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Working Paper

DELIVERING ON THE CLEAN ENERGY ECONOMY: THE ROLE OF POLICY IN DEVELOPING SUCCESSFUL DOMESTIC SOLAR AND WIND INDUSTRIES

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EXECUTIVE SUMMARY

The renewable energy industry is expanding to meet the needs of a large and growing global market for clean and secure energy. This growth is likely to continue, with electricity production from non-hydro renewable energy sources expected to grow more than eight-fold from 2009 to 2035, if countries implement their existing commitments, and draw nearly US$3 trillion in investment.[1] In this globalized industry, no single country has a monopoly on the supply chain or the opportunities to benefit from this expansion.

Competition is fierce and the industry is changing rapidly. Energy—and electricity in particular—is a highly policy dependent market, strongly shaped by regulation, incentives, and public goals. There are a number of different factors that drive policymakers to consider the development of domestic renewable energy industries including energy security, environmental considerations, providing more universal access to energy, and as an economic development opportunity.[2] Now, many policymakers are weighing how to take advantage of improvements in the renewable energy global supply chains that include lower costs, higher quality equipment, and improved performance to deliver domestic energy more cheaply, while still nurturing and protecting domestic industries that create highly visible "green jobs."

These two goals—creating robust and growing domestic industries and delivering affordable domestic energy—are both central to business-as-usual economic development. Doing both in the context of reducing greenhouse gas (GHG) emissions and other environmental impacts

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Suggested Citation: Barua, Priya, Letha Tawney, and Lutz Weischer. 2012. "Delivering on the Green Economy: The role of policy in developing successful domestic solar and wind industries." Washington, DC: World Resources Institute. http://www.wri.org/publication/delivering-on-the-clean-energy-economy.

delivers on the promise of green growth in the energy sector.[3] In nearly every country, it is politically very difficult to pursue one of these goals to the exclusion of the other. There is little political patience with using public resources to support a highly import-dependent clean energy deployment strategy, while raising energy costs, including to support domestic manufacturing or subsidize technologies, is equally politically challenging.

The renewable energy industry seems to offer opportunities to meet energy and economic development goals, but is there evidence that this promise has come to fruition? If there is, how did policymakers help deliver those results for their countries? This paper focuses on solar PV and wind industries in China, Germany, India, Japan, and the United States (U.S.) and provides a historical cross-country analysis, drawing from individual country cases, which aims to:

- Determine which policies have been introduced to support the broader value chain—research and development (R&D), manufacturing, installation, and power generation—of the solar PV and wind industries in each country;

- Track the trends in industry development in terms of size, installed capacity, jobs created (where available), and equipment prices (where available); and

- Analyze how countries are finding success in both creating a healthy domestic industry and delivering low-cost, domestic clean energy.

This working paper emerges from a collaboration of five leading research institutions: World Resources Institute (WRI), Institute for Global Environmental Strategies (IGES), Öko Institut, Renmin University of China, and The Energy and Resources Institute (TERI), based in the target countries. Researchers at each institution reviewed and gathered information from domestic and international data sources to create a richly nuanced but still comparable review of the development of these industries.

The assessment attempts to uncover in particular how policymakers have cultivated successes. Countries have pursued a range of policies to accomplish these goals and there is now sufficient history in the solar PV and wind industries to begin to draw conclusions about whether countries have met their goals and what policy steps have been effective along the way.

Findings

- The technical differences between solar PV and on-shore wind technologies, particularly their international tradability, mean that very different policy approaches are necessary to build domestic industries based on them.

- Both industries can be divided into upstream activities related to R&D and manufacturing the equipment itself and downstream activities related to deployment of the equipment and generation of electricity. While politics focus tends to fall on the very visible upstream activities, particularly large and expensive manufacturing facilities, the downstream portions of the industries make up a very significant number of potential jobs and economic activity.

Comparing policy strategies for the solar PV industries in the five countries and the resulting performance of those industries shows:

- **A large domestic manufacturing industry and significant domestic deployment do not necessarily go hand-in-hand.** Japan and China have built solar manufacturing industries that far outstripped their domestic deployment by pursuing an export driven strategy. Even in Germany, where production does not outstrip domestic deployment and imports are important to the industry, a significant amount of its solar module production is exported and thus takes advantage of deployment policies in other markets rather than the German market.

- **Annual deployment rates for solar PV correlate to average system prices.** Germany and China have the lowest installed system prices,[4] significantly lower than Japan and the United States. Meanwhile, they sustain annual deployment rates three to seven times higher than Japan or the United States have achieved. Even while they reduce subsidies to align with rapidly falling solar panel prices, Germany and China's domestic deployment of new solar PV systems continues to far outpace Japan and the United States. Stable and well-designed deployment policy has had a strong role in driving system prices down in these economies, both by enabling the industries to achieve economies of scale and by reducing transaction and finance costs. In addition to creating a positive feedback loop, where falling system prices drive further growth in the industries, these countries' large annual deployments cost public budgets (electricity consumers in general through fees or taxpayers through direct budget support) less per kilowatt hour (kWh). Lower system prices mean fewer subsidies over and above the average cost of electricity are necessary to support deployment.

- **A successful domestic manufacturing industry is driven through cost or niche competiveness strategies, rather than domestic deployment.** China has successfully captured a significant portion of the module market globally through low prices. However, Japan and Germany have maintained market share, despite much higher module prices, by competing on performance and quality.

Comparing policy strategies for the on-shore wind industries in the five countries and the resulting performance in those industries shows:

- **Domestic deployment is key to building both upstream (manufacturing) and downstream domestic industries.** Unlike solar PV, large wind components have high logistical costs and spare parts need to be nearby to limit outages, so manufacturing hubs tend to develop in areas with large hardware deployment.

- **Annual deployment rates, and the size of the upstream and downstream domestic industries they support, correlate to maintaining policy stability for at least three to four years.**[5] Since 2005 in India, 2007 in China, and 2008 in the U.S., each country has significantly increased their domestic manufacturing capacity and the local content of their wind turbines. By 2011, they all had around 70 percent or better local content in their wind industry. In each case, support policies with at least a three-year horizon, often with an accompanying government commitment to the wind industry and ambitious targets for deployment, were established prior to the manufacturing scale-up.

- **Most export opportunities emerge from a strong domestic manufacturing industry, supported by domestic deployment.** Among the five countries analyzed, only the United States has maintained a long-term trade deficit in wind equipment. All others have become net exporters as their domestic wind industry has developed. While the leading manufacturers do export to countries worldwide, much of the trade is among countries in the same region rather than global, following the pattern of regional hubs in the wind supply chain. Some wind services—turbine design, wind assessment, project development, and financing—are increasingly traded internationally.[6] An emerging trend is the combination of services and equipment trade: manufacturers, in particular from China and India, offer turnkey solutions where they develop projects, secure project financing, and supply the equipment.

The five study countries have had varying success creating domestic solar PV and wind industries, and that variation provides some guidance on which policy strategies have had an impact and why. The story is not finished in solar PV and wind and is only just beginning for other clean energy technologies. These findings should inspire policymakers to continue to drive after the green economy and the economic development opportunities it offers.

INTRODUCTION

Renewable Energy Industries Offer Economic Development Opportunities

Renewable energy industries are expanding to meet the needs of a large and growing global market for clean, secure energy.[7] Approximately half of the estimated 208 gigawatts (GW) of new electric capacity added globally in 2011 came from renewable energy sources.[8] In addition, total investment in new non-hydro renewable energy generating capacity continued a near decade-long trend of growth and surpassed investments made in fossil-fuel generating capacity in 2010.[9] Clean energy investments across the supply chain, including research and development reached a record $257 billion in 2011, a near doubling of the investments made in 2007, the year before the global financial crisis.[10]

This tremendous growth is expected to continue. The International Energy Agency (IEA) projects in their New Policies Scenario, where countries implement their existing low-carbon pledges, that non-hydro renewable energy electricity production will grow from 3 percent of total generation in 2011 to over 15 percent by 2035, totaling 5,582 terawatt hours (TWh) a year.[11] To reach this, solar, wind, and other renewables (excluding hydro) will attract approximately $2.9 trillion in investment between 2011 and 2035.[12] A study by Pew Charitable Trusts projects the renewable energy investment opportunity in G-20 countries alone to range from $1.75 to $2.3 trillion between 2010 and 2020, depending on the stringency of clean energy policies implemented.[13] Continued investments and growth in the renewable energy sector are projected for a number of reasons: high growth in energy demand from developing economies, rapidly falling costs of renewable energy technologies, emerging concerns about energy security and the volatility of fossil fuel prices, and an increase in international and domestic commitments to low-carbon development as collected in the pledges under the 2010 United Nations Framework Convention on Climate Change (UNFCCC) Cancun Agreements.

In today's integrated global economy, it is very difficult for a single country or company to develop a monopoly on renewable energy production. However, participating in the global renewable energy value chain presents countries with the opportunity develop new industries, both to supply their own energy needs and to export to emerging markets globally.

Challenges for Policymakers

Competition in the fast-moving renewable energy sector is fierce, driven by improvements in technology and performance, plummeting prices, and domestic policy incentives that support local growth in manufacturing and deployment over imports. This is exemplified in the solar photovoltaic (PV) industry, which has witnessed remarkable price declines at each point along the supply chain, resulting in unprecedented growth in installations globally but also significant margin collapse for suppliers and oversupply conditions across the industry.[14]

Energy—and electricity in particular—is a highly policy-dependent market, strongly shaped by regulation, incentives, and public goals like energy security and reducing greenhouse gas emissions and other pollution.[15] In this competitive environment, policymakers face a challenging trade-off in designing national trade and investment policies for the clean energy sectors. Increased global integration of the supply chain would help to accelerate the large-scale deployment of renewable energy technologies globally by increasing efficiencies and driving down overall costs.[16] These improvements in turn provide broad economic benefits through lower energy costs and increased jobs in downstream renewable energy activities such as installations, system design, and financing. However, policymakers also want to nurture and protect the development of domestic clean energy manufacturing industries to maximize the highly visible "green jobs" seen on manufacturing floors, and to ensure political support for more ambitious climate policies.[17] Some approaches to building this domestic industry can inadvertently keep costs for renewable energy higher than they might otherwise be.[18]

In the context of fueling economic growth in a business-as-usual approach, policymakers are focused on both of these goals—creating new and growing industries and delivering affordable energy. Managing to deliver on these goals, while reducing GHG emissions and other environmental impacts, is the definition of green growth in the energy sector.[19] The politics of spending public budgets, raised either from taxpayers or from surcharges on energy consumers, makes pursuing one of these goals to the exclusion of the other difficult in most economies. Spending public budgets on expanding renewable energy deployment through equipment imports, even when it keeps the cost of the energy low, is sensitive. This is evidenced in the rising tide of trade disputes in renewable energy equipment and local content requirements, from both developed and developing countries, for access to renewable energy incentives.[20] However, raising energy costs or taxpayer burdens for any reason, including supporting nascent domestic renewable energy industries, is also sensitive. Disputes over the burden on households, particularly poor households, or on energy intensive industries, of renewable energy surcharges have erupted from Germany to the Philippines.[21]

Can policymakers ensure that competitive industry players locate in their countries, delivering both domestic manufacturing jobs and low cost energy? How do they most effectively take advantage of the global supply chain to keep costs low? Is there evidence of policy strategies that have enabled countries to achieve the economic benefits of having a growing domestic renewable energy industry while also being able to deliver relatively lower-cost energy to domestic consumers?

OBJECTIVES AND METHODOLOGY

Assessment Objectives

This assessment aims to shed light on whether policymakers are successfully meeting these two goals—delivering affordable domestic energy and a growing domestic industry. If they are, what policy strategy did they use to nurture that success? This is evaluated through a unique cross-country, historical analysis of the solar PV and onshore wind industries in Germany, the U.S., Japan, China, and India over the past 10–12 years. Building on country case studies, the cross-country assessment aims to:

- Determine which policies have been introduced to support the broader value chain—research and development (R&D), manufacturing, installation, and power generation—of the solar PV and wind industries in each country;

- Track the trends in industry development in terms of size, installed capacity, jobs created (where available), and equipment prices (where available); and

- Analyze how countries are finding success in both creating a healthy domestic industry and delivering low-cost, domestic clean energy.

