been commercially operational for only a few years.[11] In addition, many of the solar technologies are still in a rapidly evolving phase, and businesses have a difficult time in making long-term investment decisions.[12]

11 Solar PV has been used in niche applications for more than 50 years while the oldest CSP power plants have been in operation for more than 20 years. However, widespread commercial deployment of these technologies has occurred only in the last decade.

12 Dixit, A., and Pindyck, R. (1994), "Investment Under Uncertainty", Princeton, NJ.



Source: *U.S. Department of Energy, Advanced Research Projects Agency-Energy (2010), "$1/W Photovoltaic Systems".*

Figure 4: Comparison of efficiencies of existing solar PV technologies across three contexts - typical production, laboratory results, and the theoretical maximum

Since the current crop of solar power policies are essentially, direct interventions in the market, it is necessary for policy makers to ensure that businesses are provided with transparent, long-term, and certain signals that help achieve the ideal market structure.

From the perspective of achieving rapid cost reductions, the market structure should ideally have attributes including but not limited to the ability to deploy resources optimally across the world, competitiveness, the ability to sustain business models over a long term, the ability to support processes that yield 'disruptive innovations', minimal transaction costs, and the ability to effectively manage risks.

For optimal allocation of resources in today's globalized trade regime, businesses make full use of the 'comparative advantages' that different regions demonstrate relative to one another. Competitive markets are more likely to result in lower prices, as opposed to uncompetitive markets. Consolidation of markets where only one or a few firms dominate is likely to lead to monopolistic or oligopolistic behavior, which can adversely affect progress towards rapid cost reductions.

Case Study Summaries

In this section, we summarize the experience of solar policy development and implementation in each of the seven case-study countries selected for the study. The intention is not to provide a comprehensive account of the evolution and implementation of solar policies, but to highlight key observations for policy makers in countries such as India, which are in the process of developing their long-term solar policy.

Germany

German solar policy's objectives – both explicit and implicit – are among the most aggressive in the world. Germany has a strong tradition of environmental protection, including consistent support for renewable energy. Ambitious EU-wide targets for both renewable energy and reduction in carbon emissions contributed to a rapid expansion of Germany's renewable energy portfolio including solar.[13] Germany's planned phase-out of its substantial carbon-free nuclear generation plants, as well as its vulnerability to political uncertainty of natural gas supplies from Russia, has exacerbated its energy security concerns: a development that has accelerated its support for renewable energy.[14] On the domestic value addition front, solar PV has been a major part of Germany's export-oriented economic development approach.

Although FiTs were introduced in 1991, it was the aggressive regime created under the German Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz* or EEG) in 2000, especially the attractive FiTs offered under amendments to the EEG in 2004, that were responsible for the high growth of PV in the country. Germany's long-term and consistent FiT policy has resulted in the largest cumulative solar PV installed capacity in the world, which is 17 GW, or 43 percent of the total global capacity in 2010.[15] Other factors, including priority connection, fixed FiT payment over 20 years, and degression rates (a pre-determined rate for reduction in FiTs which varied depending on the amount of PV deployment) were also crucial to Germany's high deployment rate of solar PV. The country offers higher FiTs for smaller installations (e.g. rooftop PV), while the lowest FiTs apply to free-field installations.

The total burden of existing commitments to solar PV undertaken by the German electricity ratepayers up to 2009 was approximately €52 billion (2007 euros).[16] The financial crisis and falling solar costs resulted in Germany slashing its solar FiTs twice during 2010, with more cuts planned for 2011. Nonetheless, Germany installed more than 7 GW of PV in 2010.[17] It remains to be seen whether Germany can maintain its momentum, especially as FiTs are reduced again in 2011. The German Environment Minister refused to categorically rule out the entire cancellation of FiTs from 2012 onwards.[18] The trends in both annual installed capacity and FiT changes since 2003 are shown in Figure 5.

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13 According to Germany's National Renewable Energy Action Plan under Directive 2009/28/EC, the share of renewable energies in the German electricity sector is expected to be 38.6 percent by 2020.

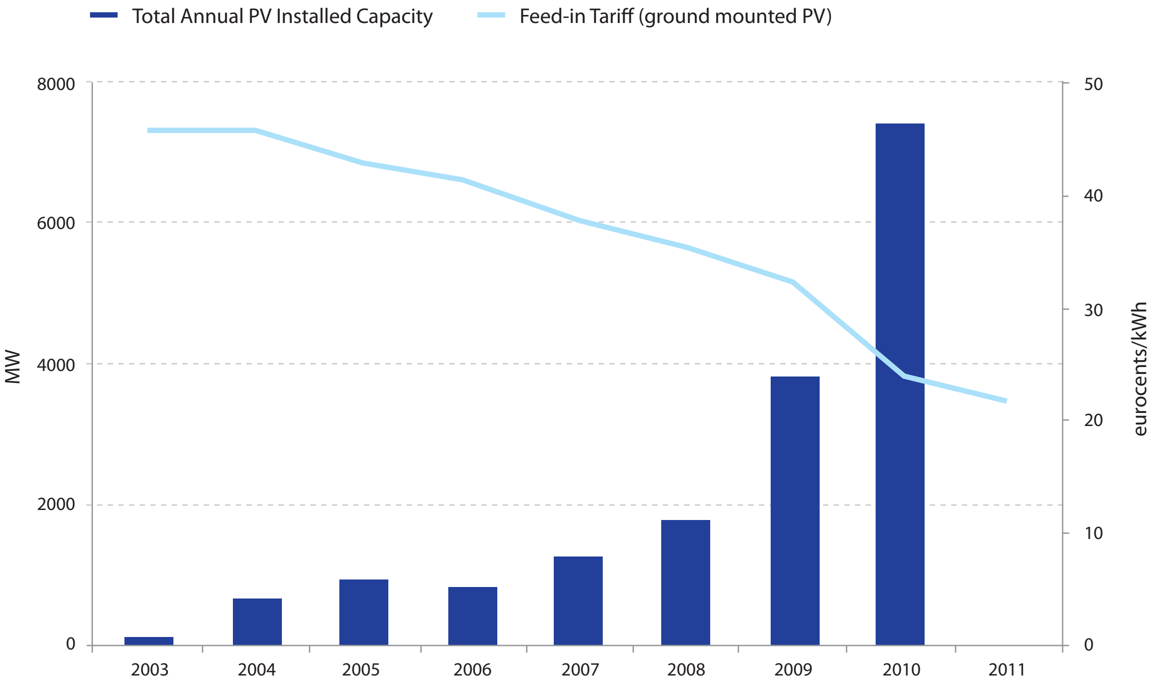
14 Germany imports 40 percent of its natural gas from Russia.

15 European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015".

16 Frondel, M., Ritter, N., Schmidt, C.M., Vance, C. (2010), "Economic impacts from the promotion of renewable energy technologies: The German experience", Energy Policy, Vol. 38(8), pp. 4048-4056.

17 European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015".

18 Reuters article December 2010, "German minister says no guarantees on solar tariffs", available at http://www.reuters.com/article/idUSTRE6B038F20101201, accessed on 3rd July 2011.



Note: *Annual Installed capacity includes all PV installations. Feed-in tariffs for only ground-mounted PV systems shown.*

Source: *Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2010), "Renewable Energy Sources 2010"; European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015"; Institute for Energy, Joint Research Centre, European Commission (2003 to 2010), "PV Status Reports"; PV News (2010), Volume 29, Issue 10.*

Figure 5: Germany's annual solar PV installed capacity and feed-in tariffs

With regards to industry incentives, the German government offers investment incentives of up to 50 percent of capital expenditure to PV manufacturing firms (regardless of whether they are from Germany or otherwise). These include cash incentives, interest-reduced loans, public guarantees, and incentives for labor and R&D. Investment projects in Eastern Germany receive additional benefits in the form of cash payments and/or tax credits, which has led to a concentration of PV cluster development in that region. The German Development bank, KfW, provides low-interest loans for private and commercial investors alike.[19]

Germany has been investing substantially in solar R&D since the early 1980s, and continues to do so. In 2009, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) committed €64 million and €16 million for new and ongoing PV and CSP projects respectively.[20] The Federal Ministry of Education and Research (BMBF) is sponsoring an Innovation Alliance between the PV industry and equipment manufacturers for cost reduction, as well as a PV industry cluster.[21] It is worth noting that although the solar resource in Germany is poor, especially for CSP, its industries and R&D programs have been developing solar thermal technologies, mainly for installations in export markets.

In 2010, 107,800 people worked in the PV sector, and an additional 2000 worked in the CSP sector. During the same year, the turnover of German manufacturers and suppliers

19 Germany Trade & Invest, February 2009, "The photovoltaic industry in Germany – The world's strongest PV cluster".

20 Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2009), "Innovation through Research: 2009 Annual Report on Research Funding in the Renewable Energies Sector".

21 International Energy Agency, Photovoltaic Power Systems Programme, Annual Report 2010.

amounted to about €12 billion and €190 million for PV and CSP respectively.[22] More than 60 research institutes in Germany are engaged in the development of PV technology, and 143 solar patents were registered in 2008 alone.[23] While German manufacturers are facing tough competition even in their domestic market, Germany still dominates the PV manufacturing equipment and inverters markets.[24]

Spain

The Spanish economy is highly dependent on imported energy sources, with 80 percent of its coal, 100 percent of its natural gas, 98 percent of its petroleum, and 85 percent of its nuclear fuel coming from outside the country.[25] Spain started encouraging renewable energy sources in the 1980s, mainly due to this high degree of dependence on energy imports, and in response to growing environmental concerns across Europe. Much as Germany did, Spain adopted a National Renewable Energy Action Plan, which sets a target of 40 percent renewable energy in electricity generation by 2020 in order to meet the EU directive target.[26]

Since the mid-1990s, several successive Royal Decrees offered FiTs for solar electricity in the form of both fixed tariffs and premiums over the market price of electricity. However, it was the Royal Decree 661/2007 that significantly increased FiTs for solar PV, and was responsible for the dramatic rise of PV installations in Spain. In 2008, Spain became the leading installer of PV, with an annual installed capacity of 2.7 GW. This exceeded the annual cap of 1.2 GW, mainly due to Spain's policy of accepting projects until one year after 85 percent of the cap was achieved. By the end of 2008, the total subsidy committed was approximately US$12.5 billion, and created approximately 14,500 jobs in the solar PV industry.[27]

The Spanish government has kept the electricity consumer tariffs low and has been reimbursing utilities from the national budget for the deficit. Because Spain has been one of the worst-hit countries during the financial crisis, Royal Decree 1578, issued in September 2008, slashed the FiTs and introduced a provision requiring that two-thirds of the capacity should be rooftop-mounted and allowed no free-field systems. The Spanish government is not only looking at further slashing solar FiTs by up to 45 percent, but is even considering retroactive FiT cuts for approved projects. The Spanish PV market crashed with less than 20 MW installed in 2009. The trends in both annual installed capacity and FiT changes since 2006 are shown in Figure 6.

The Royal Decrees 436/2004 and 661/2007 are considered to have triggered the growth of the solar thermal market in Spain. In spite of the recession, the FiTs for CSP were not reduced, and although the 500 MW annual cap set for 2009 caused some uncertainty, the CSP industry has continued to grow. By the end of 2010, Spain's total installed CSP capacity (approximately 600 MW) was at par with that of the US, the only other major CSP market.[28]

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22 Federal Ministry for the Environment, Nature Conservancy and Nuclear Safety (BMU) (2011), "Short- and Long- term impacts of the impacts of renewable energy on the German labor market: Annual report on gross employment".