Solar PV and on-shore wind have been chosen for this analysis because these are currently the most mature, global renewable energy technologies, and have experienced a large increase in both manufacturing and deployment over the last decade. In 2011 alone, solar PV and wind accounted for about 70 percent of newly installed renewable capacity globally.[22] In addition, both have the strongest projected future growth in generation among renewable energy technologies (excluding hydropower), according to the International Energy Agency (IEA).[23] The differing nature of the two technologies also reveals important insights about how policy strategies need to account for technology specific characteristics.

The five countries are all major participants in the global value chain for both solar and wind technologies, and have developed policies and incentive measures to support domestic installed capacity. They also feature amongst the top ten countries in terms of hosting renewable energy investments from the private sector.[24] And they are also among the six largest GHG emitters from the energy sector.[25]

This analysis does not attempt to predict future success of a specific country's clean energy policies, but rather takes an historical look at the key policy strategies that each country has implemented to support the value chain for the renewable energy technology, in conjunction with indicators of success, including domestic industry size and growth in installations. The assessment's distinguishing feature is its attempt to uncover whether countries are making progress towards the two goals—affordable domestic energy and a growing domestic industry, and how policymakers have cultivated that success. This work complements existing reports that track global industry trends in manufacturing capacity, installations, investment, and policy development. Since clean energy technologies, particularly solar PV, are globally traded commodities, policies introduced in another country can impact domestic development of manufacturing capacity to varying degrees, but the complex influence of such external policies are beyond the scope of this assessment.

Methodology and Approach

In order to achieve the aims of this working paper, country cases were developed for each of the five focus countries. The country cases provide summaries of both the trends in the development of the solar PV and on-shore wind industries in those countries and the evolution of the national-level renewable energy policy and other support for those industries. As they serve essentially as a data set, these five country cases are found in Annex I. Drawing from those five cases, a cross-country analysis was done for each technology (solar PV and on-shore wind) to understand where policymakers were successfully meeting the economic development goals described above and what lessons might be drawn from those successes. Those findings are presented in the following section.

The on-shore wind and solar PV industries are rapidly evolving, with tremendous changes in just the last four years. This tremendous rate of change means that this analysis cannot predict the policies that will ensure successful domestic industries going forward. However, it can look to the evolution so far and highlight where and how policymakers have successfully met their goals—developing domestic industries and delivering affordable renewable energy—in order to help inform future policy choices.

Prices for solar PV panels, and the components that make up the panels, have plummeted about 75 percent from the end of 2008 to the end of 2011.[26] Globally, by mid-2012, there were 59 GW of panel manufacturing capacity to serve a global market estimated at only 30 GW.[27] These changes are precipitating a tough industry consolidation, and bankruptcies across the upstream portion of the value chain are announced regularly. Simultaneously, the falling prices have created growing gaps between falling project costs and project investment or generation subsidy levels, driving large increases in deployment in many markets; increases that are now retreating as subsidies realign with technology costs or fall under the axe of fiscal austerity. This extremely rapid rate of change is a challenge for policymakers who are accustomed to adjusting subsidy levels annually rather than dynamically and struggle to set up the administrative systems to cope with the burst in deployment. It also means average system price and manufacturing capacity rankings fall out of date quickly and there is new opportunity to deploy solar PV more widely. The story of which economies will finally capture the largest global market share of the global solar PV industry, and at what cost to their public budgets, is not yet written.

The global on-shore wind industry has also evolved in the last several years, with significant deployment and markets for equipment emerging globally. Prices have not declined as rapidly as in solar PV but a small oversupply has put pressure on both prices and traditional industry leaders, with prices declining by 25 percent since 2000.[28] Particularly as the Chinese wind industry has matured and improved the quality of the wind equipment they manufacture, new Chinese competitors are also emerging in long established markets for wind equipment.[29] As new markets for wind equipment emerge, the opportunities for new entrants continue to expand.

This working paper emerges from a collaboration of five leading research institutions: World Resources Institute (WRI), Institute for Global Environmental Strategies (IGES), Öko Institut, Renmin University of China, and The Energy and Resources Institute (TERI), based in the target countries. Researchers in each institution reviewed and gathered information from domestic and international data sources to create a richly nuanced but still comparable review of the development of these industries.

There is no single data source with information on all the parameters this analysis sought to evaluate. Therefore, this work draws on a range of data sources from both industry and governments. Global sources include publications by the International Energy Agency (IEA), United Nations Environment Program (UNEP), Bloomberg New Energy Finance (BNEF), Global Wind Energy Council (GWEC), REN21 Global Status Reports, company web sites, and press releases. National sources include ministry of energy and environment web sites, national solar and wind energy associations in different countries, and peer reviewed articles. Global and in-country experts from leading research institutes in each country were also interviewed to bring a nuanced understanding of the domestic policy contexts.

To draw out comparable information across all countries' data, units and generation system sizes are comparable where possible. Identical or similar methodologies were used to collect individual country data points for manufacturing and installed capacities, and average price information. Jobs numbers were collected wherever possible, but methodologies for estimating these numbers varied significantly across the available literature in countries, limiting comparability for this assessment. As a result, manufacturing capacity and annual deployment are used as rough proxies for the size of the domestic industry. For example, 3 GW of manufacturing capacity may or may not require a larger workforce than 1.5 GW of manufacturing capacity depending on labor costs and factory productivity, but it certainly does lead to more, perhaps even roughly double, economic activity in the domestic economy.[30] Similarly, the level of investment required and the size of the workforce required to install 1 GW of wind power generating equipment may differ substantially between countries depending on local energy costs, structure of the subsidies, local land use regulations and other permitting issues, and size of the average wind project. However, annually installing 18 GW of wind power suggests significantly more domestic economic activity than installing 5 GW.

Since the capacity to continually innovate is critical to competing effectively in the global solar PV and wind supply chains, policy information was collected based on functions that help to support a vibrant domestic innovation system.[31] While focus often falls exclusively to national-level support for domestic deployment, the study countries also foster and invest in infrastructure, their workforce, the availability of finance, and research and development. This broader approach ensured that policies that support the entire value chain of developing, manufacturing, installing, operating, and integrating low-carbon power technologies into the grid were categorized and captured through a consistent and holistic framework across the five countries analyzed.

These are complex industries and many interesting aspects could not be addressed in the scope of this review. The researchers did not try to evaluate how effectively policy was implemented or enforced on the ground in countries. Similarly, the researchers focused on national-level policy, understanding that all of the countries, but particularly India and the U.S. have sub-national renewable energy policies and industrial strategies that impact the development of these industries. Further work could be done in the future to determine whether these nuances confirm or refute the findings of the cross-country analysis.

Finally, estimating the full burden of renewable energy subsidies, particularly in a comparable way across countries is beyond the scope of this review. The relative economics of renewable energy projects in each country depends on the price of the project (including factors beyond the equipment, such as the cost of finance) and on the overall cost of electricity. The relative cost of energy in these countries is already widely divergent. There are also some questions about whether renewable energy projects are always built based strictly on their return on investment, making a comparison of project economics even cloudier. Similarly, in some electricity markets, renewable energy is lowering the clearing price for wholesale electricity, resulting potentially in cost savings for consumers that offset the impact of the subsidies.[32] While this quantitative economic analysis would be potentially fruitful for understanding the total public budget burden, or at least the impact on end consumer energy prices, this report has relied on average system prices, the total price of the installed equipment, as a rough proxy for how successfully policymakers have driven down the cost per kWh of the renewable energy deployment.

KEY CROSS-COUNTRY FINDINGS

Having drawn upon comparable data on policy measures, industry development, and equipment prices from the five study countries, this analysis examines which countries are finding success and how they are doing so. The electricity sector is highly shaped by policy and particularly shifting the incumbent system to incorporate renewables will require at least regulatory reform.[33] Additionally, meeting the goal of developing domestic supply chains that provide "green jobs" encourages policymakers to intervene further in the market. A close analysis of the solar PV and on-shore wind industries reveals that different policy strategies are needed to deliver on the two central goals with different clean energy technologies. Each technology has characteristics such as complexity, optimal size, and tradability of both individual components and complete systems that impact how the global industry and competition develop.

A historic look at market development along with policies implemented reveals that some countries do seem to be more effective at achieving their goals and building upstream and downstream portions of the supply chain while driving equipment costs down. In the case of solar PV, strategies that focus on driving down manufacturing costs and/or establishing competency in quality products or niche applications are needed to achieve the benefits of the upstream (manufacturing) portion of the supply chain; whereas policies geared towards driving down domestic system prices seem most important to attain the benefits of the downstream (deployment) activities. Alternatively, in the wind industry, developing a strong domestic manufacturing industry is strongly linked to stable domestic deployment. Key lessons from a cross-country analysis of solar PV and on-shore wind industries follow.

Solar PV

Although the solar PV value chain is made up of a number of segments (refer to Annex 2 for a detailed break-down of segments), the industry can be broadly divided into upstream activities (related to developing and manufacturing the equipment itself) and downstream activities (related to deployment of the equipment and generation of electricity). An analysis of the solar PV industry across the five countries reveals key lessons on how countries are finding success in creating a healthy domestic industry and delivering low-cost, domestic clean energy through policies that target both portions of the value chain.

For solar PV, a large domestic manufacturing industry and significant domestic deployment do not necessarily go hand-in-hand.

Successfully building a domestic manufacturing industry appears to be only loosely related to domestic deployment. A closer analysis of trends in annual module production versus annual installed capacity across the five countries reveals that the growth in annual module manufacturing capacity does not generally correlate with growth in annual installed capacity (refer to Figures 1 - 4). Even in Germany, where aggressive deployment policies are widely credited with supporting the development of a significant domestic manufacturing industry, exports to other markets have played an important role in the growth of that industry.[34] Both Japan and China have created substantial export-driven solar manufacturing industries alongside relatively smaller annual domestic deployment. The recent uptake of solar PV deployment in Japan and China corresponds to introductions of deployment-focused policies in both countries. A similar trend is evident in India, where the manufacturing portion of the value chain for modules and cells has been primarily export-focused since the mid-2000s, and domestic deployment has only grown in the last two years, due to the recent introduction of deployment-focused policies.[35]

Figure 1 | **Comparing Solar PV Production to Deployment in Japan**[36]

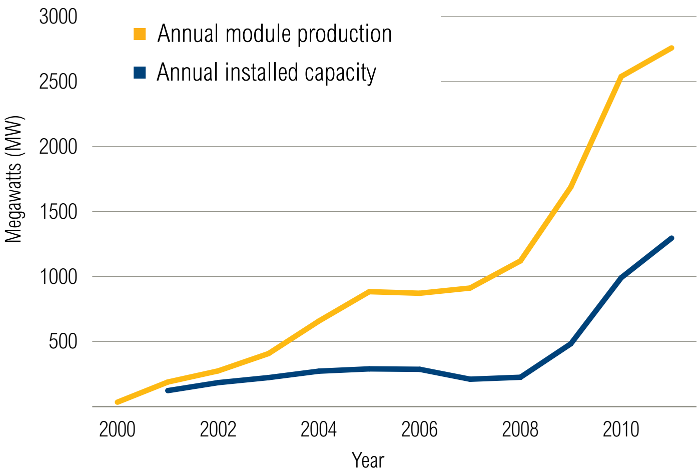
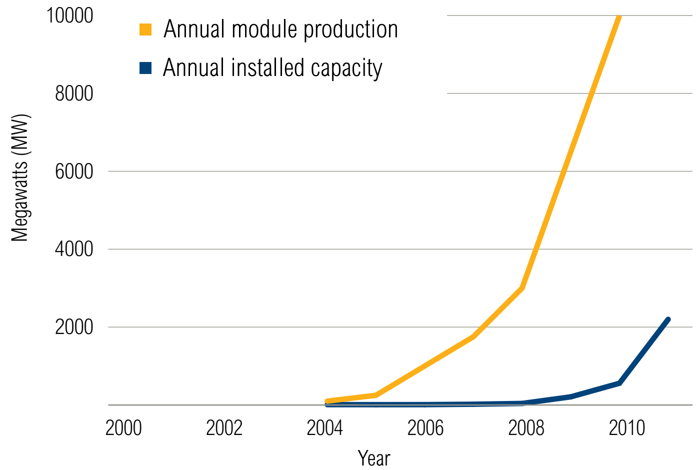


Figure 2 | **Comparing Solar PV Production to Deployment in China**[37]



In Germany, domestic deployment, which helped to drive a large installation market, also supported the growth of a significant domestic manufacturing industry. However, the manufacturing capacity has not kept pace with increases in deployment, nor is all manufacturing production going toward domestic deployment. A closer analysis of German-manufactured solar PV products reveals that a larger proportion of products are being exported from Germany, despite the higher domestic demand than supply capacity.[39] In addition, the average domestic system prices are lower than average domestic module prices (a component of the larger system), indicating the broad use of cheaper imported modules in domestic system installations.

Annual deployment rates for solar PV correlate to average system prices

Of the five[41] countries analyzed, Germany and China have the lowest installed average solar PV system prices. Meanwhile, these countries are also sustaining annual deployment rates that are three to seven times higher than Japan or the United States have achieved (refer to Table 1 and Figure 5). Since India's increase in domestic deployment is much more nascent than the other countries, it's inclusion in the cross-country analysis has been difficult due to more limited available information on average system prices. However, there has been a 38 percent decrease in the prices of grid-connected solar projects between 2010 and 2011[42] and an accompanying significant increase in domestic deployment.

Figure 3 | **Comparing Solar PV Production to Deployment in India**[38]

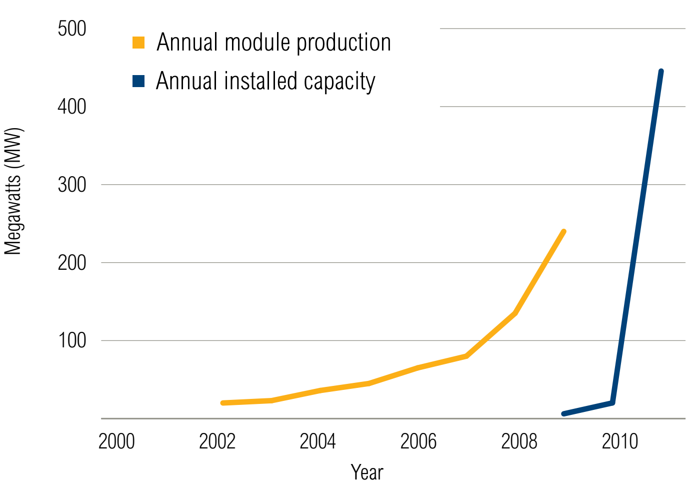
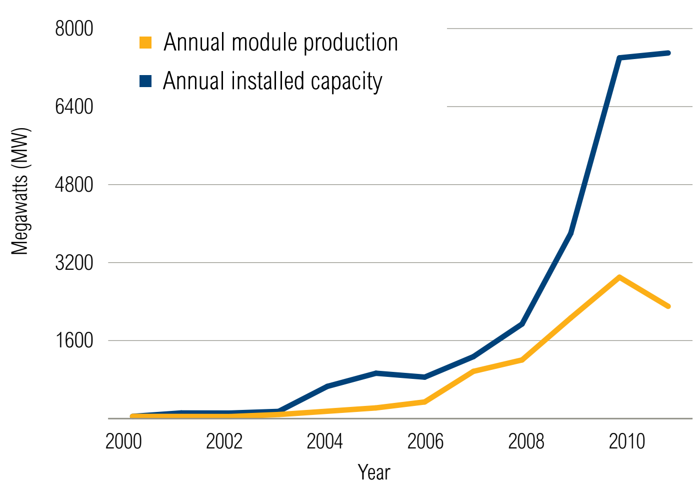


Figure 4 | **Comparing Solar PV Production to Deployment in Germany**[40]



Differences in installed system prices among countries are a result of a variety of factors including differences in various incentive levels, module prices, labor costs, grid interconnection procedures and standards, average system sizes, and local component requirements. In both China and Germany stable and well-designed deployment policy strategies appear to have played a strong role in driving system prices down by enabling the industries to achieve economies of scale and by reducing transaction and finance costs. This focus on the price of systems has an important nuance since most policy discussions emphasize deployment alone and assume prices will fall naturally as deployment increases.

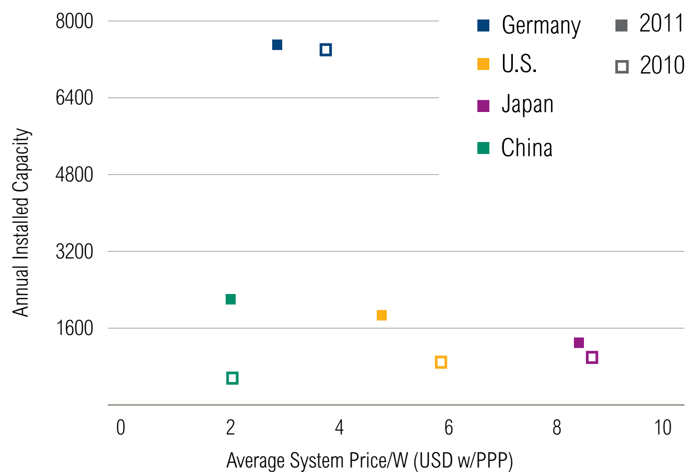
In Germany, the feed-in tariff policy is tied into a sophisticated overarching Renewable Energy Act (EEG), which was introduced in 2000 and incorporates important elements such as fast permitting processes and priority access to the grid for renewable energy. In China, domestic deployment policies have been tied directly to goals in the national Five Year Economic development plan, which include incentives to drive economies of scale and access to low-cost finance. Fierce competition and mandated requirements to increase efficiencies in solar PV manufacturing have helped to drive down solar PV system prices which have also had a positive influence on domestic deployment in China.

Both Germany and China have created a positive feedback loop whereby relatively low and declining solar system prices are fueling further deployment. This, in turn, is helping their downstream domestic solar industries to continue to reduce costs and create local jobs. The job creation potential from these downstream activities is actually higher than the job potential from the manufacturing segments of the solar PV value chain, per installed MW of solar PV capacity, with as much as 60 percent of the jobs in solar PV related to small-scale installations in downstream activities.[43] Lower solar system prices also keep the cost of subsidies and their impact on energy costs down. This positive feedback loop delivers a large domestic deployment industry and lower energy costs, an ideal combination for policymakers (as represented by the upper left quadrant in Figure 5).

The U.S. and Japan, in contrast, have not had stable deployment policies that target system price reduction. The U.S. has relied primarily on a patchwork of sub-national incentives for deployment, and Japan has relied heavily on subsidizing average system costs that are deployed domestically.

Although the Indian market is still nascent, deployment policies are tied to ambitious national targets for deployment of over 20 GW of grid-connected solar by 2022. Key deployment policies are geared toward the reduction of system prices through reverse auctions to select projects that will be supported by national incentives. This competitive bidding mechanism offers feed-in tariffs and long-term Power Purchase Agreements (PPAs) to the least-cost developers that are selected. So far two national reverse auctions have taken place, with a resulting 38 percent decrease in prices for grid-connected solar projects between 2010 and 2011.[46] The second batch of projects drove prices for grid-connected solar energy as low as Rupees 7.49 ($0.15) per kilowatt-hour, approaching grid parity with fossil fuel-powered electricity.[47] This has been accompanied by in an increase in installations from about 50 MW to nearly 500 MW in 2011 alone.[48]

Figure 5 | **Comparing Country Performance in Deployment**[44]



For more details on specific countries policy strategies and impacts, please refer to the country profiles in Annex I.

Both Germany and China still provide subsidies to deployment, but these are declining rapidly.[49] Some of the recent increase in installations in all of the markets has developed as subsidies have not fallen as fast as technology costs, making new installations very attractive to developers and investors. It is anticipated that Japan will see a significant increase in installed solar PV capacity following the recent introduction of generous renewable energy feed-in tariffs in July 2012, but Japanese systems also appear to continue to have the highest prices (refer to Table 1).[50] The correspondingly higher feed-in tariffs will come at a higher economic burden to domestic consumers.

Table 1 | **Average Installed Solar System Price per Watt**[45]

COUNTRY	AVERAGE SYSTEM PRICE / W (LOCAL CURRENCY)			AVERAGE SYSTEM PRICE / W (NOMINAL, USD)			AVERAGE SYSTEM PRICE / W (USD W/PPP)		
	2009	2010	2011	2009	2010	2011	2009	2010	2011
China	27.00	25.37	23.91	3.79	3.60	3.55	1.90	2.16	2.13
US	6.45–9.00	4.05–7.51	4.75	7.73	5.78	4.75	7.73	5.78	4.75
Japan	547–613	566–615	521	5.96	6.46	6.28	7.15	8.40	8.17
Germany	3.20	2.70	2.00	4.28	3.44	2.67	4.71	3.78	2.94

Notes:
1. Since comparable data on average system prices was not available for India, that country is not included in this comparison.
2. This data represent average system prices as reported by countries under Task 1 of the IEA PVPS Program. The prices excludeVAT/TVA/sales tax per Watt. for the various categories of installation. Prices do not include recurring charges after installation such as battery replacement or operation and maintenance.
3. Exchange rates sourced from http://www.irs.gov/businesses/small/international/article/0,,id=206089,00.html
4. PPP sourced from World Bank Data, http://data.worldbank.org/indicator/PA.NUS.PPPC.RF
5. U.S. figures are national weighted average system prices

A successful domestic manufacturing industry is driven through cost or niche competitiveness strategies, rather than domestic deployment

Successful strategies for supporting a globally competitive manufacturing industry are more complex, since there are numerous components, each requiring different capabilities, and there is a high level of global tradability of solar PV components and equipment. This tradability means that a domestic manufacturing industry can also be supported by increasing demand for solar PV equipment from another country.

Given the very tough competition in the solar PV industry today and the high degree of tradability, the assumption might be that the most successful countries are those with the lowest prices for the tradable components such as modules.[51] However, comparing countries' manufacturing capacity and module prices (refer to Figure 6) demonstrates that high price module producers are also successfully creating manufacturing industries. Germany and China are leading in manufacturing capacity, but have widely divergent module prices (refer to Figure 6 and Table 2).