23 Germany Trade & Invest, February 2011, "Photovoltaic R&D in Germany".

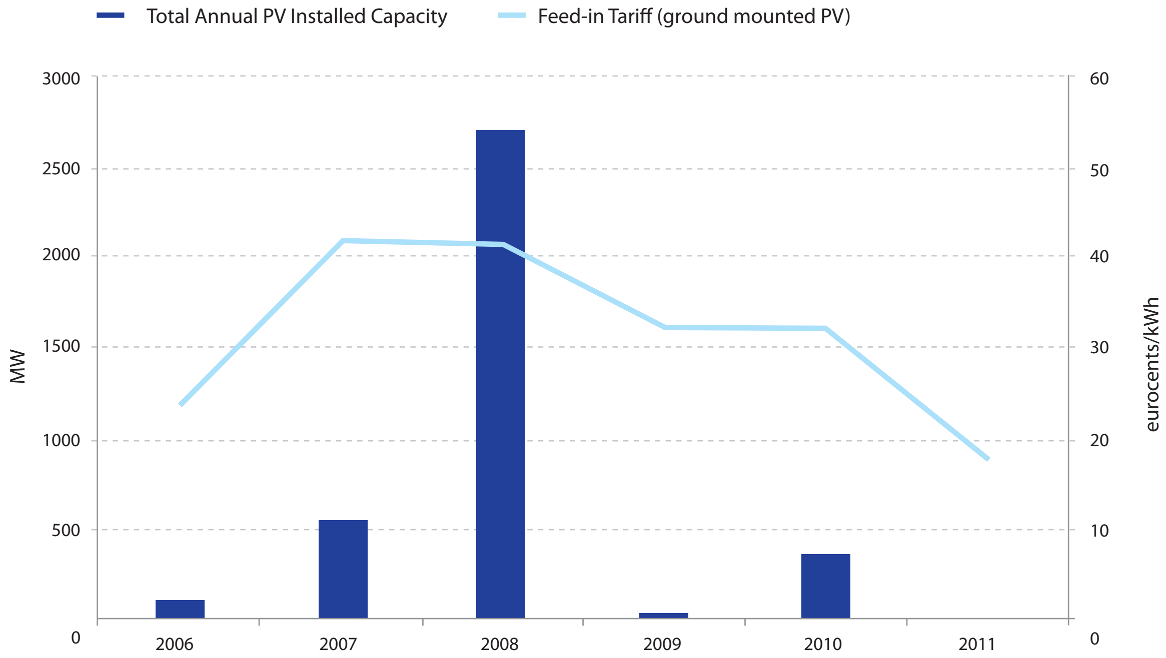
24 According to the report by IMS, "The world market for photovoltaic inverters – 2010", Germany's SMA alone controlled approximately 37 percent of the inverter market in 2009.

25 US Energy Information Administration Statistics, data for 2008.

26 Beurskens, L.W.M & Hekkenberg, M. (2010), "Renewable energy projections as published in the National Renewable Energy Action Plans of the European member states," ECN and European Environment Agency.

27 Gabriel Calzada Álvarez (2009), "Study of the effects on employment of public aid to renewable energy sources", Procesos de Mercado, Volumen VII, Número I, Primavera 2010.

28 REN21, Renewable Energy Policy Network for the 21st Century (2011), "Renewable 2011 Global Status Report".



Note: *Annual Installed capacity includes all PV installations. Feed-in tariffs for only ground-mounted PV systems shown.*

Source: *European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015"; Institute for Energy, Joint Research Centre, European Commission (2006 to 2010), "PV Status Reports"; PV News (2010), Vol 29, Issue 10.*

Figure 6: Spain's annual solar PV installed capacity and feed-in tariffs

United States

The US electricity generation sector is dominated by coal (45 percent), followed by natural gas (23 percent) and is not significantly dependant on imports for either fuel.[29] At the same time, the US is the second largest annual greenhouse gas emitter after China.[30] Hence, climate change concerns, more than energy security in the short term, seem to drive the development of renewable energy generation. Although the US did not ratify the Kyoto protocol and subscribe to binding targets at the national level, various states and other jurisdictions within the US have voluntarily set emissions reduction and renewable energy targets.

The US solar policy is fragmented by various entities and agencies pursuing diverse support mechanisms. Federal, state, and local governments provide various tax incentives, including below market-rate loans and grants.[31]

Although a few jurisdictions have FiT programs, RPS is the more popular pull policy mechanism. By 2010, 14 out of the 30 states with RPS policies had solar-specific set asides, while four states had distributed generation set asides that will likely serve, to a large degree, to support solar.[32] In addition, five states had adopted solar multipliers, either in lieu of or in combination with set asides, and two additional states had multipliers for distributed generation.[33,34]

29 US Energy Information Administration, Electric Power Annual, data for 2009.

30 World Resources Institute – Climate Analysis Indicators Tool, data for 2005.

31 A comprehensive listing of various types of solar policies offered in the US can be reviewed at the Database of State Incentives for Renewables and Efficiency (DSIRE), available at http://www.dsireusa.org/solar/index.cfm?ee=1&RE=1&spf=1&st=1

32 Set asides in an RPS policy consist of different targets for different renewable energy technologies or applications.

33 Credit multipliers for solar or distributed generation provide those preferred applications additional credit or renewable energy certificates towards meeting the supplier's RPS compliance obligation.

34 Wiser, R. and Barbose, G. (2010), "Supporting solar power in renewable portfolio standards: Experience from the United States", Lawrence Berkeley National Laboratory.

Although the states of New Jersey, Colorado, Arizona, Florida and others have initiated significant efforts to support solar over the past couple of years, the US experience in solar capacity installation has largely been dominated by California. The California Solar Initiative (CSI) targets installation of approximately 2,000 MW of mainly rooftop solar capacity (smaller than 1.5 MW) over the period 2007-2016.[35] Improved solar economics has led to more than 22 GW of utility-scale solar capacity being announced, mainly in California and parts of the desert southwest to meet general RPS compliance obligations.[36] In December 2010, California regulators introduced an auction-based feed-in tariff program to encourage solar projects that are greater than 1.5 MW but less than 20 MW connected at distribution level.[37]

Apart from these incentives, the US federal government also offers various types of support for solar, including a 30 percent investment tax credit, loan guarantees (under the 2009 American Recovery and Reinvestment Act), RD&D funding for basic research, business incubators, and other support.

In 2010, the US was the fifth largest PV market with nearly 900 MW installed, taking its cumulative installed capacity past 2.5 GW.[38] The country also had the world's largest installed CSP capacity of 507 MW in 2010, and has more than 9 GW of CSP projects in the pipeline.[39]

The US is a net exporter of solar energy products with total net exports of US$723 million in 2009. The largest solar energy product export was polysilicon and the US accounted for 40 percent of global production.[40]

State and federal government budget deficits, the lack of long-term certainty about climate change legislation, and transaction costs such as environmental permits and REC trading mechanisms have inhibited the growth in solar investments. One of the consequences has been the sudden surge in investment of both public and private venture capital in the last three to four years for RD&D, and the incubation of new companies; however, the investment now appears to be abating.[41]

The US Department of Energy (DOE) Solar Energy Technologies Program (SETP), with a 2009 budget of nearly US$300 million, has four sub-programs. The photovoltaics and concentrating solar power sub-programs focus on lowering the levelized cost of solar energy through R&D. The systems integration sub-program deals with the integration of solar energy into the grid, while the market transformation sub-program addresses the non-R&D barriers to achieve high market penetration of solar energy technologies.[42] Currently, SETP is developing a roadmap for achieving the target of US$1/MW for solar PV, which would more or less achieve the target of grid-parity in most locations in the US.

China

China's electricity generation is dominated by thermal sources, with coal providing close to 80 percent of the total generation.[43] Coal consumption is a major cause of local pollution as well as the main source of China's greenhouse gas emissions. Although China ranks low in per capita emissions, it had the largest CO_{2eq} emissions in the world, accounting for almost 20 percent of the global

35 California Energy Commission and California Public Utilities Commission, "The California Solar Initiative", available at http://www.gosolarcalifornia.ca.gov/csi/index.php

36 Wiser, R. and Barbose, G. (2010), "Supporting solar power in renewable portfolio standards: Experience from the United States", Lawrence Berkeley National Laboratory.

37 California Public Utilities Commission (2010), "Decision adopting the renewable auction mechanism".

38 European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015".

39 Solar Energy Industries Association and GTM Research (2010), "U.S. Solar Market Insight: 2010 Year in Review".

40 Solar Energy Industries Association and GTM Research (2010), "U.S. solar energy trade assessment 2010: Trade flows and domestic content for solar energy-related goods and services in the United States".

41 US Department of Energy (2010), "2008 Solar Technologies Market Report".

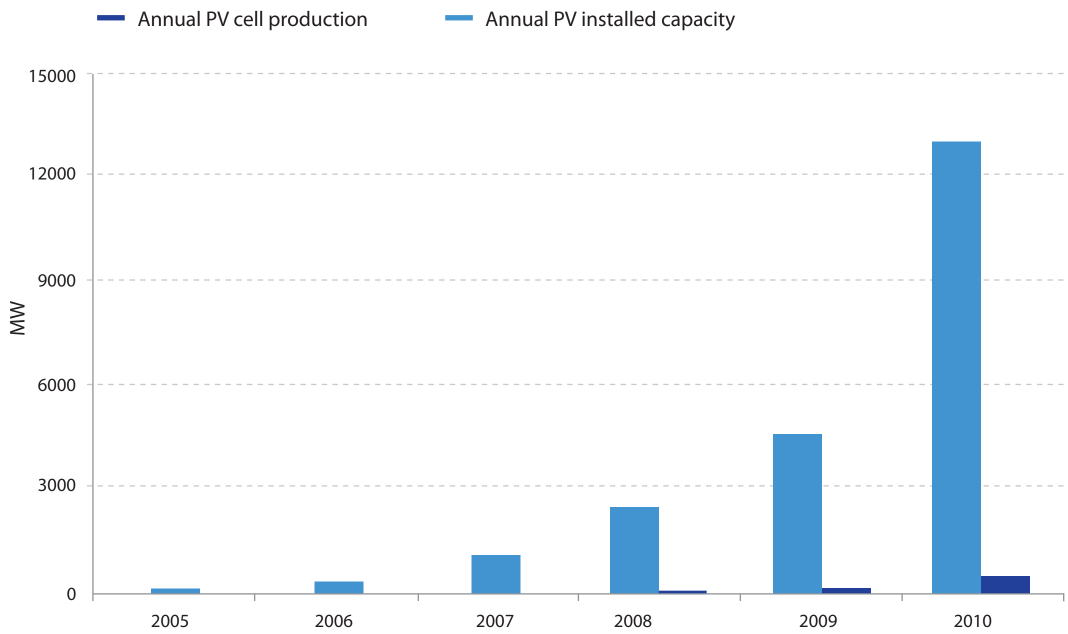
42 US Department of Energy (2010), "2008 Solar Technologies Market Report".

43 International Energy Agency Statistics, data for 2008.

emissions flow in 2005.[44] As a developing nation, China has no binding emissions targets under the Kyoto Protocol. However, just prior to the Copenhagen talks in 2009, China voluntarily committed itself to a target of reducing its carbon intensity, or carbon emissions per unit of gross domestic product, by 40 to 45 percent by 2020 compared to 2005.

China enacted its landmark Renewable Energy Law in 2005, which gave a high priority to the development and utilization of renewable energy. This led to a big push in renewable energy deployment, especially in the wind sector where China now has the largest wind deployment (approximately 45 GW) in the world.[45] However, solar capacity additions have been relatively small until recently. The total installed solar capacity by the end of 2010 was approximately 900 MW, with more than half of this capacity (520 MW) coming in 2010 alone.[46]

Until 2009, the main push for solar PV in China was in off-grid installations for remote rural communities, the result of Brightness Rural Electrification and Township Electrification programs that started almost a decade ago. In 2009, China launched its most ambitious solar deployment program, the Golden Sun initiative, to create some domestic demand for its solar manufacturers in anticipation of reducing the international PV demand during the early days of the financial crisis. The program aims to install approximately 642 MW of grid-connected and off-grid solar PV at a cost of approximately US$3 billion over the next three years.[47] However, the annual demand is an order of magnitude smaller than China's PV cell manufacturing capacity (Figure 7).



Source: *Photon International (2011), "Cell Production Survey 2010".*
European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015".