The large solar PV manufacturing industry in China has been mostly driven by access to capital at low and subsidized costs and the focus on manufacturing-targeted policies that drive efficiencies in manufacturing processes, which has allowed for the development of large economies of scale and lower costs. Policies have also supported an influx of foreign technical knowledge through joint ventures with domestic firms and foreign-trained management. Taken together this has led to very low prices. Low enough that quality concerns are sometimes accepted by

Figure 6 | **Comparing Module Manufacturing Production to Average Module Price in 2010**[52]

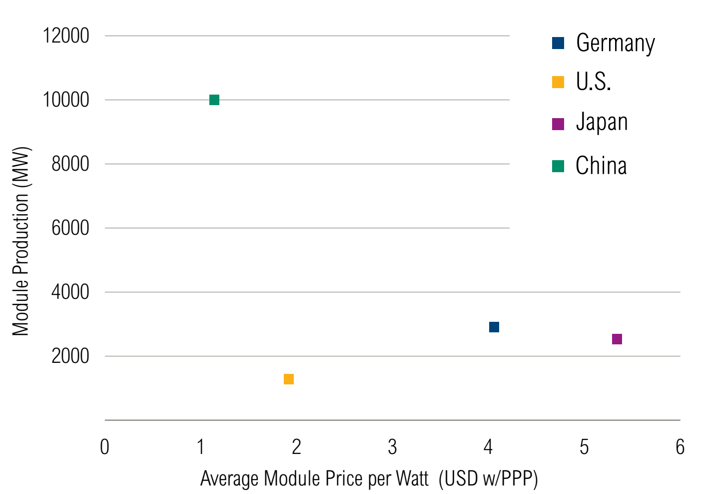


Table 2 | **Average Module Price per Watt**[53]

COUNTRY	AVERAGE MODULE PRICE / W (LOCAL CURRENCY)			AVERAGE MODULE PRICE / W (NOMINAL, USD)			AVERAGE MODULE PRICE / W (USD W/ PPP)		
	2009	2010	2011	2009	2010	2011	2009	2010	2011
China	15.00	13.37	11.91	2.11	1.90	1.77	1.05	1.14	1.06
US	2.10	1.92	1.67	2.10	1.92	1.67	2.10	1.92	1.67
Japan	402	375	335	4.13	4.11	4.04	4.95	5.34	5.25
Germany	1.50–2.50	2.20–3.60	1.12	2.67	3.69	1.50	2.94	4.06	1.65

Notes:
1. Average module price per watt (excluding VAT/TVA/Sales tax)
2. Exchange rates from: http://www.irs.gov/businesses/small/international/article/0,,id=206089,00.html
3. PPP sourced from World Bank data, http://data.worldbank.org/indicator/PA.NUS.PPPC.RF

buyers, who assume that even if a certain percentage of the delivered panels will fail to work, the overall cost will still be advantageous.[54]

Germany, alternatively, has been successful in supporting a large manufacturing industry despite the fact that modules produced in Germany have been, on average, more expensive than those produced in the U.S or China. While a proportion of German products are sold in Germany for the domestic market, many are exported. The reputation for high quality and high efficiency products supports a competitive manufacturing industry.[55]

Even Japan has higher manufacturing production than the U.S., despite the higher module price because of their competitive strategies to support the manufacturing through close government and industry collaboration on research and development.[56]

The U.S. has had a largely passive approach to supporting manufacturing, aside from the large influx short-term support through the 2009 stimulus package (refer to country profile for more details). In the midst of volatile global competition, this approach seems to be less effective at supporting a large solar PV manufacturing industry, despite the lower average module prices in comparison to Germany and Japan.

On-Shore Wind

The wind power industry has grown to be a significant economic force and source of employment in several countries. A rough estimate by the Renewable Energy Network for the 21st Century (REN21) puts global jobs in the wind industry at 670,000 in 2011.[57] Employment estimates in the country profiles are based on the methodologies used by domestic institutions from those countries and are not directly comparable. However, these estimates all confirm that a discussion of wind energy jobs cannot focus on manufacturing alone. The value chain for wind power includes the manufacturing of components and the assembly of many of these components into the nacelle, as well as a number of services such as: wind measurements and site selection, project development and financing, installation, operations and maintenance. Across the five study countries, 50 percent or fewer of the jobs are in manufacturing, while the remainder is in installation, operations and maintenance, and other services. See Annex 3 for details on the wind power value chain.

For on-shore wind, domestic deployment is key to building both upstream (manufacturing) and downstream domestic industries

Many of the downstream jobs related to building and maintaining wind projects are location-bound. Any country that invests in wind power can expect to create these jobs and see the emergence of specialized companies. The key seems to be creating stable and reasonably large demand for wind power with well-designed policies that can include feed-in-tariffs (FITs), renewable portfolio standards (RPS), or power purchase agreement or concession auctioning schemes. Until recently wind power has been policy-dependent, as it has been more expensive than conventional power sources. All of the countries analyzed have used one or several of these policies and seen growth in domestic wind deployment as a result (Figure 7). When policies have lapsed, deployment has declined dramatically.[58] Larger annual capacity additions and the larger downstream industry to support them have emerged in those countries where the targets have been more ambitious.

Analysis across the five countries confirms that there is also strong correlation between the size and stability of the domestic wind power deployment and the size and success of a domestic wind power equipment manufacturing industry. The wind power industry tends to organize its manufacturing in regional supply hubs serving the large markets. There are strong advantages from manufacturing close to the installation sites. First, many of the components are heavy or bulky and therefore difficult and expensive to ship. Second, component manufacturers also are encouraged to locate close to the assembly sites, likely driven by a desire by manufacturers to be able to more easily ensure quality.[60] Finally, wind turbines are expensive pieces of capital equipment and down time can be very costly, so that there may be certain advantages in having spare parts available close by.[61]

Figure 7 | **Cumulative Installed Wind Capacity, 2000–2011[59]**

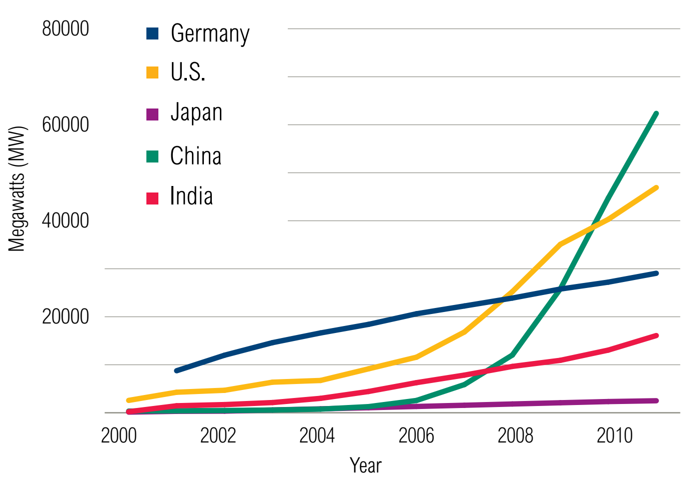
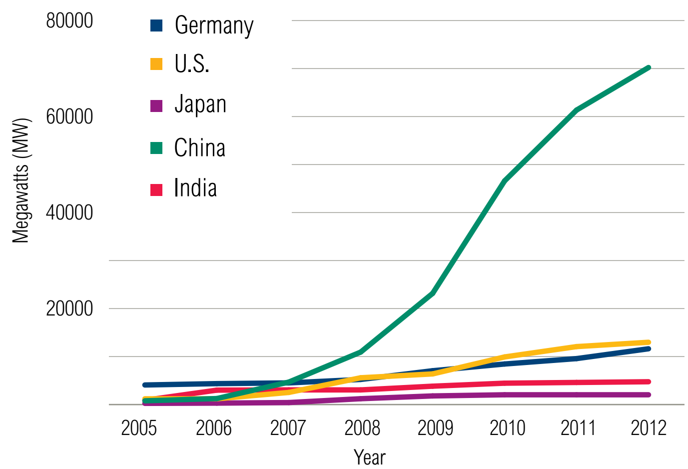


Figure 8 | **Comparison of Wind Turbine Manufacturing (Final assembly) Capacity, 2005–2012[62]**



Domestic manufacturing plants can be owned and operated by either domestic or foreign companies. Domestic companies usually enjoy certain advantages, such as knowing the market better, and usually have had the longest presence in the country. In all of the markets studied—with the exception of the smallest market, Japan—the supplier with the largest market share is a domestically-owned company. However, in addition, many of the global players have also set up assembly plants in large markets and encourage their suppliers to do the same.

Annual deployment rates, and the size of the upstream and downstream domestic industries they support, correlate to maintaining policy stability for at least three to four years

Both upstream and downstream jobs correlate closely with having policies in place that create a significant market for wind power. However, it also appears that predictability and stability are critical to establishing a domestic manufacturing industry.[63] While all four major markets, Germany, the U.S., India, and China have reached around 70 percent local content, the timing of the manufacturing capacity additions has been closely linked to the time horizons of the support policies. Policies with horizons shorter than three years may have stimulated bursts of deployment but did not serve to localize manufacturing effectively, despite the industry's tendency to build hubs.

The short-term and unstable nature of the U.S. Production Tax Credit (PTC), the central federal wind subsidy since 1992,[64] has meant annual deployment swung from far less than 1 GW to more than 5 GW through 2007.[65] Local content was only 35 percent by value through 2006.[66] The climb in local content began in 2007 as two-year renewals were accomplished before the policy lapsed entirely. It exploded with the four-year extension accomplished in 2009. The current uncertainty in the future of the PTC has led to a dramatic drop off in turbine orders for 2013, estimates that annual deployment will fall to 10 percent of the 2012 total,[67] and announcements of layoffs and cancelled manufacturing facilities.[68]

Germany has had both steady policy since 1991 with a declining subsidy level, and steady annual deployment rate around 2 GW a year. Even with the declining subsidy, Germany has higher than 70 percent local content[69] and a manufacturing capacity of more than 11 GW a year.[70] Similarly China established both aggressive targets on five-year horizons and a renewable energy law in 2006 that did not include expirations. They began offering wind power concessions for auction, in order to meet the planned targets. This provided the industry with a degree of certainty about the market size over the coming years. While they began building the industry with a local content requirement, by 2009 they had already reached 70 percent local content and removed the requirement. They also reformed the concession bidding system in 2009 to a simplified and standardized feed-in-tariff, set again to support the widely publicized targets. Deployment doubled annually from 2006 through 2009 and has since leveled off at a steady 18 GW a year, while maintaining the substantial local content proportion. Finally, India saw two large increases in domestic wind manufacturing capacity. The first, in 2006, coincided with establishment of the renewable portfolio obligations and national renewable energy targets. The second, in 2009, coincided with both the aggressive renewable energy targets in the 2008 National Action Plan on Climate Change and the creation of generation based incentives, essentially a kWh premium for projects built between 2010 and the end of 2012.

While many factors, economic and political, play into the decision to invest in wind deployment or in manufacturing capacity, stable deployment policy seems to play a key role in encouraging the industry to follow its natural inclination to localize manufacturing. The role of local content requirements is hotly debated, and perhaps China would not have reached such high levels of local content so quickly without the requirement, but the U.S. reached similar levels over a similar timeframe by stabilizing its deployment policy horizon.

While there are important cost and logistical reasons to locate manufacturing near large markets, the capital required to establish manufacturing plants and the time required to establish a sufficiently skilled workforce are substantial. This may be why manufacturing is slow to localize when the stability of the deployment policy is too short-term. A growing over-capacity in the U.S. (due to the impending PTC expiration),[71] in India (due in part to the expiration of the investment subsidies), and in China (as the government stabilizes annual deployment at a rate the grid can absorb) will test the build-out that all three countries have accomplished.[72]

Most export opportunities emerge from a strong domestic manufacturing industry, supported by domestic deployment.

Even with the importance of geographic proximity, there still is international trade in wind energy equipment. However, where it is possible to pursue an export-centric strategy in the solar industry and neglect domestic deployment, exporting wind equipment seems more often to correlate with building a domestic manufacturing industry which in turn depends on stable domestic deployment policies.

Exports of wind equipment follow a pattern that matches the strong inclination to localize manufacturing. First, regional trade plays a very important role as hubs develop near stable markets. Almost all German imports come from neighboring Denmark, while European countries are the major destination for German exports. Conversely, Latin American countries are among the important export destinations for the U.S. Asian neighbors are important importers of Chinese, Indian, and Japanese products. Second, while heavy and bulky pieces such as blades or towers are difficult and expensive to ship, other components are more tradable. For example, the United States imports many smaller components from European manufacturers.

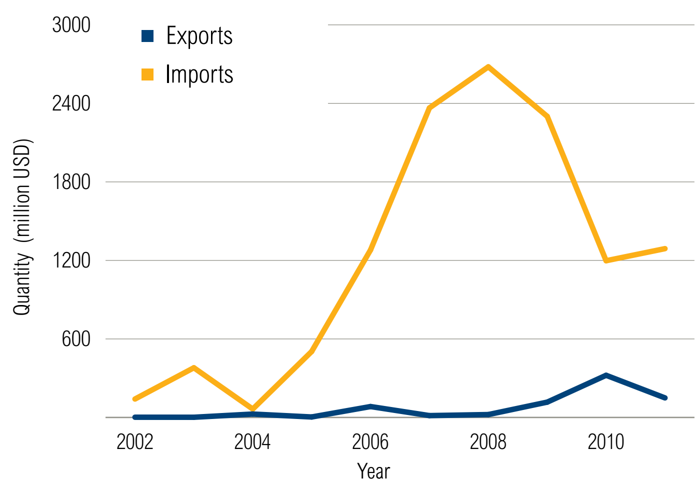
The largest exporters are those countries that have been successful in creating large and stable domestic markets. The U.S. is the only market, among those analyzed, to maintain a long-term trade deficit in wind equipment, importing more equipment than it exports. However, the tradable components do not compete on price alone, so creating a wind industry that is competitive in export markets seems to require a strategic approach, combining a commitment to innovation and an identification of the niches where the domestic industry is most likely to be able to compete. Japan is unique in establishing an export-oriented wind manufacturing industry with only a small domestic deployment market, which was dominated by other foreign companies. They were able to do this by building on strong industrial bases in related fields (electro-mechanical engineering, steel) and by moving into the wind industry early on, with Mitsubishi producing its first turbines in 1980. Germany has a strong export base, built on a traditionally strong domestic industry, the proximity of an export market in neighboring European countries, and large investments in R&D and other aspects of innovation. U.S. public investments in R&D are the largest among the countries, yet the manufacturing industry has lagged under the weight of the market instability.[73] While perhaps the United States' geographic constraints, with a smaller regional market than Japan, might help to explain low exports, the United States has also remained a net importer, even in 2011. The irregular growth of domestic manufacturing capacity and overall supply chain has not allowed for the development of exports.

Aside from wind equipment exports, there is a growing trade in services. Some wind services—turbine design, wind assessment, project development, and financing—are increasingly traded internationally.[74] An emerging trend is the combination of services and equipment trade. Manufacturers, in particular from China and India, offer turnkey solutions where they develop projects, secure project financing, and supply the equipment.

Figure 9 | **Germany: Imports and Exports of Wind Turbines, 2002 – 2011**[75]

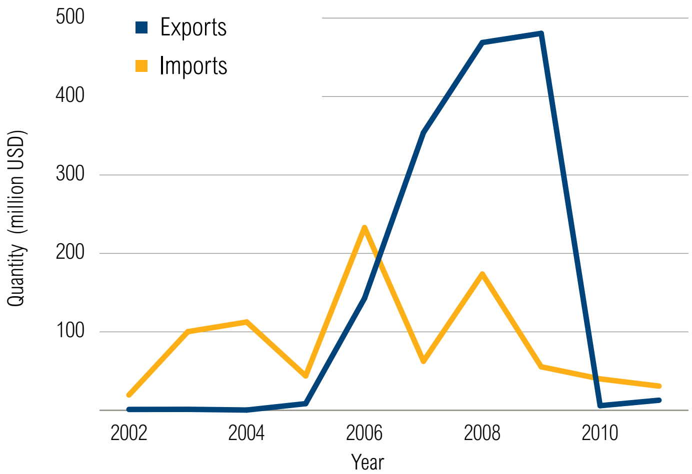
Note: Data collected as defined under HS code 850231 (wind turbines)

Figure 10 | **United States: Imports and Exports of Wind Turbines, 2002 – 2011**[75]



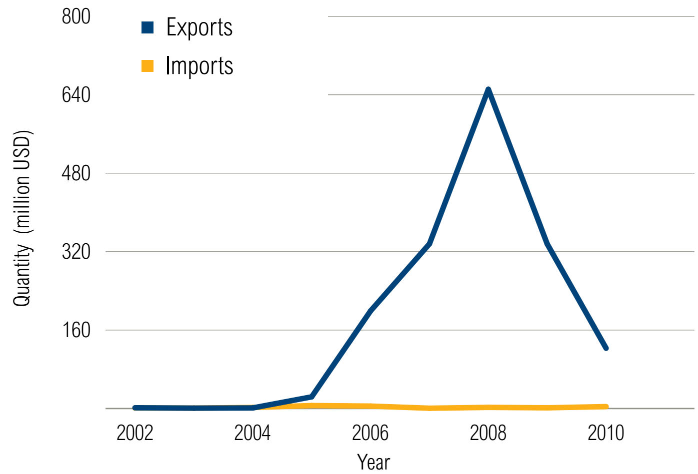
Note: Data collected as defined under HS code 850231 (wind turbines)

Figure 11 | Japan: Imports and Exports of Wind Turbines, 2002 – 2011[75]



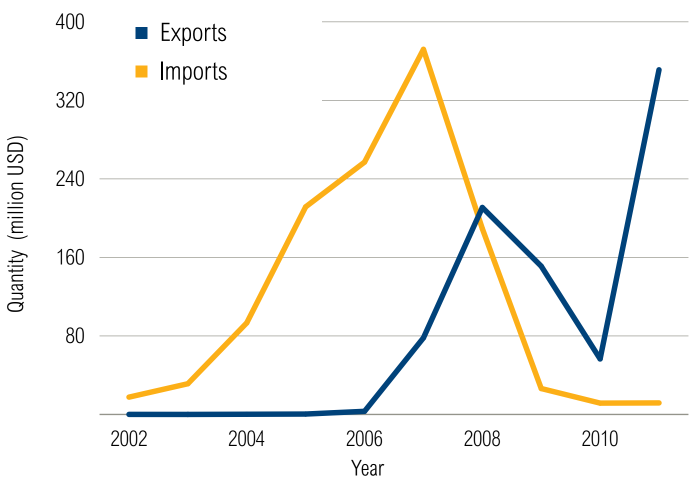
Note: Data collected as defined under HS code 850231 (wind turbines)

Figure 13 | India: Imports and Exports of Wind Turbines, 2002 – 2011[75]



Note: Data collected as defined under HS code 850231 (wind turbines)

Figure 12 | China: Imports and Exports of Wind Turbines, 2002 – 2011[75]



Note: Data collected as defined under HS code 850231 (wind turbines)

ANNEX I: COUNTRY PROFILES

Germany

Key National Targets and Key Policies for Renewable Energy

Germany has set clear and ambitious national targets for clean energy. In addition to a national goal of reducing emissions to 40 percent of 1990 levels by 2020 (which is double the EU target of 20 percent), specific energy goals include expansion of renewable electricity generation capacity to 35 percent by 2020, 50 percent by 2030, 60 percent by 2040 and 80 percent by 2050.[76] These targets—and the unambiguous political support they enjoy in Germany—signal to investors that there will be a large market in the years to come, even if the details of the support policies might change.

Germany also has a renewable energy policy framework that has helped support the development of both the solar PV and wind industries since 1991, with the introduction of the Electricity Feed-in Law. This initial law gave eligible renewable energy projects the right to be connected to the grid and guaranteed producers a fixed price for the power generated. The law was further expanded to become the more comprehensive Renewable Energy Act (EEG) in 2000, with major revisions in 2004 and 2009. Under the EEG,[77] feed-in-tariffs (FITs) are guaranteed for a 20 year period and rates offered to new projects decline periodically and predictably, following a scheduled rate reduction. There is no cap on the annually available budget or volume of new installations and the rates are differentiated by clean energy technology. The EEG does more than guarantee a price. The law stipulates that all eligible renewable energy projects will enjoy priority connection to the grid and priority dispatch (used first to meet electricity demand). Also, if the utility is not able to dispatch the power generated, it must compensate the project owner for the lost revenue. The scheme is not financed by the governmental budget. Instead, costs are allocated to electricity consumers through a surcharge on the price of electricity. These provisions provide certainty to renewable energy developers, generators and investors, and reduce the financial risks associated with installing renewable energy projects.

German technical universities and research institutes are among the leading global research institutions. The federal government supports research, development and innovation under the High Tech Strategy 2020.[78] Climate and energy is one of the five focus areas of the strategy.

Research and development is often closely connected to the manufacturing industry in Germany. The Fraunhofer Institutes are a good example. With 60 research units in Germany,[79] more than 18,000 staff and a €1.65 billion annual research budget, they are Europe's largest application-oriented research organization. Fraunhofer research projects are co-financed by industry partners, through contract research, which increases the likelihood that topics are relevant and findings are directly applicable to industry. Of the €1.65 billion budget, approximately 30 percent comes from public funding and the rest from private sources.[80]

Solar PV

KEY DRIVERS

Growth in installations is supported by a sophisticated FIT model, strong industrial base and the biggest semiconductor industry in Europe, cluster-development, and enhanced public awareness about solar technology.

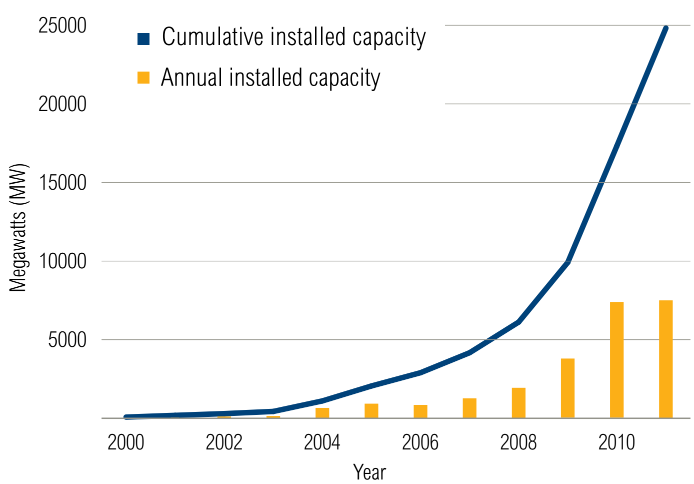
KEY CHALLENGES

Aligning FIT reductions with the recent precipitous decrease in solar PV costs, and competition to the manufacturing sector from global manufacturing overcapacity.

TRENDS IN MARKET SIZE AND VALUE CHAIN

Installed Capacity | Germany continues to be the dominant leader in cumulative solar PV installed capacity, with a total installed capacity of 24.8 GW at the end of 2011, which was 35 percent of the total global installed capacity.[81] Since the introduction of the EEG in the year 2000, the country has seen an overall increase in annual additions (refer to Figure 14). The dramatic drop in solar PV prices beginning in 2008 spurred a record jump of 7.4 GW of newly installed capacity in 2010, which was more than the entire world added the previous year.[82] This was followed by another 7.5 GW of newly installed capacity in 2011.[83] Three GW of new PV systems were installed in December 2011 alone.[84]

Figure 14 | **Installed Solar PV Capacity for Germany, 2000 – 2011[85]**



Solar PV Manufacturing | Germany's solar PV manufacturing industry more or less grew at the same pace as new annual installations until 2009, with a steady increase in the production of polysilicon, wafers, cells, and modules. Annual manufacturing levels for individual components in 2010 had grown to between 4 to 7.5 times higher than the annual production levels in 2006 (refer to Figure 16). In the last two years, however, despite an increase in domestic manufacturing production, the annual installed capacity has surged to more than double the annual manufacturing production of cells and modules (refer to Figure 15). Domestic supply is being supplemented through a significant increase in the imports of these components from cost-competitive Chinese and other Asian manufacturers.[86]

Figure 15 | Comparing Solar PV Production to Deployment in Germany[87]