Figure 7: China's annual solar PV installation and PV cell production

44 World Resources Institute – Climate Analysis Indicators Tool, data for 2005.

45 Global Wind Energy Council (2010), "Global Wind Report - Annual Market Update 2010".

46 European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015".

47 Yuan Ying (2011), "Burned by the Sun", China Dialogue, available at http://www.chinadialogue.net/article/show/single/en/4232-Burned-by-the-sun, accessed on 11th May 2011.

China has shown phenomenal growth in production, increasing its PV manufacturing capacity eighty-fold in the last five years; it was the largest manufacturer in 2010, producing approximately 13,000 MW, or 48 percent of the global capacity.[48] The Chinese solar energy industry began in the mid-1980s, when semiconductor companies started manufacturing solar cells with waste raw material from wafer production. By 2000, the domestic industry could fulfill the modest Chinese domestic market demand, although there were very little exports. Since 2005, China has focused on supplying solar PV equipment to Western countries such as Germany, Spain, and the US, where demand was buoyed by generous purchase support for PV deployment. The Chinese solar industry started developing a comprehensive supply chain, including the manufacture of polysilicon material, ingots, wafers, cells, and modules.[49] This growth in the solar PV industry was concurrent with the Chinese government's push after 2000 to develop a comprehensive semiconductor industry from chip design to production and testing.[50]

The Chinese government's pro-export currency policy arguably played a major role in its export-oriented growth. This currency policy (used by Japan in the 1980s and Korea in the 1990s) pegged the Chinese currency to the US dollar, thus preventing it from appreciating against the same.[51] The Chinese government also offers tax incentives and low-cost credit and financing from state-controlled banks to its solar industries, advantages enjoyed by other Chinese manufacturing sectors as well.[52,53] Chinese manufacturers have also benefited from low labor costs, subsidized electricity rates, and close proximity to raw material suppliers.

In terms of RD&D support and strategic goals, the Chinese government has identified energy technologies such as hydrogen fuel cells, energy efficiency, clean coal, and renewable energy as focuses of the National High-Tech Development Plan (863 program), while making utility-scale renewable energy development central to the National Basic Research Program (973 program). It approved US$585 million jointly for the 863 and 973 programs in 2008.[54]

China's recent purchase support policy initiatives do show promise, but it might be hard to raise domestic demand to match its manufacturing capacity, since the relatively high costs will be borne by the electricity consumers and the state exchequer via the National Renewable Energy Fund.

Japan

Japan ranked sixth in terms of total greenhouse gas emissions, although its per capita emissions were relatively low compared to other Annex I nations.[55] Over 65 percent of Japanese electricity generation is thermal-based, and the nation relies almost completely on imports for its fossil fuel needs.[56] Hence, energy security and reduction of carbon emissions is high on the Japanese government's agenda.

The long-term Japanese PV research and development programs, as well as market implementation, started in

48 Hering, G. (2011), "Year of the Tiger", Photon International Cell Production 2010 Survey, Photon International, March 2011, available at http://www.photon-international.com/download/photon_cell_production_2010.pdf

49 Myers, S. and Yuan, L.Y. (2007), "China's Solar Energy Industry: Polysilicon 2007-2011", TFT Research.

50 SEMI, "China market growth fueled by government spending during industry downturn", available at http://www.semi.org/en/MarketInfo/ctr_027596?id=highlights, accessed on 5th July 2011.

51 From 1995 to 2005, China pegged the yuan at 8.3 yuan to one USD. In 2005, amidst international pressure, China let the yuan appreciate a little before pegging it again in 2008 at 6.8 yuan to one USD (Hester, 2010). International pressure mounted once more and in mid-2010, China announced its decision to make the yuan more flexible. (Wei, M. and Bull, A. (2010), "Peg is dead as China vows yuan flexibility before G20", Reuters, available at http://in.reuters.com/article/idUSTRE65I11B20100619, accessed on 5th July 2011.)

52 Campbell, R.J. (2010), "China and the United States—A Comparison of Green Energy Programs and Policies", Congressional Research Service Report for Congress.

53 In 2009, the state-controlled China Development Bank extended US$ 24 billion in loans to five major Chinese green technology companies, four of which were solar PV manufacturers. (Morales, A., (2010), "Fossil fuel subsidies are twelve times renewables support", Bloomberg, available at http://www.bloomberg.com/news/2010-07-29/fossil-fuel-subsidies-are-12-times-support-for-renewables-study-shows.html, accessed on 5th July 2011.)

54 Gordon, K., Wong, J., McLain, J.T. (2010), "Out of the Running? How Germany, Spain and China are seizing the energy opportunity and why the United States risks getting left behind", Center for American Progress, available at http://www.americanprogress.org/issues/2010/03/pdf/out_of_running.pdf, accessed on 5th July 2011.

55 World Resources Institute – Climate Analysis Indicators Tool, data for 2005.

56 International Energy Agency Statistics, data for 2008.

1994.[57] In 2005, PV devices manufactured in Japan had a world market share of just over 50 percent, and four of the top ten companies were Japanese.[58] Japan was the leading market for solar PV until 2003, as well as the largest manufacturer of PV cells until 2006. As of 2010, Japan has the third largest installed solar PV capacity of 3.6 GW. However, its share of PV cell production has fallen below 10 percent in 2010. [59]

The Japanese government is renewing its push for solar, and approved the 'Action Plan for Achieving a Low-Carbon Society' in 2008. This plan calls for increasing installations of solar power generation systems tenfold by 2020 and fortyfold by 2030, while roughly halving the current price of solar power generation system within three to five years. That same year, the 'Action Plan for Promoting the Introduction of Solar Power Generation' announced measures to support technology development and increase international competitiveness of the Japanese industry, as well as promote installation of solar power generation systems in selected sectors.[60]

The Ministry of Economy, Trade and Industry (METI) announced its FiTs policy in July 2010, which is supposed to take effect in 2012. There has been a general lack of support for the climate change policy of the Democratic Party of Japan and its 25 percent target, disagreement about the large payments made to China which is the world's largest polluter for green credits, and opposition from the industry which is worried that higher electricity prices due to FiTs would put it at a disadvantage against Chinese competition.[61] However, in the wake of the Fukushima nuclear disaster, Japan has pledged to generate 20 percent of its electricity through renewables by 2020.[62]

Japan has traditionally invested in RD&D and the current solar research program under the New Energy Development Organization (NEDO) focuses on cost reduction of solar cells and PV systems, as well as future technology.[63] Japan had the highest share of patent applications in the field of solar energy from 2005-2009.[64]

Taiwan

Taiwan's electricity sector is dominated by thermal power generation and relies almost completely on imports.[65] Recognizing the importance of energy security, climate change mitigation, and its own economic growth, the Taiwanese government announced its Sustainable Energy Policy Principles in 2008 to push the development of renewable energy.[66]

Much as Germany and Japan did, Taiwan followed an export-oriented economic growth model that made it one of the four Asian Tigers. In 2009, the Taiwan National Energy Conference concluded that while geographical limits made Taiwan unsuitable for the large-scale renewable energy industry, Taiwan could become the major provider of solar power and wind power equipment in the world.[67]

In 2006, the Photovoltaic Industry Action Plan became part of the 'Industry Flagship Development Plan' for green industry of the Executive Yuan, the Taiwan Cabinet. In 2007, the Executive Yuan's 'Emerging Industrial Technology

57 PV Status Report (2009), European Commission, Joint Research Center, Institute for Energy

58 PV Status Report (2005), European Commission, Joint Research Center, Institute for Energy

59 Photon International (2010), "Cell production survey 2010".

60 Ministry of Economy, Trade and Industry (2008), "Action Plan for promoting the introduction of solar power generation", available at http://www.meti.go.jp/english/press/data/pdf/081111_ActionPlan.pdf, accessed on 5th July 2011.

61 Sagara, Takashi (2010), "METI discloses a summary of Japanese Feed in Tariff", Climatico, available at http://www.climaticoanalysis.org/post/meti-proposed-a-summary-of-japanese-feed-in-tariff-without-social-support/, accessed on 5th July 2011.

62 Ito, A. (2011), "Kan says renewables to generate 20% of Japan's power next decade", Bloomberg, available at http://www.bloomberg.com/news/2011-05-25/kan-says-renewables-to-generate-20-of-japan-s-power-next-decade.html, accessed on 20th July 2011.

63 PV Status Report (2010), European Commission, Joint Research Center, Institute for Energy.

64 World Intellectual Property Organization (2010), "World Intellectual Property Indicators 2010".

65 International Energy Agency Statistics, data for 2008.

66 Ministry of Economic Affairs, Republic of China (2008), "Framework of Taiwan's Sustainable Energy Policy".

67 Yung-Chi Shen, Grace.T.R Lin, Kuang-Pin Li, Benjamin J.C. Yuan (2010), "An assessment of exploiting renewable energy sources with concerns of policy and technology", Energy Policy, Vol. 38, pp. 4604-4616.

Strategy Review Board' resolved that Taiwan should make use of its semiconductor and flat panel display industrial manufacturing and control technology to develop its crystalline silicon and its thin film photovoltaic manufacturing industries respectively. Taiwan relied on its competitiveness in industry cluster development to support complete industrial chains for production of crystalline silicon and thin film solar cells by setting up industrial parks. The Government also made a deliberate push to develop all aspects of the PV supply chain by organizing conferences and facilitating technology cooperation between domestic and international factories.[68]

In 2009, the Executive Yuan established the Green Energy Industry Sunrise Program, which set a goal of building a complete photovoltaic industry cluster capable of sustaining the world's third largest solar cell production capacity, with an annual production value of 450 billion TWD.[69] By the end of 2010, Taiwan was the second in production of solar PV cells worldwide.[70] As a strategic development objective, the nation is increasing its investment in R&D through the National Development Fund and the Green Energy Industry Rising Program.

On the deployment side, Taiwan's Energy Bureau of the Ministry of Economic Affairs has been strategically promoting the installation of PV systems since 2000 through various plans. The Legislative Yuan passed the Renewable Energy Development Act in June 2009. The Act aims to increase the total renewable energy capacity from 6.5 GW to 10 GW over the next 20 years, out of which 1.2 GW is expected to be solar PV capacity.[71] However, Taiwan's geographic and solar resource limitations mean that the solar PV deployment targets are relatively very small compared to its manufacturing output.

India

India's electricity generation is dominated by coal (70 percent).[72] Although the country ranks low in per capita emissions, it is amongst the top five emitters of overall greenhouse gas emissions. As a developing country, it does not have binding emissions reduction targets, but voluntarily declared a reduction of 20-25 percent in emissions intensity by 2020 compared to 2005, at the Copenhagen talks.

India has been promoting renewable energy through its Ministry of New and Renewable Energy (MNRE) since the 1980s. Under the Electricity Act (2003) and the National Tariff Policy (2006), the Central Electricity Regulatory Commission sets indicative preferential FiTs for different grid-connected renewable energy technologies including solar, while individual state electricity commissions are free to adopt these tariffs or set their own norms.

The big push for solar came in 2010, when the Central Government of India launched the Jawaharlal Nehru National Solar Mission (JNNSM), which set a target of developing 22,000 MW of solar installed capacity by 2022.[73] The mission stated the following deployment objectives – clean energy, energy security, environmental awareness and, most importantly, access to energy, given that a large section of the population is deprived of it. The mission also has domestic value addition objectives of job creation, economic development (by developing the domestic industry), and strategic support for RD&D.[74]

Given the high interest in setting up large-scale grid-connected solar plants (1000 MW target for phase I), the Government selected projects through the reverse auction mechanism. Auction of the first 150 MW of solar PV and

68 Hwa Meei Liou (2009), "Overview of the photovoltaic technology status and perspective in Taiwan", Renewable and Sustainable Energy Reviews, Vol. 14, pp. 1202-1215.

69 Hwa Meei Liou (2009), "Overview of the photovoltaic technology status and perspective in Taiwan", Renewable and Sustainable Energy Reviews, Vol. 14, pp. 1202-1215.