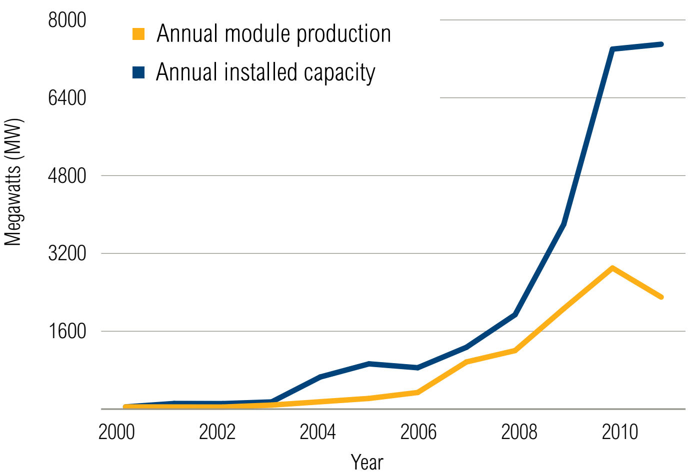
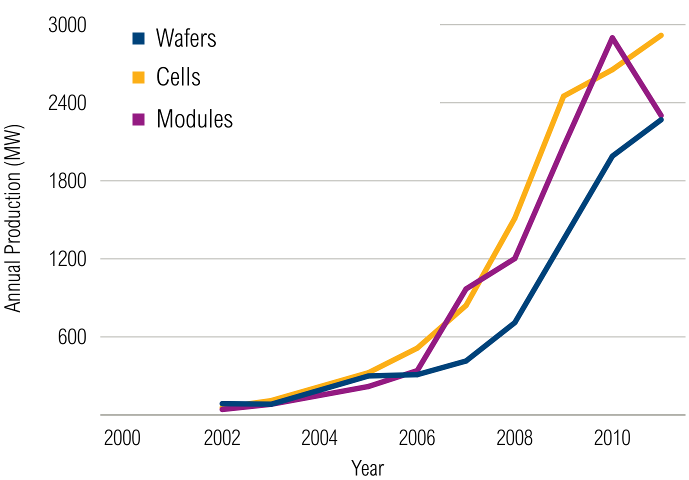


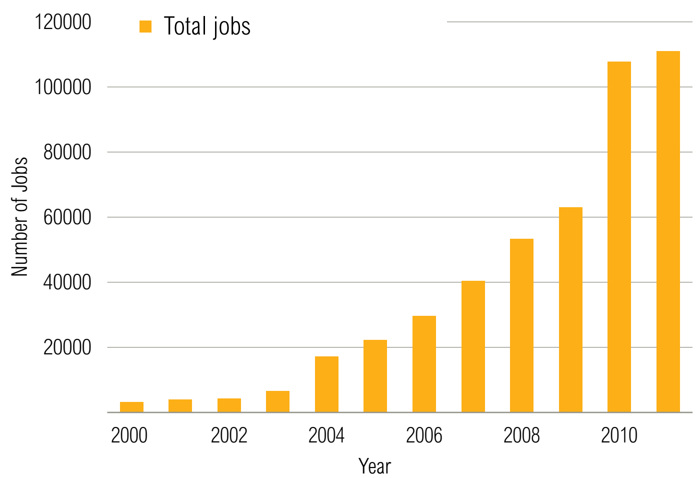
Figure 16 | Annual Production of Wafers, Cells and Modules in Germany, 2000 – 2011[88]



Since Germany was an early entrant into the solar PV industry, the country has players across each segment of the value chain. The European Photovoltaic Industry Association (EPIA) estimates that Germany has approximately 70 manufacturers of silicon, wafers, cells and modules, more than 200 PV material and equipment suppliers, and over 100 balance-of-system (BOS)[89] component manufacturers.[90] Fierce global competition from Asian competitors and the associated unprecedented decline in solar PV costs since 2008 led to bankruptcy announcements and idling of production lines of some leading German solar PV cell manufacturers, including Q-Cells,[91] Solar Millennium,[92] and Solon since the last quarter of 2011. However, Germany continues to play an important role in upstream components, including manufacturing equipment used by global module makers and polysilicon (with about 11 percent global market share in 2011, according to GTM Research), and in downstream BOS components such as inverters,[93] which require sophisticated technical expertise. In addition, German solar PV products have a global reputation for quality, which makes them preferable over lower cost products in some instances.[94]

Jobs | It is estimated that in the German solar industry for every firm that is involved in module manufacturing there are more than six firms in other parts of the solar PV value chain.[95] This highlights the large number of jobs available in segments outside of the manufacturing portion of the value chain, including research and development (R&D), installation, system design, and project management for both domestic and international projects. These jobs, mostly in the "downstream" portions of the value chain, are largely dependent on levels of local deployment activity. Total solar PV job estimates have therefore increased significantly over the last few years with the boom in installations jumping from estimates of between 53,300–60,300 jobs in 2008 to an estimated 111,000 jobs in 2011.[96] This is despite the challenging competition that German manufacturers face.

Figure 17 | Solar PV Jobs in Germany, 2000 – 2011[97]



KEY POLICIES AND IMPACTS ON SOLAR PV COMPETITIVENESS

Germany has struggled to reduce the solar PV FIT quickly enough in the face of the rapid global decrease in system costs. An attempt to shift from annual scheduled rate reductions to bi-annual rate reductions failed in 2011 and the absence of the expected FIT adjustment in July 2011 drove significant installations in the latter half of the year.[98]

There has been an evolution of key policies for solar PV since 1991, starting with the FIT Law, followed by the introduction of rooftop solar grants and loan programs, and finally the stable and predictable policy framework of the EEG in 2000, entailing sophisticated feed-in tariffs with pre-determined, scheduled reductions in rates and guaranteed rates for 20 years. Following the introduction of the EEG, cumulative installed capacity more than doubled within a year, from 76 MW in 2000 to 186 MW in 2001, and similar significant increases occurred after amendments to the EEG in 2004 and 2009. The misalignment of feed-in tariff levels with rapidly decreasing solar PV costs contributed to the significant boom in domestic deployment over the last two years.

Although the rates under the EEG are often highlighted as the key driver to the industry, the included stipulations for grid connection and priority power dispatch have also been instrumental in providing fast project realization times, investment certainty, and lower associated costs, which has helped to drive solar PV deployment in the market. According to the EPIA, Germany enjoys the lowest installation and BOS costs in the world, which is likely to also have contributed to higher deployment of solar PV systems.

In addition to the EEG, with its emphasis on installation and power generation, there is a broader supportive framework for the domestic PV industry, both for upstream manufacturing portions of the value chain and for downstream activities. These include:

- Investment incentive packages that can contribute up to 50 percent of investment costs (including cash incentives, especially in the Eastern region,[99] reduced-interest loans,[100] public guarantees, and tax credits from local fiscal authorities);
- Operational incentive packages (including subsidies for work force recruitment, training support and wage subsidies, and subsidies for R&D projects at the regional, national and European level); and
- Supportive innovation policies and programs that are designed as public-private partnerships for the solar PV industry.[101]

R&D and cluster development are two additional important components that support the manufacturing industry, as the German government spent $77 million on solar R&D in 2010.[102] EPIA estimates that in Germany, 90 percent of all solar PV companies cooperate with others within a cluster setting and partner with research organizations, including universities. This is in part due to the fact that regional policies led to more than one third of German solar PV production capacity being located in East Germany.[103] From a manufacturing perspective, this cluster development provides not only a readily accessible supply chain with the associated lower costs, but provides a conducive environment for innovation, and ensures that research remains relevant to industry needs. These are all factors that are likely to have contributed to growth and competitiveness of Germany's large solar PV manufacturing industry over the last decade. Additionally, in response to global competition from Asian countries, and an accelerated schedule for the reduction of FITs following the amendment of the EEG in 2009 and 2012, the German government has introduced the InnovationsallianzPhotovoltaik[104] in 2010 through the Federal Ministry of Education and Research (BMBF), as a public-private partnership to keep the German solar PV industry competitive. This is being supported by up to €100 million invested in PV research from BMBF and €500 million from industry.

Besides supportive policies, Germany has a stable and transparent legal system, has historically had a strong industrial sector for machinery and equipment development, and also houses the largest semiconductor industry in Europe, which are all important assets that have contributed to competitive solar PV industry development. In addition, Germany has excellent transportation infrastructure and the advantage of having no exchange rate risk for supplying to the European markets, which has helped to maintain competitiveness of German solar PV exports in the region. Germany's global reputation of quality and innovation has also helped to maintain market share in the broader global markets, particularly for niche applications and for components such as polysilicon and inverters.

Wind

KEY DRIVERS

Steady growth in on-shore installations supported by sophisticated FIT, availability of low-interest rate project financing, research/industry clusters, public awareness about and support for wind power.

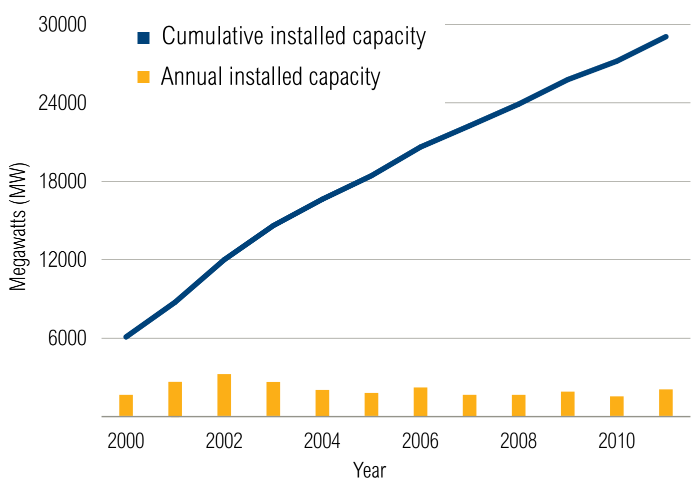
KEY CHALLENGES

Need to develop new lines of business (offshore, repowering) as onshore market approaches saturation.

TRENDS IN MARKET SIZE AND VALUE CHAIN

Installed Capacity | Germany has successfully created a sizeable market for wind power that has been stable for the last 10 years, with about 2 GW installed each year, with a peak of over 3.2 GW in 2002 and around 2.7 GW in 2001 and 2003 (See Figure 1).[105] Overall, there are now over 22,000 wind turbines with a generating capacity of 29 GW, supplying around 8 percent of Germany's electricity.[106]

Figure 18 | **Installed Wind Capacity for Germany, 2000 – 2011**[107]



Wind Manufacturing | Germany has built a strong wind industry that dominates the domestic German market, but also exports a significant share of its products and services. Germany has a manufacturing capacity of more than 11 GW a year.[108] The largest suppliers to the German market are German manufacturers producing in Germany (see Figure 19). A 2011 study based on industry surveys estimated that 93 percent of wind turbines installed in Germany were also assembled in the country; on average, 71.4 percent of the content, including all components in German wind installations, was produced domestically.[109] Sixty-five percent to 80 percent of German wind power equipment is exported, predominantly to European neighbors (see Figures 20 and 21, as well as Table 3). With the emergence of domestic manufacturers in many export markets, German exports have fallen since 2009, yet with an export share of 66 percent, export markets continue to play an important role for the German wind industry, supplementing the steadily growing domestic market.[110]

Figure 19 | Turbine Supplier Share in Newly Installed Capacity, 2011[111]

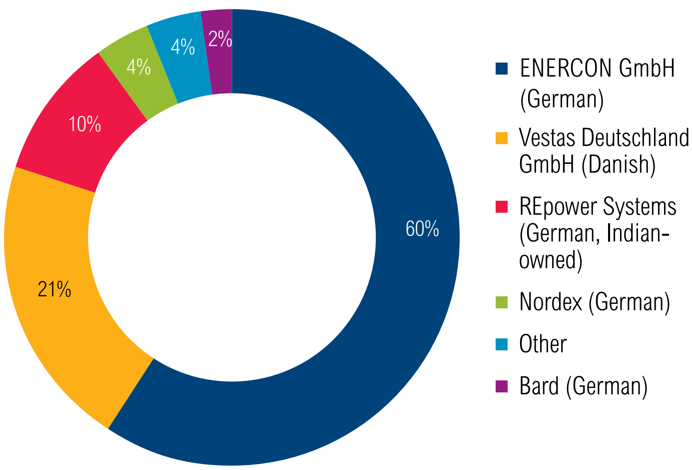


Figure 20 | Annual Turnover of German Wind Power Manufacturers on Domestic and Export Markets[112]