70 Photon International (2010), "Cell production survey 2010".

71 PV Status Report (2009), European Commission, Joint Research Center, Institute for Energy.

72 International Energy Agency Statistics, data for 2008.

73 The overall JNNSM target includes individual targets of 20,000 MW for grid-connected solar (both PV and CSP) and 2000 MW of off-grid solar by 2022. Phase I of the JNNSM has a target of 1000 MW (half PV and half CSP) of large scale grid-connected solar, 100 MW of rooftop solar PV, and 200 MW of off-grid solar by 2013. The mission also sets targets for solar home lighting systems aimed at providing clean lighting solutions to a large section of the population without access to electricity.

74 Ministry of New and Renewable Energy, Government of India (2010), "Jawaharlal Nehru National Solar Mission: Towards Building Solar India", available at http://mnre.gov.in/pdf/mission-document-JNNSM.pdf, accessed on 5th July 2011.

470 MW of CSP yielded tariffs that were on an average 30 percent lower than the Central Electricity Commission's cost-plus-based tariffs.[75]

The first 1000 MW of solar power from large-scale plants will be 'bundled' with 1000 MW of cheap coal power from the government-owned National Thermal Power Corporation, and sold at a bundled rate to the distribution utilities. This cheap coal power is highly valued by state utilities, and its bundled price with solar is also expected to be attractive compared to market prices in power-deficit India. However, this arrangement is limited to phase I of the JNNSM, following which the demand for solar is expected to be driven through solar-specific RPOs. In 2011, the National Tariff Policy was amended to prescribe a solar-specific RPO, starting from 0.25 percent in 2012-13 to 3 percent by 2022.[76] However, given the poor financial health of electric utilities, it remains to be seen whether individual states (where state electricity regulatory commissions are independent and free to set their own RPO targets) will set and enforce solar-specific RPOs that are aligned to national targets. [77]

While the JNNSM is a Central Government initiative, solar is being pushed at the state level as well. Gujarat is planning to procure 1000 MW of solar power (PV and CSP combined) by 2012 at fixed levelized FiTs under its Solar Power Policy - 2009 and has signed Power Purchase Agreements with 968 MW of solar projects.[78] Rajasthan is planning to develop an additional 300 MW of megawatt-scale solar projects by 2013, and another 400 MW by 2017 under its own solar energy policy.[79] The state plans to use competitive bidding for this solar procurement. Maharashtra is also forming its own solar policy to develop 500 MW of megawatt-scale solar over the next three years.[80] A Renewable Energy Certificate (REC) mechanism has also been introduced, where solar and non-solar RECs can be bought as green attributes to fulfill RPOs. With various initiatives at the central and state levels, there seems to be an eagerness to push solar deployment. However, there is a lack of coherency in the efforts. It remains to be seen if the long-term targets are financially sustainable, given that the cost is borne by consumers and taxpayers.

In addition to expanding deployment, India aspires to develop its domestic solar manufacturing industry. The Indian government is providing a 20-25 percent capital subsidy through the Special Incentive Package Scheme of the Department of Information Technology for different parts of the PV manufacturing supply chain.[81] To encourage the development of its domestic PV manufacturing industry and avoid potential imports from lower cost suppliers from other countries, the government of India has imposed some mandates for domestic content for its utility-scale solar power projects under the JNNSM.[82]

Forty percent of India's households (approximately 70 million) have no access to electricity, and have to rely on subsidized kerosene for lighting. Many more households that are connected to the grid do not get reliable electricity, especially in the rural areas, where power cuts are frequent. Solar home lighting systems and solar system micro-grids are being looked upon as an option to provide clean lighting to rural households. [83]

75 Prayas (2011), "India's Solar Mission: Procurement and Auctions", Economic and Political Weekly, Vol XLVI, No 28, pp 22-26.

76 Ministry of Power, Government of India (2011), "Amendment to the Tariff Policy".

77 In 2008-09, state owned utilities in India (that form the bulk of utilities) reported aggregate losses (without accounting for state government subsidies) of ₹53,000 crores (~US$12 billion) (Power Finance Corporation (2010), "Performance of State Power Utilities for the years 2006-07 to 2008-09").

78 Government of Gujarat (2009), "Solar Power Policy – 2009", available at http://www.geda.org.in/pdf/Solar%20Power%20policy%202009.pdf, accessed on 5th July 2011.

79 Rajasthan Solar Energy Policy, 2010. Government of Rajasthan Energy Department (2010), "Rajasthan Solar Energy Policy 2010", available at www.rrecl.com/Rajasthan%20Solar%20Energy%20Policy%20-2010, accessed on 5th July 2011.

80 Pearson, N. (2011), "Indian State's Solar Program Will Avoid Using Reverse Bids, Official Says", Bloomberg, available at http://www.bloomberg.com/news/2011-04-15/indian-state-s-solar-program-will-avoid-using-reverse-bids-official-says.html, accessed on 5th July 2011.

81 Department of Information Technology, Ministry of Communications and Information Technology, Government of India (2007), "Special Incentive Package Scheme to encourage investments for setting up semiconductor fabrication and other micro and nano technology manufacture industries in India", available at http://mnre.gov.in/notification/notification-210307.pdf, accessed on 5th July 2011.

82 Ministry of New and Renewable Energy (2010), "Guidelines for selection of new grid-connected solar power projects", available at http://www.mnre.gov.in/pdf/jnnsm-gridconnected-25072010.pdf, accessed on 5th July 2011.

83 Deshmukh, R., Gambhir, A. and Sant, G. (2010), "Need to realign India's National Solar Mission", Economic and Political Weekly, Vol xlv No 12, pp 41-50.

Observations and Conclusions

In this section, we assess various nation-specific objectives against the policies adopted to achieve them and their key outcomes to determine their relative effectiveness. Subsequently, we assess the effectiveness of these policies on overall solar cost reduction and the factors that affect it.

Effect of Policies on National Objectives

Various metrics can be used to assess the effectiveness of policies to promote solar electricity, including installed capacity, manufacturing capacity in different stages of the supply chain, number of jobs created, number of patents filed, RD&D budgets, and subsidy amounts. Our analysis uses these metrics wherever they are available. Most importantly, we provide a qualitative assessment using various examples to judge the outcomes of these policies. Table 1 summarizes a qualitative assessment of the effectiveness of pull and push policies in achieving nation-specific objectives, mainly in the short-term.

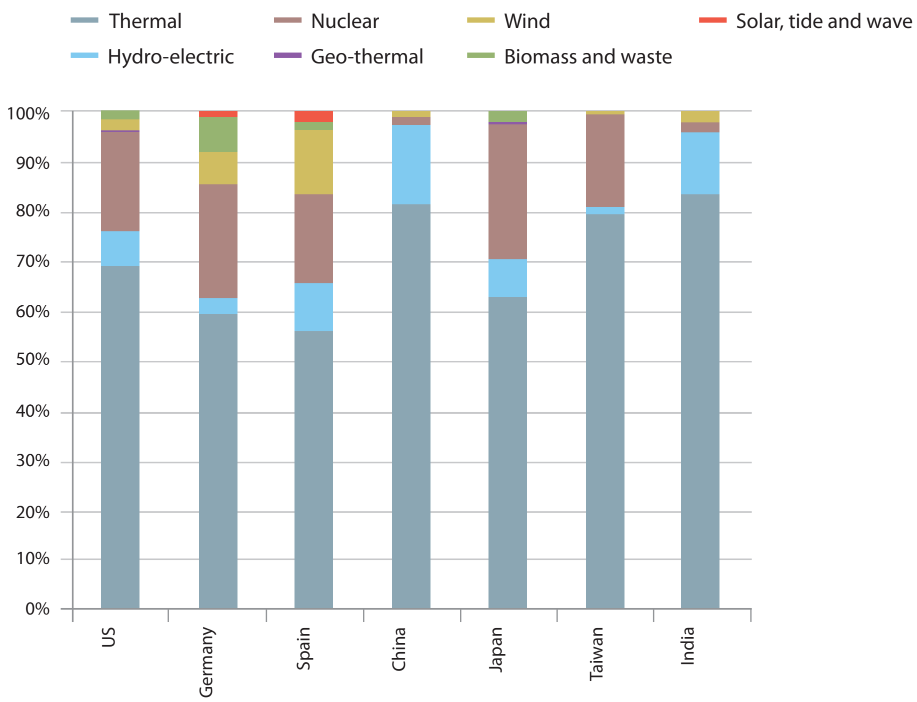
Table 1: Summary of push and pull policies with respect to their effectiveness in achieving national objectives

Objectives	**Pull Policies**	**Push Policies**	
	Deployment support	Manufacturing support	RD&D support
Deployment			
Clean Energy	Direct way of achieving clean deployment. However, costly compared to other clean energy deployment alternatives	Indirectly may lead to clean deployment in the nation providing support	Indirectly supports clean deployment due to increased market adoption because of cost reduction from RD&D breakthroughs.
Energy security	Achieves energy security, but costly compared to other clean deployment alternatives Without domestic industry development, energy security may be compromised	Indirectly may lead to energy security due to domestic industry development	Indirectly supports clean deployment leading to increase in energy security
Environment and Political Support	Deployment support depends on environmental and political support. May lead to solar deployment in sub-optimal locations	Satisfies environmental and political support by providing incentives to 'green' solar industry	Indirect correlation by supporting RD&D of 'green' solar technologies
Access to Electricity	Direct support for decentralized off-grid solar for providing access	Support for off-grid/micro-grid applications manufacturing	Support for off-grid/micro-grid applications development
Domestic Value Addition			
Increase in GDP	May indirectly increase GDP if deployment leads to industry development	Directly increases GDP, especially in export oriented industrialization	Increases GDP through development of intellectual property
Jobs	Creates jobs in installation sector	Creates jobs in the manufacturing sector	Increases high skill jobs
Strategic development	Strategic to the extent of energy security and clean energy deployment	Strategic development of manufacturing industry with spillover effects	Strategic for intellectual property development that creates high end industry and jobs

Deployment Objectives

a. Spain, Japan, and Taiwan, on the one hand, rely significantly on imports for the energy used for electricity generation. On the other hand, China, the US, India, and Germany (the world's top four coal consumers) use mostly domestically produced coal to generate electricity.[84] The eventual dwindling of coal reserves and, more importantly, the growing public opposition to coal and other fossil fuel-based electricity generation due to local and global pollution, has made clean energy a major objective of energy policy in these countries. However, the share of solar energy generation is very small and will continue to be so in the near future, even in Germany with its largest solar PV deployment. Figure 8 shows the contribution of various fuels to electricity generation for various nations and regions. Till solar costs drop, countries may prefer investing significantly more in other lower cost renewables, such as wind, hydro and biomass, to meet their objective of achieving higher clean energy penetration and ensuring energy security. In other words, the contribution of solar power deployment to achieving those national objectives may remain small in the near future.