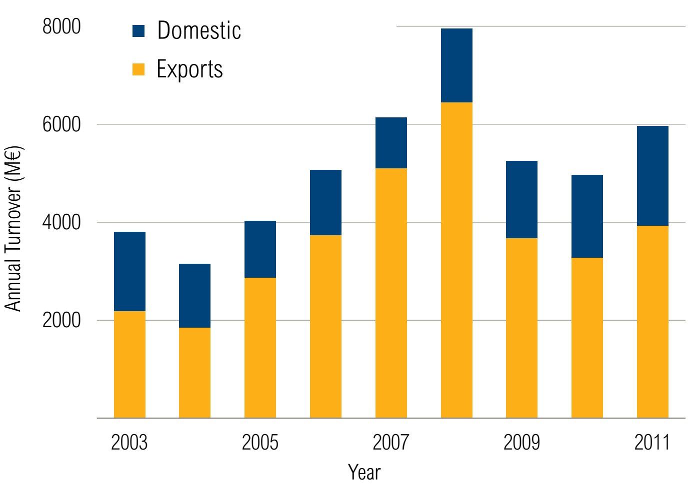


Figure 21 | Germany: Imports and Exports of Wind Turbines, 2002 – 2011[113]

Note: Data collected as defined under HS code 850231 (wind turbines)

Figure 22 | Wind Power Jobs in Germany[118]

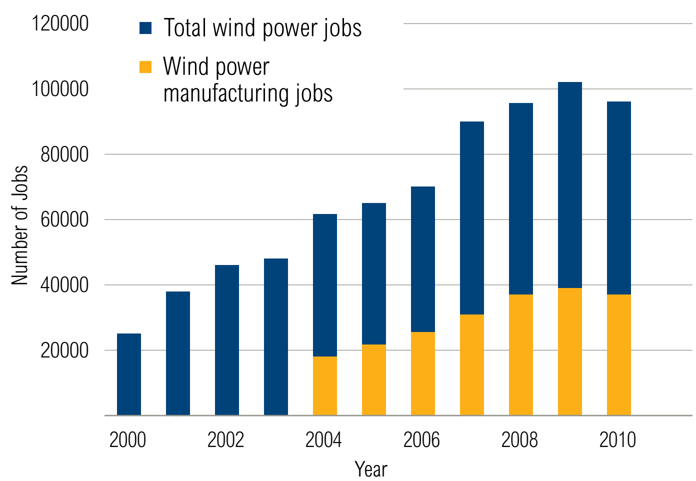


Table 3 | **Germany's Main Trading Partners for Wind Turbines (HS code 850231)[114]**

TOP 5 EXPORT PARTNERS 2002–2011 (US$)			TOP 5 IMPORT PARTNERS 2002–2011 (US$)		
USA	$1,181,266,395	15%	Denmark	$4,940,341,271	97%
France	$1,113,712,788	14%	Spain	$51,261,831	1%
United Kingdom	$769,611,424	10%	United Kingdom	$23,724,882	0%
Italy	$662,485,211	8%	Finland	$23,298,547	0%
Japan	$630,715,147	8%	Brazil	$16,164,330	0%
Other partners	$3,698,789,345	46%	Other partners	$42,203,632	1%
Total	$8,056,580,310		Total	$5,096,994,493	

Jobs | The German wind power industry is a major job creator, accounting for over 101,000 jobs across the value chain in 2011.[115] It should be noted that only about 40 percent of German wind energy jobs are in manufacturing (see Figure 22).[116] The other jobs are in a broad range of related services, including installation. Germany is now also exporting this service know-how, such as turbine designs, or project development services. For instance, German utility E.ON is one of the largest wind developers in the United States.[117]

KEY POLICIES AND IMPACTS ON WIND COMPETITIVENESS

Germany has been an early mover on wind energy with a very stable policy environment since 1991 that has focused on creating demand for wind energy and thus built a stable market for wind power equipment and services.

In the case of wind, the FIT rate-setting methodology is sophisticated and includes:

- A mechanism to adjust the FIT to the location, so that wind power projects also become viable in less than ideal locations (also contributing to a more balanced distribution of projects across all of Germany), but not in very inefficient locations.
- A bonus for repowering, such as for the replacement of old equipment with new, more efficient equipment, or increasing the capacity for existing projects.
- A bonus for "system service", such as for projects that meet certain criteria that make it easier to integrate wind power into the electricity system.

The increased certainty for investors and reduced risk created by EEG provisions for priority dispatch and reimbursement for curtailment have bolstered the wind industry and kept the cost of capital low. Because the EEG provides a very predictable stream of revenue, banks are more likely to provide finance. In addition, concessionary capital has also been made available. Germany's public bank KfW has invested directly in projects and provided low-interest capital to commercial banks which they could loan onto project developers as long-term, low-interest loans with fixed interest rates and grace years in the start-up phase.[119] Around 80 percent of all wind turbines installed in Germany have been co-financed by KfW.[120]

The development of the domestic industry has also been supported by a number of other policies, namely support for R&D, industrial clusters, and workforce training.

In 2010, the German government spent $233 million on renewable energy R&D, $46 million of which specifically on wind power.[121] Eight of the Fraunhofer institutes work on wind energy, including the Fraunhofer Institute for Wind Energy and Energy System Technology and the Fraunhofer Institute for Systems and Innovation Research.[122] There are several wind energy clusters across Germany, particularly in the Northwest. These clusters are characterized by a large numbers of component and turbine manufacturers, project development and financing companies, research institutes and universities that interact closely. These clusters are usually supported and coordinated by regional economic development agencies set up by the German states.[123]

As far as building competence in the workforce is concerned, Germany has over 250 dedicated renewable energy university degree programs now, all across the country. There are also dedicated workforce development programs, particularly in regions undergoing industrial restructuring.

The government has also financed manufacturing facilities, particularly in Eastern Germany where industry benefited from a variety of incentives after reunification.

United States

Key National Targets and Policies for Renewable Energy

Unlike the other countries in this assessment, the United States has not established any national level renewable energy targets. As of 2011, twenty-nine out of fifty U.S. states (and the District of Columbia) had adopted mandatory renewable portfolio standards (RPS) and eight additional states had adopted renewable energy targets, but the target levels and timeframes vary widely.[124] These state level incentives have primarily driven the renewable energy market in the U.S.

In terms of key policies for renewable energy at the federal level, the Energy Security Act of 1980 (ESA) brought renewable energy and renewable energy technologies to the policy forefront after the oil crisis of the 1970's, but the legislation primarily focused on providing federal funding for research and not deployment. Provisions for tax credits and loan guarantees for renewable energy technologies, which have been the key incentives for renewable energy development and deployment were eventually introduced within the framework of the Energy Policy Acts of 1992 and 2005.The American Recovery and Reinvestment Act (ARRA) of 2009, which was enacted as a stimulus measure to aid economic recovery, brought the first large infusion of federal funding of more than $45 billion[125] toward renewables through investment tax incentives, loan guarantees, and grants.

Solar PV

KEY DRIVERS
Individual state policies, federal tax credits and loan guarantees.

KEY CHALLENGES
No clear national targets, uncertain climate regulations, high relative capital expenditures (CAPEX).

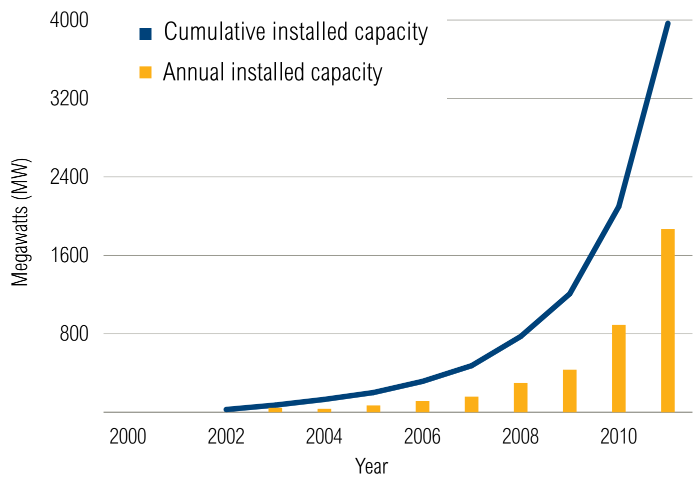
TRENDS IN MARKET SIZE AND VALUE CHAIN

Installed Capacity | Although there has been a somewhat steady increase of cumulative installed capacity in the U.S. since 2000, and there is deployment across residential, commercial, and utility sectors, generation from solar PV remains small. Until 2009 the U.S. market had lower relative demand and pricing pressure. Since 2009, the growth rate in capacity additions year over year has been higher than 100 percent. In 2011, the deployment market finally grew to larger than 1 GW of capacity in a single year (2011 additions were 1855 MW), representing a jump of 109 percent from the 887 MW installed in the previous year.[126]

Solar PV Manufacturing | Manufacturing production increased relatively steadily from 2001 to 2010 (refer to Figure 24), but the rate of increase in domestic manufacturing pales in comparison to the expansive build-out in Germany and China over the same time period. By the end of 2010, Chinese module manufacturing production was 7.8 times higher and German module manufacturing was 2.3 times higher than the annual manufacturing production of the United States, even though both countries had lower production capacity than the U.S. in 2001. Annual manufacturing production levels in the U.S. also experienced a dip in 2011 as increasing global production shifted to China. Wafer production decreased by 36 percent and module production dipped by 4 percent from 2010 levels. Polysilicon, holding relatively steady, was an exception to this trend.

There are about 100 active facilities manufacturing PV components in the U.S. (including polysilicon, wafers, cells, modules and inverters).[129]

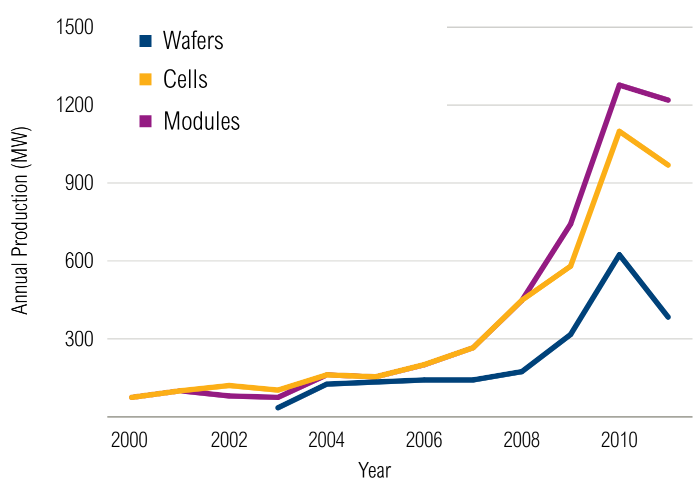
Figure 23 | **Installed Solar PV Capacity for United States, 2000 – 2011[127]**



U.S.-based manufacturing is most competitive in higher value-added segments such as polysilicon production, high efficiency wafers, and the capital equipment used to manufacture wafers, cells, and modules. A number of global PV manufacturers purchase their solar factory equipment for wafer, cell, and module production from U.S firms such as Applied Materials and GT Solar.[130] In fact, when the broader manufacturing value chain is considered, the U.S. is a net exporter of products and boasts a positive trade balance of $1.9 billion, according to a 2011 analysis by GTM Research for SEIA.[131]

The capacity additions and price competitiveness of Chinese cell and module manufacturers have slowly forced plant closures of U.S. manufacturing facilities that were dominant in the PV market in the early 2000s (including BP Solar, Schott Solar, GE, and Unisolar). However, the U.S. has remained a relatively competitive player in the thin film[132] segment of the PV market,

Figure 24 | **Annual Production of Wafers, Cells and Modules in United States, 2000 – 2011[128]**

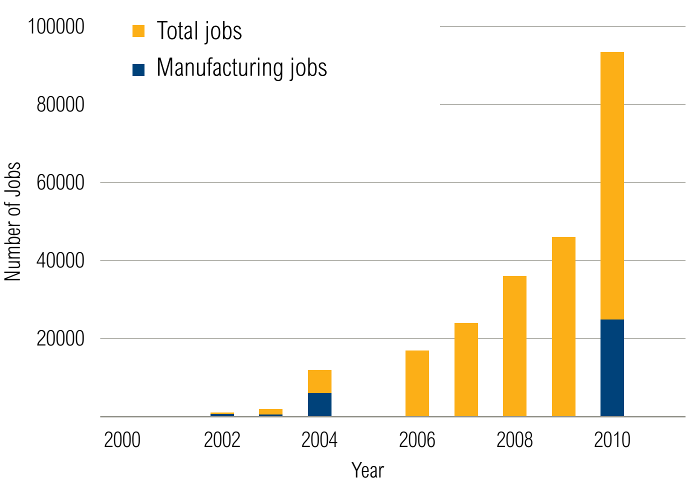


where U.S. firms continue to offer higher quality and efficiency. In fact, virtually all the expansion in manufacturing capacity prior to 2009 was for thin film manufacturing facilities.[133] The U.S. has a competitive advantage in producing thin film technologies because it is a less labor intensive process and requires a skilled workforce to maintain high efficiencies and production yields. However, the price advantage of thin film technologies has been eroded by significant price drops of crystalline-silicon (c-Si)[134] technologies, which are more mature technologies and offer higher efficiencies. Therefore, it is not surprising that both 2010 and 2011 saw closures of large domestic manufacturing facilities and bankruptcy announcements of thin film companies, such as Solyndra, as well.