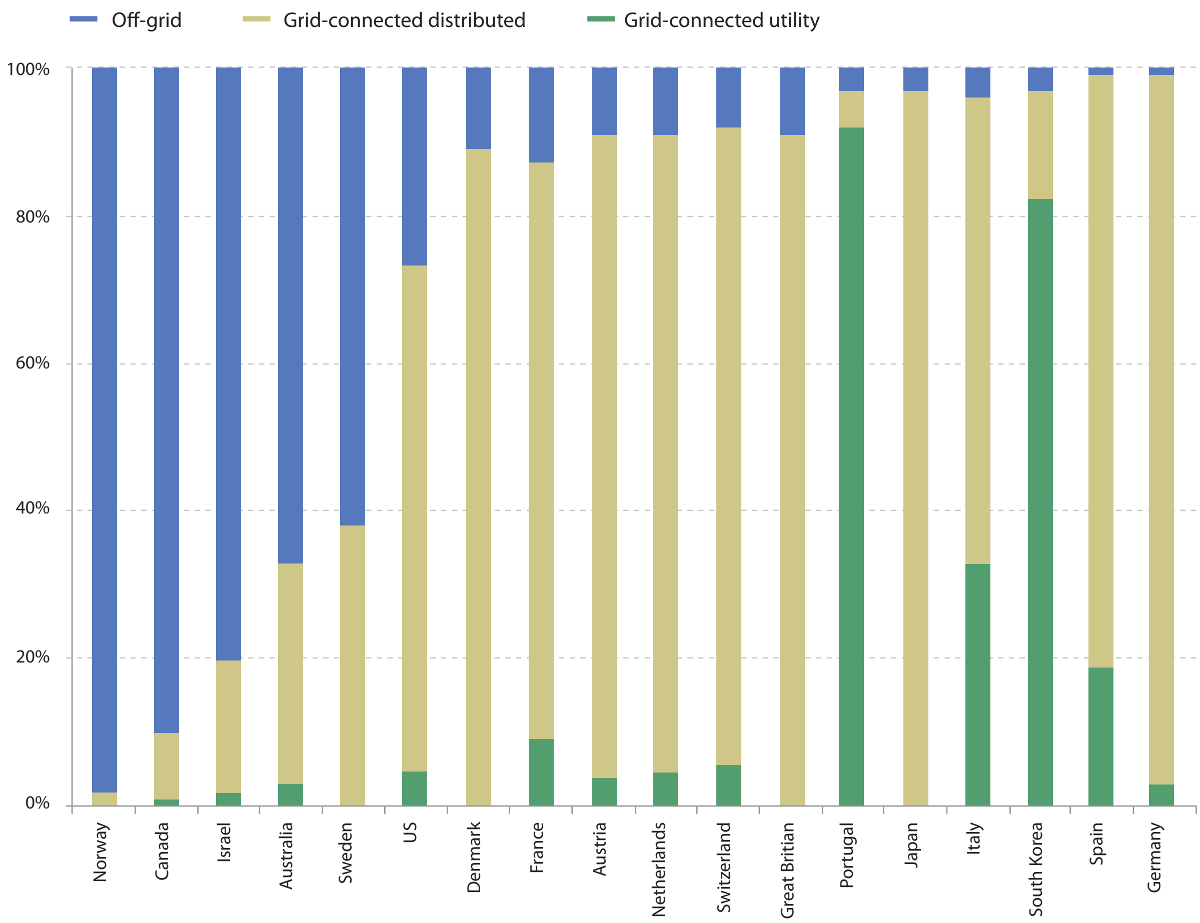
b. Most countries explicitly promote distributed applications, both grid-connected and off-grid, rather than utility-scale plants which are the cheapest option for PV deployment. Figure 9 shows the distribution of solar PV systems in the member countries of the International Energy Agency by type of application. Germany, Spain, the US, Japan and others offer much higher generation tariffs for smaller-sized distributed systems. Until recently, China was concentrating only on off-grid solar PV deployment through its Brightness Rural Electrification Program (started in 1998) and the Township Electrification Program (Song Dian Sao Xiang Program started in 2001) to provide energy to its remote communities. The contribution of solar power to a nation's objectives of achieving increasing public awareness and/or increasing access to electricity and clean lighting for the under-served population is substantial.



Source: *US Energy Information Administration, data for 2009.*

Figure 8: Electricity generation by technology in 2009

84 US Energy Information Administration, Electric Power Annual, data for 2009.



Source: *U.S. Department of Energy (2010), "2008 Solar Technologies Market Report".*

Figure 9: Application market share of cumulative installed PV capacity in IEA countries through 2008

Domestic Value Addition Objectives

a. According to New Energy Finance, in 2008, the solar electric industry was responsible for 173,000 direct and indirect jobs.[85] Of this total, approximately 169,000 were accounted by the PV sector, and about 4,000 by CSP.[86] Table 2 shows the global PV labor intensity in 2008 for operating 14.7 GW of installed capacity and manufacturing 5.7 GW of PV equipment. Another study by the United Nations Environment Programme for the year 2007 estimates 170,000 global PV jobs, with China accounting for the highest (55,000), followed by Germany and Japan (both about 35,000) and Spain (26,000).[87] Pull policies directly create jobs in the installation sector, while push policies directly create jobs in the manufacturing and RD&D sectors.

85 Unit of measure is a job-year or its full-time equivalent, which represents full-time employment for one person for the duration of one year.

86 McCrone, A.; Peyvan, M.; Zindler, E. (2009), "Net Job Creation to 2025: Spectacular in solar, but modest in wind", New Energy Finance; U.S. Department of Energy (2010), "2008 Solar Technologies Market Report".

87 Renner, M., Sweeney, S., Kubit, J. (2008). "Green Jobs: Towards decent work in a sustainable, low-carbon world", Worldwatch Institute, commissioned and funded by United Nations Environment Programme (UNEP).

Table 2: Estimated job-years in the global PV industry in 2008

Job Category	GW	Job-years/MW	Total Jobs
Operation of PV capacity during 2008	14.7	0.6	8,820
Manufacturing/Installation in 2008			
PV project construction and rooftop installation	5.8	11.0	63,800
Silicon and wafers	5.8	3.5	20,300
Cell manufacture	5.8	5.0	29,000
Module manufacture	5.8	6.0	34,800
Inverters	5.8	1.3	7,540
Research	5.8	0.4	2,320
Development and services	5.8	0.4	2,320
Total (manufacturing/installation and operation)		28.2	168,900

Source: *U.S. Department of Energy (2010), "2008 Solar Technologies Market Report".*

b. Broader economic development is likely to result from supporting the solar sector especially using push policies but also pull policies. The US has been a significant net exporter of solar energy products, with total net exports of US$723 million in 2009.[88] In the same year, 74 percent of the value of all US solar installations and 71 percent of all PV projects remained in the US, directly benefiting American industries or subsidiaries and their workers.

c. Pull policies alone may not lead to economic development through industry growth, since they may result in imports of lower cost solar equipment from already developed industries in other countries. Such an outcome may result in loss of political support for those pull policies. To develop their domestic industry, countries may use push policies or opt to mandate domestic content in their pull policies. India and Ontario both have domestic content clauses in their deployment support policies.[89,90] Although such policies may lead to higher deployment costs in the short term due to the infancy of the domestic industry and a lack of exposure to international competition, these may lead to the development of the domestic industry and realize potential cost reductions for the global industry in the future. China introduced domestic content mandates for its wind deployment in 2005, when international companies were dominating its wind market.[91] Within four years, by 2009, out of the world's top ten wind manufacturers, three were Chinese.[92] However, countries with established industries may oppose such moves, as illustrated by Japan's trade dispute with Canada (Province of Ontario) at the World Trade Organization, and the United States' protest against India; the latter despite the United States' own domestic content mandates for solar projects funded under the American Recovery and Reinvestment Act.[93,94]

88 Solar Energy Industries Association and GTM Research (2010), "U.S. solar energy trade assessment 2010: Trade flows and domestic content for solar energy-related goods and services in the United States".

89 Ministry of New and Renewable Energy (2010), "MNRE Guidelines for selection of new grid connected solar power projects", available at http://www.mnre.gov.in/pdf/jnnsm-gridconnected-25072010.pdf

90 Ontario Power Authority (2010), "Micro-feed-in tariff program".

91 Bradsher, K. (2010), "To conquer wind power, China writes the rules", The New York Times, available at http://www.nytimes.com/2010/12/15/business/global/15chinawind.html?_r=1&hp, accessed on 11th May 2011.

92 Global Wind Energy Council (2010), "Global Wind Report – Annual Market Update 2010".

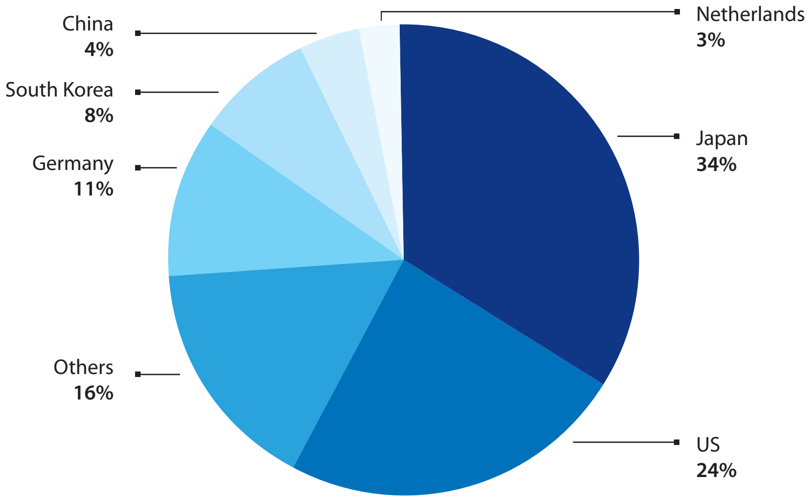
93 Shiao, M.J. (2010), "The Great Solar Trade Wall", GreentechMedia, available at http://www.greentechmedia.com/articles/read/the-great-solar-trade-wall, accessed on 19th May 2011.

94 Sharma, A. (2011), "India Solar Rules burn US", The Wall Street Journal, available at http://online.wsj.com/article/SB1000142405274870350780457613006294951704.html, accessed on 19th May 2011.

d. Several countries have a long history of supporting their industries including solar through push policies by subsidizing their costs of inputs. Germany provides incentives to solar manufacturing industries to set up facilities in former East German provinces. The US provides loan guarantees and other incentives to its industry. China's currency policy of pegging the yuan to the US dollar arguably has an effect on making China's exports more competitive, as does low-interest finance from state-owned banks. However, the present economic slowdown has led to a tussle between nations to secure the financial and employment gains associated with developing the clean energy industry. For example, in September 2010, the 850,000-member United Steelworkers Union, a US labor union, filed a trade case accusing China of violating the World Trade Organization's free trade rules by subsidizing exports of clean energy equipment like solar panels and wind turbines.[95]

e. Push policy support for RD&D creates intellectual property rights in a future growth industry so that domestic firms might steadily rise through the value chain of products. Countries like Japan, the US and Germany have traditionally invested in RD&D, which is reflected in the number of their patent applications in the field of solar energy (Figure 10).

In general, profit margins for most products are higher at the two ends of the supply chain – RD&D and sales/marketing. The middle portion of the supply chain, manufacturing, – typically accrues the lowest profit margins per unit. This phenomenon is described by the 'Smiley Curve' (Figure 11). The Smiley Curve is a U-shaped curve that characterizes the profit margin or value-addition on the y-axis and the stages in the product cycle from creation to final sale on the x-axis. The three product cycle stages on the x-axis are: 1) activities pertaining to brand, design, and RD&D, 2) manufacturing, and 3) marketing and retail sales. Chinese industries have initially focused on manufacturing, while US companies that outsourced manufacturing to China controlled the first and last parts of the curve or its two ends, i.e. brand-design-RD&D and retail sales. Consequently, the US operations enjoyed the highest profit margins, while the Chinese firms had the lowest.[96] Chinese firms have



Source: *World Intellectual Property Organization (2010), "World Intellectual Property Indicators 2010".*

Figure 10: Country share of patent applications in the field of solar energy from 2005-2009

95 Bradsher, K. (2010), "Union accuses China of illegal clean energy subsidies", The New York Times, available at http://www.nytimes.com/2010/09/10/business/energy-environment/10steel.html, accessed on 11th May 2011.

96 Fallows, J. (2007), "China makes, the world takes", The Atlantic Monthly, July/August 2007, available at http://www.theatlantic.com/magazine/archive/2007/07/china-makes-the-world-takes/5987/, accessed on 11th May 2011.

recently taken several steps to move out from the middle of this curve to the two ends. They have acquired famous brands (e.g. IBM's Lenovo), developed design and RD&D (e.g. the shift of Applied Material's research facility to China from the US), and developed their own brands (e.g. three Chinese companies are in the top ten global solar PV cell and module manufacturers list). A recent review of Chinese patent activity indicated that in 2009, about 300,000 applications for utility patents were filed in China, and the goal for 2015 is approximately 2 million. One impetus for Chinese patent activity is active support from the Chinese government, which offers incentives such as cash bonuses and better housing for individual filers, and tax breaks for companies that are prolific patent producers.[97]

Effect of Policies on Solar Cost Reduction

Cost reduction is acknowledged as the broader objective of the solar power policy statements of several jurisdictions. However, policies of individual countries cater to their own specific objectives and are influenced by political-economic factors. Hence, although each of these policies and their implementation mechanisms has reduced solar power costs, they have done so with varying degrees of effectiveness.

In Table 3, the key interactions between the various policies and cost reduction mechanisms are presented. Pull-policies directly influence two cost reduction mechanisms – economies-of-scale and learning-by-doing. Depending on their scope and long-term sustainability, pull policies may also indirectly affect input prices (due to large-scale production), incentivize RD&D (mainly among firms that invest in RD&D to remain competitive), and impact market structure (fragmented small players versus large companies). Manufacturing support directly affects costs of inputs, economies-of-scale, learning-by-doing and market structure, but has limited or no effect on RD&D. Similarly, RD&D support directly affects costs of inputs and RD&D, but has limited or no effect on economies-of-scale, learning-by-doing and market structure.

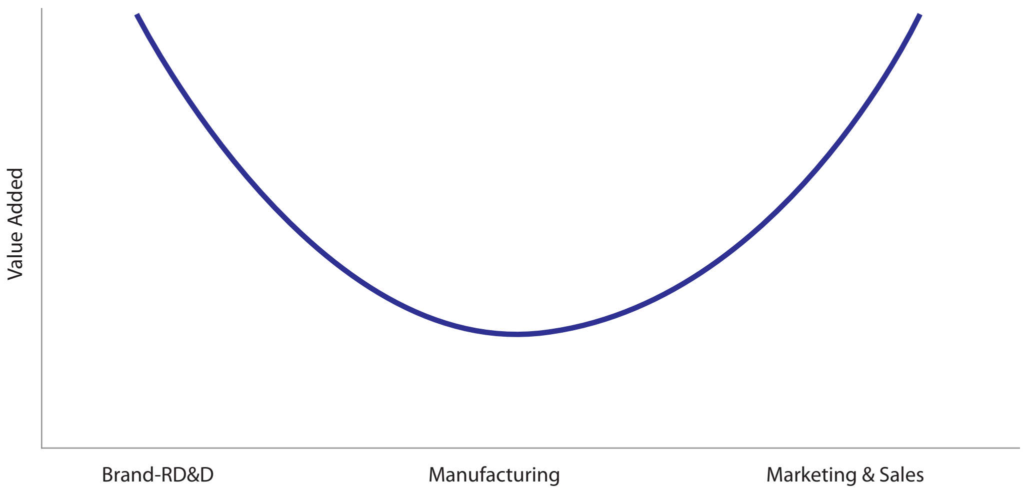


Figure 11: Illustration of the 'Smiley Curve'

97 Lohr, S. (2011), "When innovation, too, is made in China", The New York Times, available at http://www.nytimes.com/2011/01/02/business/02unboxed.html?_r=1, accessed on 11th May 2011.

Table 3: Effect of national push and pull policies on cost reduction mechanisms

Cost Reduction Mechanisms	Pull Policies	Push Policies	
	Deployment support	Manufacturing support	RD&D support
Inputs	Indirect - mainly due to economies-of-scale effect, i.e., large-scale production and location of projects.	Direct	Direct
Economies-of-Scale	Direct - project sizes being promoted	Direct - in manufacturing scales	Does not affect
Learning-by-Doing	Direct	Direct	Does not affect
RD&D	Indirect - incremental RD&D investment by companies	Does not affect	Direct
Market Structure	Indirect	Direct	Does not affect

Figures 12 and 13 present different snap-shots of the trends in the average module price of solar PV. In Figure 13, the cumulative capacity additions are also presented. The key observations from these trends are:

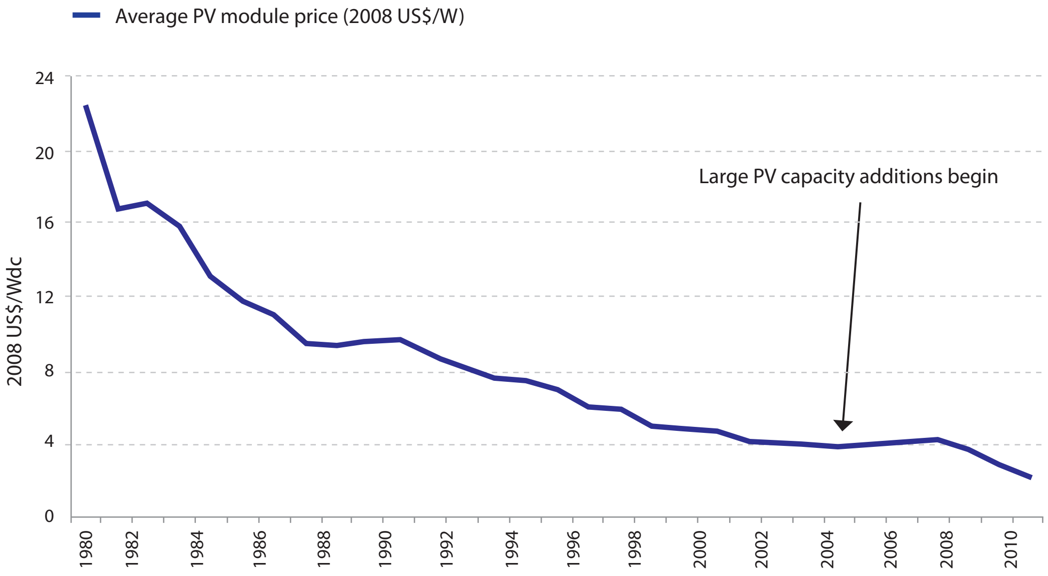
a. Large price reduction from the early 1980s through the early 2000s. Most of the price decrease during this period was mainly a result of sustained RD&D in developed countries such as Germany, Japan and the US.

b. The interest of policy makers to target substantial capacity additions arose only in 2000 after the price had decreased significantly. The growth in cumulative installed capacity began in the early 2000s, with rapid acceleration taking place in the late 2000s.

c. The real price remained relatively stable through the growth period of installed capacity (2000 onwards), and the cost reductions were not as significant as those achieved during the 1980-1999 period. However, starting in 2008, prices have resumed their downward trend.

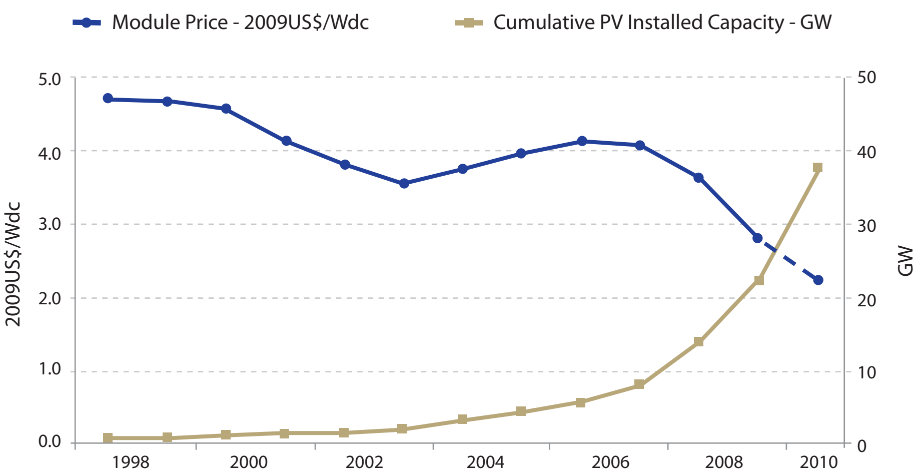
d. As the demand for solar grew rapidly as a result of generous support, the supply side ramped up (especially since 2007) when the main drivers for cost reductions were economies-of-scale (e.g. large factories), reduction in input costs (e.g. shift of manufacturing to low-cost locations), learning-by-doing (e.g. improved processes), and market structure (e.g. high levels of competition).

e. As a result of macroeconomic conditions, various countries have started reconsidering their generous support for solar since 2008. At the same time, supply has ramped up substantially, which has yielded several large manufacturers with large production capacities. The sudden drop in expected demand coupled with new supply coming on line has led to an over-supply situation, which in turn is driving prices down.



Source: *U.S. Department of Energy (2010), "2008 Solar Technologies Market Report".*

Figure 12: Long-term trend in average solar PV module prices



Note: *Data for 2010 is an estimate from various sources.*

Source: *Barbose, G., Darghouth, N. and Wiser, R. (2010), "Tracking the Sun III: The installed costs of photovoltaics in the U.S. from 1998-2009", Lawrence Berkeley National Laboratory; European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015".*

Figure 13: Trend over the last decade in average solar PV module prices and cumulative installed capacity

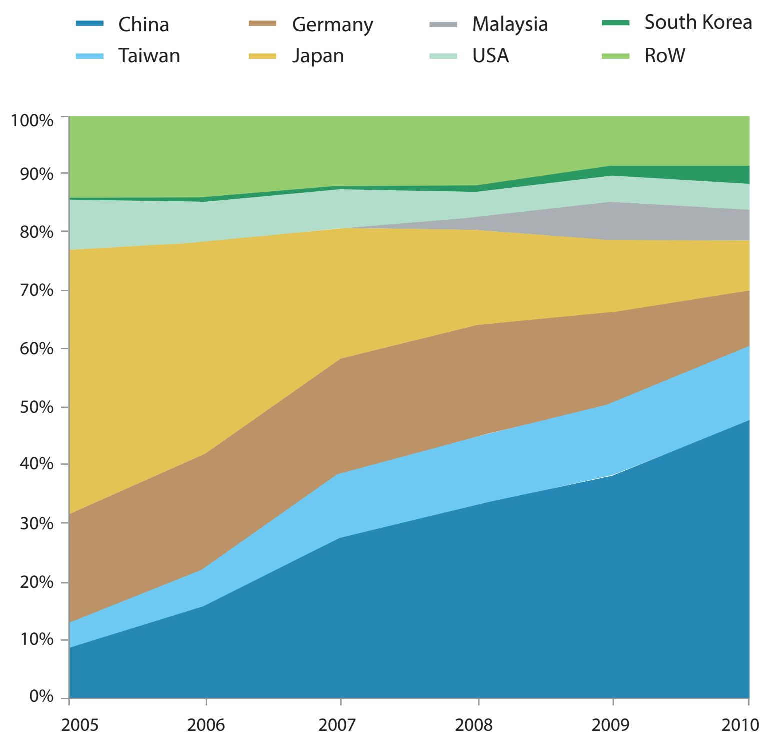
There is no doubt that costs have decreased through reducing costs of inputs, economies-of-scale, learning-by-doing, RD&D and market structure or competition. However, policy makers need to assess the relative contributions of each of these mechanisms to determine how best to achieve further cost reductions. We highlight some of the trends in the underlying cost reduction mechanisms that may have contributed to the overall trends shown in Figures 12 and 13, and the policies that may have contributed towards them.

Inputs

a. Until 2006, Japan and Germany dominated solar PV cells manufacturing. However, push policies adopted by China and Taiwan providing manufacturing support shifted a huge share of PV cell and module production from Japan and Germany to China and Taiwan (Figure 14). This shift in PV cell production was due to the comparative advantage that China and Taiwan enjoy in terms of lower labor, electricity, and land costs, in addition to other incentives.

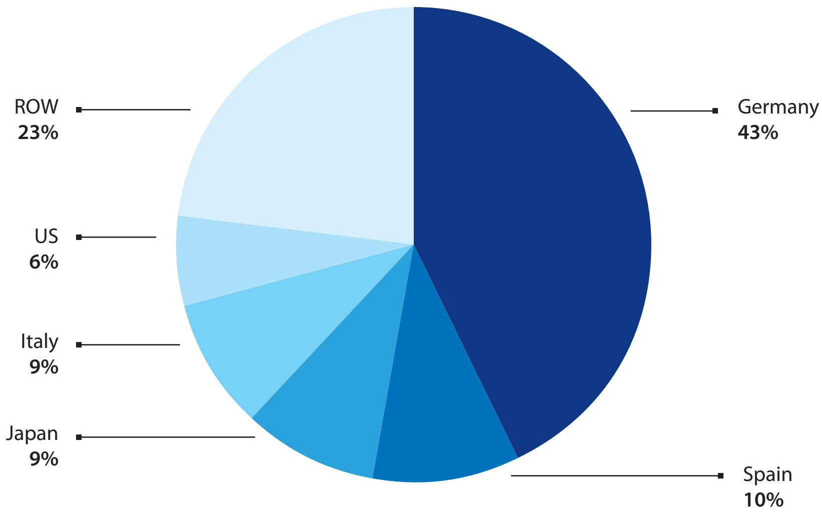
b. Support from governments for the solar industry subsidizes the costs of their inputs. Interest subsidies that reduce the cost of capital, land allotment, subsidized utility services and currency policies, all play a role in reducing the costs of inputs for the industry. Although these subsidies are by themselves not real cost reductions, they may eventually reduce the costs of solar by establishing an industry and encouraging its development.

c. The levelized cost of solar power is directly affected by the quality of the solar resource. By the end of 2010, the PV installed capacity of Germany (17.2 GW) and Japan (3.6 GW) was more than 50 percent of the global capacity. However, because both Germany and Japan have poor solar resources (nearly half as much as Spain or India), the large installed PV capacity in these countries generates only half as much electricity as that in sunny countries, raising its levelized cost of generation.



Source: *Photon International Cell Production Surveys.*

Figure 14: Country share of solar PV cell production from 2005-2010



Source: *European Photovoltaic Industry Association (2011), "Global market outlook for photovoltaics until 2015".*

Figure 15: Country share of cumulative PV installed capacity till 2010

Economies-of-Scale

a. In barely one decade (1999-2010), solar PV capacity grew from a modest total of less than 0.5 GW to approximately 40 GW –approximately a hundred-fold increase. Over the same decade, the average module price at the factory gate (in real dollars) was more or less steady at approximately US$4/watt till 2007. The price saw a decrease since 2008 when more than 75 percent of the cumulative PV capacity till 2010 was installed.[98] Although economies-of-scale in terms of global PV demand during the 2000s had a role in the reduction in cost of solar power, they may not have delivered cost reductions commensurate with the subsidies provided.

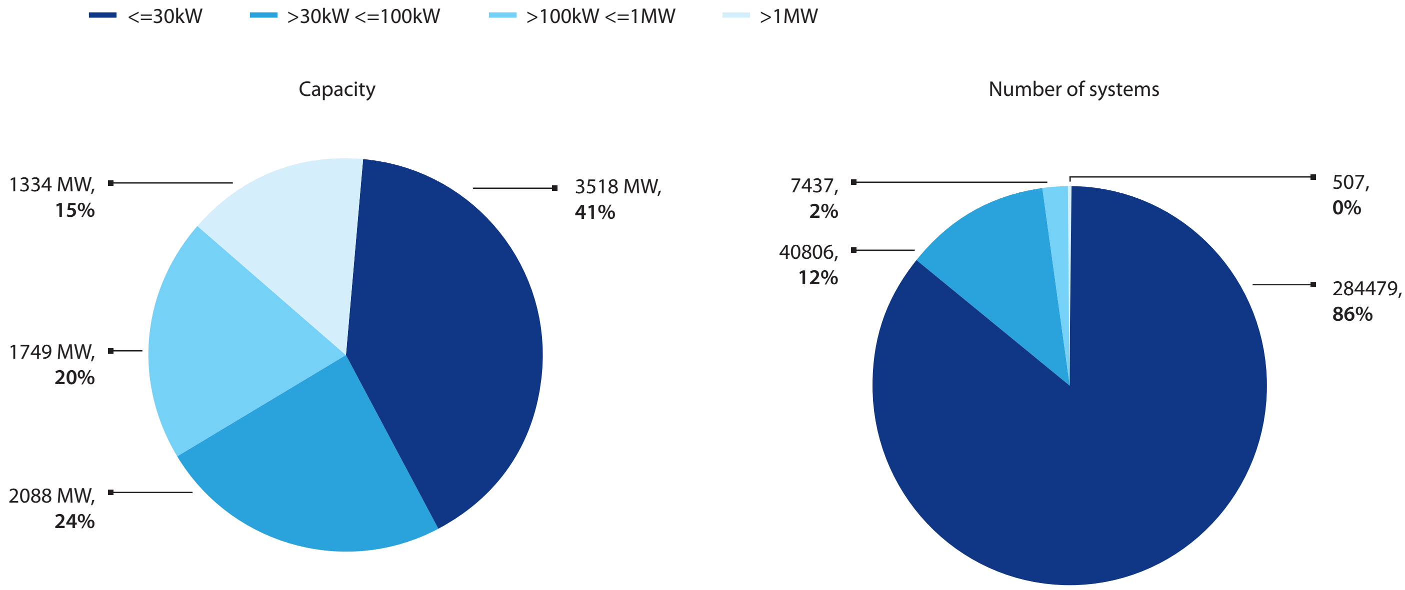
b. Many leading firms have already achieved 1 GW-plus manufacturing capability at the plant level, thanks to increasing automation. Consequently, the future incremental potential to reduce production costs through economies-of-scale in manufacturing remains to be seen.

c. At the project deployment scale, the least-cost option for solar PV deployment is free-field installations, which have the advantage of economies-of-scale. However, most countries encourage smaller scale PV plants by offering higher feed-in tariffs compared to free-field installations, thereby forgoing any cost reductions from economies-of-scale. (For example, more than 99 percent of Germany's PV installations from January 2009 to August 2010, accounting for 85 percent of the 8.7 GW installed capacity during that period, were less than 1 MW in size. [99] See Figure 16.)

98 The authors of this study noted several caveats for the module costs:

- The PV industry is dynamic and rapidly changing, with advances in cost reductions for segments of the industry masked by looking at average prices, e.g. thin-film PV modules are cheaper than crystalline-Si but incur a higher balance of system costs due to lower efficiencies.
- Applications such as large ground-mounted PV systems, for which deployment is increasing, and applications in certain countries and locations, accrue cost advantages based on factors such as economies-of-scale and the benefits of a more mature market.

99 Federal Network Agency, German Federal Ministry of Economics and Technology (2010), German PV installation data (January 2009 to August 2010) available at Bundesnetzagentur.de,



Source: *Federal Network Agency, German Federal Ministry of Economics and Technology (2010).*

Figure 16: Germany's distribution of PV installed capacity (MW) and the number of systems by system size (January 2009 to August 2010)

Learning-by-Doing

a. Average installed cost of 3-5 kW residential PV installations in 2009 (excluding sales/value added tax) was significantly lower in both Germany (US$4.7/W) and Japan (US$5.9/W) than in the US (US$7.7/W).[100] These lower costs can be attributed to the learning-by-doing phenomenon, brought about by greater number of installations in both Germany and Japan.

b. Countries like Taiwan, Germany and China got an edge in the international PV market by developing industry clusters for learning across such industries as semiconductors and flat displays (TFT-LCD).

Research Development & Demonstration

a. Incremental RD&D, especially that pursued by leading industries that are continuously striving to improve their technology and processes in order to remain competitive, have been responsible for a steady decline in solar costs. Economies-of-scale or volumes do provide revenues and profits for industries to invest in RD&D. Some examples are RD&D to reduce the amount of material and energy inputs, as well as improving efficiencies of the solar modules while lowering costs. Various solar PV technologies have steadily improved, with efficiencies of mono-crystalline cells (which account for more than 90 percent of cumulative installed capacity) rising from approximately 14 percent to more than 19 percent (Figure 17).

b. Breakthrough RD&D has a large potential to leapfrog existing technologies and ultimately bring about major reductions in costs of solar power. For example, Cadmium Telluride (CdTe) thin film technology lowered solar costs[101] enough to pose a big challenge to the dominant crystalline-Si technology, and First Solar (the company promoting CdTe) has one of the largest PV market shares.

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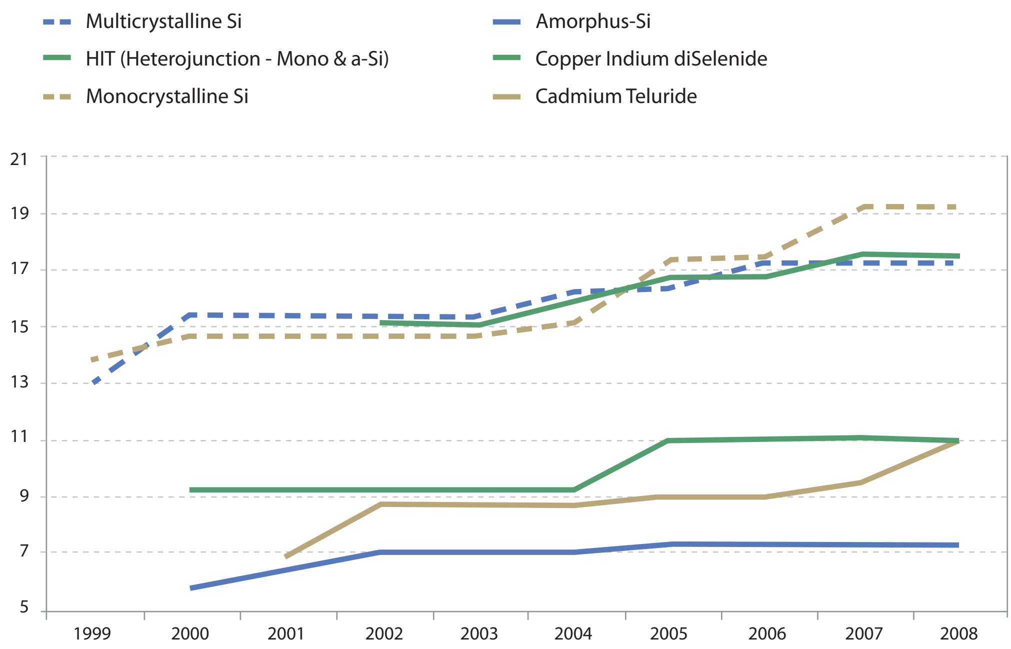
100 Barbose, G., Darghouth, N. and Wiser, R. (2010), "Tracking the Sun III: The installed costs of photovoltaics in the U.S. from 1998-2009", Lawrence Berkeley National Laboratory.

101 Solar costs are on a per watt basis. So although thin film technologies have lower efficiencies, their per watt costs can be lower than crystalline-Si technology.



Source: *U.S. Department of Energy (2010), "2008 Solar Technologies Market Report".*

Figure 17: Trends in solar PV module efficiencies in commercial applications over 1999-2008

Several leapfrog technologies such as Copper Indium Gallium Selenide (CIGS), Concentrated Photovoltaic (CPV) with multi-junction cells, and others are in various phases of development. However, the focus on pull policies may not be directing sufficient funds to sustain the RD&D for these new technologies.

c. Cutting-edge technologies resulting from a government-supported RD&D policy will not be accessible only to that government's domestic industries. Direct and spillover effects of these RD&D efforts will contribute substantially to the overall solar sector in reducing costs.

d. The industry is likely to invest in technologies that can be commercialized in 2-4 years, rather than investing in those that are capital-intensive.[102] Subsequently, the industry may under-invest in the development of next generation solar technologies, both due to the high capital requirement and spillover effects that may not let them take total advantage of their RD&D investments. Hence, it is critical for governments to provide adequate investment in basic research and innovation.

Market Structure

a. The prices of inputs such as polysilicon, silicon, steel, and glass depend on the status of their demand and supply. The shortage of polysilicon in 2005-2008 was followed by massive investments by the industry in new capacities that led to an oversupply in 2009, sending the spot price down from its maximum of US$500 per kg to approximately US$55 per kg.[103]

b. Increased reliance on solar technologies such as thin films has increased the reliance on specific metals mined in only a few geographic locations. China controls approximately 97 percent of the world's 'rare earth'

102 National Renewable Energy Laboratory (NREL) (2010), "$1/W Photovoltaic Systems: White Paper to Explore A Grand Challenge for Electricity from Solar", available at http://www1.eere.energy.gov/solar/sunshot/pdfs/dpw_white_paper.pdf

103 Bernreuter. J and Haugwitz. F. (2010), "The Who's Who of Solar Silicon Production: Companies, Technologies, Costs Capacities, Global Perspectives through 2012", Bernreuter Research, Photovoltaic Special Reports.

market.[104] Because of diplomatic tensions between China and Japan over a security incident in 2010, the Chinese government blocked the exports of some of these 'rare earth' minerals to Japan.[105] Individual countries or regions can thus exploit monopolies based on strategic considerations, in this case by restricting the export of 'rare earth' materials to the global market, thereby distorting the supply-demand equilibrium and artificially raising their costs.

c. In an over-supply market scenario, the ongoing commoditization of solar PV technology components – especially, for the mature and dominant c-Si technology – combined with existence of hundreds of manufacturers, has exerted substantial downward pressure on the profit margins of all the manufacturers. Consequently, in the quest for sheer survival, the industry as a whole is less likely to be able to continue funding leapfrog RD&D, for which gestation times may be long and the return on investments uncertain.

104 Hurst, Cindy. 2010. "China's Rare Earth Elements Industry: What Can the West Learn?", Institute for the Analysis of Global Security (IAGS).

105 Bradsher, K. (2010), "Amid Tension, China blocks vital exports to Japan", The New York Times, available at http://www.nytimes.com/2010/09/23/business/global/23rare.html, accessed on 11th May, 2011.

Recommendations

Optimal mix of policies and allocated resources

Given the stagnation or progressive reduction expected in taxpayer and ratepayer funds available for solar energy, optimal use of these funds has become even more critical. Understanding which policies are more effective in achieving the long term objective of making solar power competitive with other renewable energy options and subsequently conventional generation, leading to its widespread adoption, is required for allocating scarce ratepayer and taxpayer resources.

Despite ongoing cost reductions, solar power is still substantially more expensive (more than 200 percent) than conventional alternatives. Further, it is unclear that the current emphasis on demand pull policies for rapid scale-up of deployment of solar is sustainable or will lead to required cost reduction so that solar power is close to being competitive with conventional generation. Although it has been argued that capacity addition leads to cost declines due to economies-of-scale and learning-by-doing, it is unclear whether these cost reductions were commensurate with the extent of deployment support provided over the last decade.

At the manufacturing plant level, the leading firms have already achieved more than 1 GW manufacturing capability with increasing levels of automation. Consequently, the potential for further reductions in costs through economies-of-scale and learning-by-doing may be low. Further, for technologies such as CSP that consist of mature commodities such as mirrors, power blocks, and others, it is not clear whether marginal increase in economies-of-scale would achieve further significant cost reductions. Since 2008, various media reports have indicated that the global production capacity continues to ramp up rapidly and appears to be yielding further reductions in module prices. However, the source of these price reductions has not yet been systematically assessed.

It is imperative that policy makers systematically assess the future potential for cost reductions of both mature and new technologies caused by economies-of-scale. If the further potential cost reduction from economies-of-scale for mature technologies is low, policy makers should incentivize both new RD&D and economies-of-scale for new technologies. On the one hand, the subsidies from pull policies would need to be diverted directly to RD&D and supporting innovation (e.g. government RD&D support for basic and applied research, incubating 'start-ups' etc). On the other hand, if the future potential for cost reduction from economies-of-scale for mature technologies is indeed high, the pull policies would need to be appropriately designed for long-term sustainability.

It has been recognized that some major breakthroughs are needed for solar power to become more competitive.[106] Resources spent on deployment of solar are comparatively an order of magnitude higher than those spent on RD&D focused on achieving major breakthroughs for cost reduction. For example, approximate estimates of the total of ratepayer and taxpayer subsidy typically needed per GW of solar power installed are in the range of US$200 million to US$300 million per year, where as the Net Present Value (NPV) of the subsidy is US$2.2 billion over the project life. Given that approximately 17 GW of PV capacity was installed in 2010, the additional subsidy committed in that year was approximately US$4.5 billion per year, with the NPV of the subsidy committed being US$37 billion.[107] As

106 https://www.fedconnect.net/FedConnect/?doc=DE-FOA-0000484&agency=DOE

107 Assuming capital cost, cost of capital, life, and capacity factor to be US$3500/kW, 10%, 20 years, and 20% respectively for solar power leads to an unsubsidized cost of 23 US cents/kWh. Cost of conventional power assumed at 5 US cents/kWh and 10 US cents/kWh as low and high scenarios respectively.

installation of solar power is expected to increase rapidly in the future, the total subsidy requirement will also grow significantly, in spite of falling solar costs. In this context, the global budget for solar RD&D (PV, CSP and solar heating) as reported by the International Energy Agency (2010), is US$680 million/year, which is a fraction of the subsidy committed for deployment and is estimated to be as less as about one-third of the total required RD&D budget.[108]

National efforts and international collaboration on solar energy RD&D need to be expanded based on a systematic assessment of RD&D gaps and funding needs. Expanded international collaboration on RD&D offers additional benefits, including cost savings, accelerated learning, harmonization of standards and approaches, and elimination of duplication.

Strategic deployment of solar

Ideally, solar should be deployed in 'sunny' areas with a high solar resource to maximize input energy and generate electricity at the lowest cost. However, a majority of the solar deployment has been in Germany and Japan, countries with only a moderate solar resource. There are many other examples where solar PV projects (mostly rooftop installations) are being promoted and installed at suboptimal locations such as in some parts of the US and UK. Also, most countries encourage smaller scale PV plants by offering higher feed-in tariffs compared to lower cost free-field installations that have the benefit of economies-of-scale. Smaller installations, especially rooftop PV, are more expensive due to higher labor, transaction and implementation costs. Rooftop PV systems are argued to have the potential to reduce transmission and distribution losses due to on-site electricity generation, and reduce the need for long transmission lines from central power stations. However, transmission and distribution losses may be more than compensated by siting the solar installation in high solar resource areas. Some studies also question the actual reduction in costs of transmission and distribution infrastructure.[109]

The main reason to adopt these pull policies to promote smaller PV installations in sub-optimal locations and sizes is environmental and political support. It is this support that was behind the policies adopted in Germany, Japan and California.

With rapidly decreasing or changing costs of solar PV, it has been extremely difficult to set feed-in tariffs. Countries like Spain that ended up offering fairly high feed-in tariffs and encouraged free-field installations saw the overheating of its market. Many megawatt-scale free-field systems were installed, and Spain exceeded its cap by more than 100 percent. Reactionary policy measures saw Spain cut its tariffs and ban free-field installations.

Although rooftop PV and other grid-connected solar installations do have their benefits as pointed above, it is important to assess their true benefits to the solar sector. Given the scarcity of resources available for subsidizing solar power, it is important to systematically assess and transparently lay out costs and benefits of choosing certain locations for deployment so that informed public policy choices can be made on the same. Further opportunities for gaining public and political support for deployment at optimal locations needs to be assessed. There are examples of other clean energy options where more optimal locations have been selected considering resource quality. At the same time, solar PV continues to be an attractive proposition for decentralized off-grid installations where the central electricity grid is non-existent or unreliable. For developing countries like India with large populations without access to electricity, decentralized PV systems present a viable option for providing access to clean lighting and electricity.

On the other hand, CSP technology offers the advantage of thermal storage and subsequently, the potential of dispatchable power. The CSP industry, with just over 1 GW of installations, is relatively nascent compared to PV and may have a large potential for cost reduction, especially in high solar resource countries.

108 International Energy Agency (2010), "Global Gaps in Clean Energy RD&D", IEA report for the Clean Energy Ministerial.

109 An analysis of the actual installation of PV systems in California suggests that it has not significantly reduced the cost of transmission and distribution infrastructure (Borenstein, S. (2008), "The Market Value and Cost of Solar Photovoltaic Electricity Production", Centre for Study of Energy Markets, Working Paper 176).

Hence, in general, solar deployment needs to be strategic. While solar CSP is primarily a utility-scale technology and will always be deployed in areas with the most optimum solar resource, solar PV has the option to be deployed in rooftop and smaller installations as well as decentralized off-grid applications. While the latter has a distinct advantage of providing access to energy, the former is more advantageous from the perspective of environmental and political support. Other opportunities also need to be explored to maximize solar electricity generation, thus reducing costs without losing public support.

Domestic value addition, purchase support and trade issues

The examples of China and Taiwan illustrate that a combination of push policies and limited pull policies are more than sufficient to develop a thriving solar PV manufacturing industry. In other words, domestic value addition does not require purchase support. Over just five years, the market share of Chinese manufacturers has increased from approximately 0 percent to 50 percent of the global demand for PV cells. More than 95 percent of the Chinese solar PV cell production is exported. Although China recently did introduce programs for PV deployment, the domestic demand for PV is still very limited compared to the production. In sharp contrast, the Chinese domestic wind sector has both a growing manufacturing and a deployment industry, mainly because wind is at present a more cost-effective renewable alternative than solar. Taiwan explicitly acknowledged in its policy design that its domestic market for solar is too small relative to its capacity for supplying solar PV technology to the global market.

Both China and Taiwan have adopted an export-oriented economic growth paradigm similar to that of Germany and Japan. However, Germany and Japan were early starters in the solar industry, and have a deployment market in addition to their push policies for manufacturing and RD&D. In fact, Germany accounted for more than 40 percent of the annual PV capacity in 2010. So although China's extensive incentives for land, electricity, and low cost financing combined with its currency policy (that ensures the competitiveness of Chinese exports) makes it an attractive destination for global manufacturing industries, trade disputes such as the one illustrated by the United Steelworkers Union trade case against China, are expected to occur, especially in the present economic slowdown. Hence, for long-term sustainability of the solar sector, it is important for countries to balance pull policies (considering historical climate change responsibility and paying capacity of consumers) along with push policies, so that the burden of providing a market for solar is not borne by just a handful of nations.

Comparative advantage of countries versus national objectives

For optimal allocation of resources (e.g. land best suited for solar power, low-cost labor, RD&D capacity, etc.) in today's globalized trade regime, businesses make full use of the 'comparative advantages' that different regions demonstrate relative to one another. For example, on the one hand, because of a large pool of highly trained labor, access to state-of-the-art RD&D facilities, and a culture that supports innovation, improvement and development of new advanced solar technologies is mainly seen in developed countries (e.g. "Silicon valley" in the US, Germany, Japan, etc.). On the other hand, availability of a vast and cheap labor pool coupled with aggressive policies that support the manufacturing industry (e.g. access to cheap land, energy, water, etc.) has allowed some of the rapidly developing countries such as China to dominate the production of solar technologies at commercial scales.

Due to the latter, countries such as India that have started providing pull policies for deployment support without fully developing a large internationally competitive solar manufacturing industry are implementing domestic content mandates to prevent domestic subsidies from flowing towards imports. Although from a national perspective, the domestic content mandate seems justified, it prevents countries from utilizing each other's comparative advantages, and from realizing cost reductions because their domestic industries are shielded from international competition. A transparent assessment of these comparative advantages along with unfair incentives from countries for encouraging exports needs to be undertaken for informed policy choices across countries that would benefit the entire solar industry.

Although solar costs are dropping rapidly, solar power is still more expensive than conventional and other renewable energy options, and the solar sector still needs continuing government policy support. However, government policies are driven by objectives that go beyond the goal of achieving grid parity. These include increase in renewable energy generation to mitigate climate change, or boost energy security; develop domestic industry to create jobs and exports; develop technology and intellectual property rights via RD&D; and improve access to electricity where the electric grid is unreliable or absent. The need to achieve multiple objectives and ensure sufficient political support for solar power makes it difficult for policy makers to design an optimal solar power policy. The dynamic and uncertain nature of the solar industry, combined with the constraints offered by broader economic, political and social conditions further complicates the task of policy making.

This report presents an analysis of solar promotion policies in seven countries - Germany, Spain, the United States, Japan, China, Taiwan, and India – in terms of their outlook, objectives, policy mechanisms and outcomes. The report presents key insights, primarily in qualitative terms, and recommendations for policy makers to optimally design their solar policies by balancing national objectives and paying capacity with the global objective of solar power cost reduction in order to realize its full potential.

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