Many of the most successful U.S. solar companies import the panels they sell from China and rely on the locally-based services they provide through downstream activities.[135] Other successful companies are vertically integrated module suppliers that also produce wafers, cells, and modules in-house to streamline production and reduce costs. It could be argued that establishing c-Si module plants in the U.S. is more of a strategic move versus a cost effective move due to competition from South East Asia.[136]

Jobs | According to SEIA, solar manufacturing accounted for about 25 percent of the 100,000 full-time workers estimated to be employed directly in the solar power industry.[137] Most of the jobs in the industry are in other segments of the value chain including installation, sales and distribution, project development, research and development, and finance.[138] In fact, the growth of manufacturing jobs has been relatively flat over the last few years.

Figure 25 | **Solar PV Jobs in United States[139]**



KEY POLICIES AND IMPACTS ON SOLAR PV COMPETITIVENESS

Both solar PV manufacturing and deployment in the U.S. are still largely driven by state level policies: state level tax incentives for manufacturing facilities; state level RPS, including specific solar obligations in over 22 states and the District of Columbia (DC); subsidy, grant and tax incentive programs; and net metering.[140] This is reflected in the location of installed capacity. Despite the large increase in newly installed capacity in 2011, about 72 percent of the 1855 MW of installations was concentrated in just five states (California, New Jersey, Arizona, New Mexico, and Colorado).[141]

At the national level the key support mechanisms for solar PV development are financial incentives, largely investment tax credits or depreciation deductions. Other policy drivers included a federal loan guarantee program and the advanced manufacturing tax credit, both of which had expired by the end of 2011.[142] However, the durations of these federal incentives are not aligned with each other and are usually authorized for short periods of only a few years, with periodic re-authorization requirements. Even incentives such as the solar investment tax credit (ITC), was only renewed through 2016.

Support for domestic deployment | The sudden increased solar PV deployment witnessed in 2009 is not surprising given that the 2009 average module price per watt faced its first significant drop—over 40 percent[143] from the prior year—and the Federal government significantly bolstered incentives for installation through stimulus funding, including the introduction of the U.S. government's 1603 Treasury Grant program that provided developers cash grants of equivalent value to the 30 percent Investment Tax credit.[144] An important shift took place toward larger utility-scale projects as utilities became eligible to receive the ITC in 2009, following the enactment of the Energy Improvement and Extension Act in October 2008.[145] Moreover, in that same year about 41 percent of new added capacity nationwide consisted of utility-scale installations (28 PV projects over 10 MW in size, up from 2 in 2009[146]). Many industry experts believe that the anticipated expiration of the U.S. government's 1603 Treasury Program (which ended Dec. 31, 2011) drove much of the deployment in 2011, as developers strove to commission projects before the end of the year.

Manufacturing support | Although manufacturing tax credits have helped to drive the expansion of manufacturing capacity in all manufacturing segments in 2009 and 2010, by reducing set-up costs for new facilities, the competitiveness of U.S. manufacturing will depend on the ability to withstand continued global competition and price reductions. The United States has managed to retain its dominant position in the global economy in polysilicon production, with 19 percent of market share in 2011 (second, after China)[147] because it can leverage semiconductor industry experience, heavy manufacturing capabilities, low regional energy prices, and state incentives (e.g. tax subsidy and abatement incentives at the state level). However, production capacity in this segment of the value chain is largely dominated by 4 main players (Hemlock, REC, MEMC, and Mitsubishi America) and the most significant additions/expansions in manufacturing capacity took place through individual company expansions of between 3,100 (MEMC) to 26,000 tonnes (Hemlock)[148] from 2008 to 2010. Initial expansions were a result of global supply constraints that the industry had faced in 2007. This was followed by even higher capacity expansions and an almost doubling of production in 2009 due to strong growth in global demand, doubling of domestic demand, and the introduction of the federal manufacturing tax credits (MTC48C).The expansions far exceeded the domestic demand growth, underscoring the fact that domestic market demand is not the primary driver to manufacturing capacity.

R&D and innovation support | The U.S. has traditionally been one of the pioneering countries for the development of next generation solar PV technologies. The U.S. Department of Energy (DOE) has been the key agency involved in energy R&D and administers the national laboratories and technology centers that drive U.S. national energy research strategies. While not an official national target, DOE has set a goal for solar energy to provide 14 percent of domestic electricity by 2030 and 27 percent by 2050.[149] Key efforts to create a stronger domestic PV manufacturing base have been introduced though the Advanced Research Project Agency-Energy Program (ARPA-E) in 2007 and the SunShot Initiative in 2011.

In the current oversupplied market, project developers and banks are less willing to take on technology risks that might be more acceptable in a more balanced market. This could put new technologies—the core of U.S. manufacturing—in jeopardy, although innovative technologies that are focused on driving down manufacturing costs will be at an advantage.

Wind

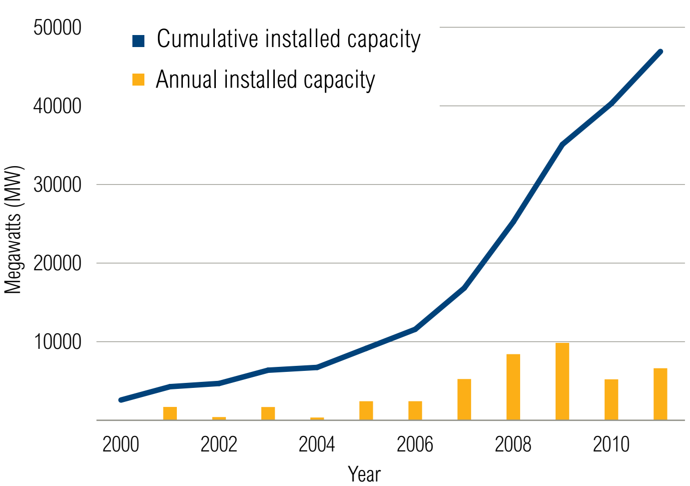
KEY DRIVERS
State-level renewable portfolio standards (RPS), federal-level tax credits (PTC and ITC), federal research programs.

KEY CHALLENGES
Policy instability, interconnection and transmission challenges, since 2008 a falling natural gas price.

TRENDS IN MARKET SIZE AND VALUE CHAIN

Installed Capacity | The United States is the second-largest wind power market in the world. At the end of 2011, there were almost 47 GW of installed capacity. In 2011, 6.6 GW had been added, representing a 16 percent year over year growth rate. As can be seen in Figure 26, growth in the U.S. wind power market has been unstable, with large declines in capacity additions in 2002 and 2004 (and, to a certain extent, 2010).

Figure 26 | **Installed Wind Capacity for United States, 2001 – 2011**[150]



Wind Manufacturing | The wind power manufacturing industry in the United States has been slow to take off, compared to other countries, due in large part to the uncertainty surrounding the longevity of support policies such as tax credits. With more stability at the federal level, supplemented by an increasing number of state-level policies, the domestic wind manufacturing industry has grown more steadily since 2008, more than doubling in capacity from 5.59 GW in 2008 to 12.08 GW in 2011.[151] In 2005, one single company assembled utility-scale turbines in the U.S.; in 2010, there were a total of 10 manufacturers assembling turbines domestically.[152] Overall, there are over 400 manufacturing facilities producing components of wind turbines in the United States.[153] Domestic content in the average U.S. wind power project has risen significantly as the market has expanded and become more stable, from 35 percent in 2005–2006 to 67 percent in 2011.[154] The large parts, including towers, blades, and increasingly gearboxes and generators, are made in the U.S., and the nacelles are assembled in the U.S. as well. Many smaller components are still imported, predominantly from Europe. Within the U.S. markets, domestic company General Electric is the largest supplier, followed by a number of European companies, most of which also manufacture in the United States (see Figure 27).

Figure 27 | **Turbine Supplier Share in Newly Installed Capacity, 2011**[155]

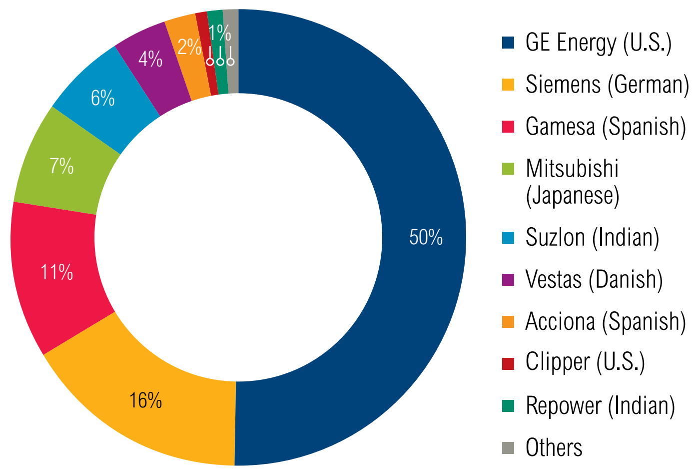
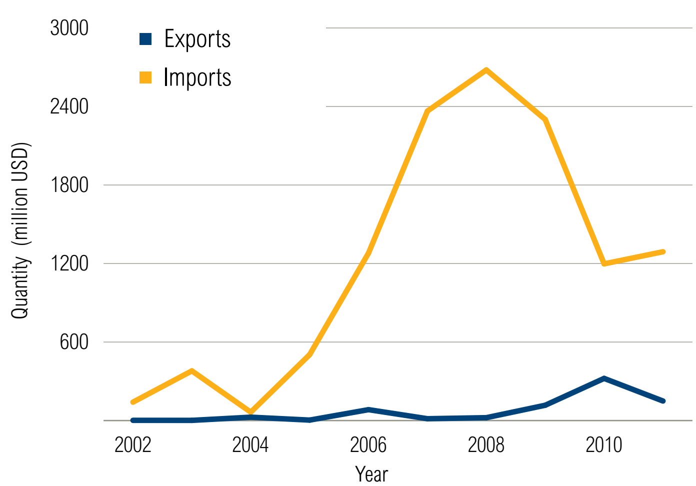


Figure 28 | **United States: Imports and Exports of Wind Turbines, 2002 – 2011**[156]



Note: Data collected as defined under HS code 850231 (wind turbines)

Table 4 | **Main trading partners of the United States for wind turbines (HS code 850231)**[157]

TOP 5 EXPORT PARTNERS 2002–2011 (US$)			TOP 5 IMPORT PARTNERS 2002–2011 (US$)		
Canada	$481,872,490	65%	Denmark	$5,530,851,264	45%
Brazil	$106,734,984	14%	Spain	$1,865,126,310	15%
Mexico	$54,291,032	7%	Japan	$1,616,915,418	13%
China	$30,499,144	4%	India	$1,030,103,400	8%
Honduras	$23,400,000	3%	Germany	$945,001,325	8%
Other partners	$44,099,720	6%	Other partners	$1,212,393,909	10%
Total	$740,897,370		Total	$12,200,391,626	

Even with its growing wind manufacturing industry, the U.S. does remain a major importer of wind power equipment (see Figure 28 and Table 4).

Jobs | According to industry estimates, the wind industry accounted for 33,000 jobs in manufacturing and 39,000 in installation, operations, and maintenance in 2011.[158]

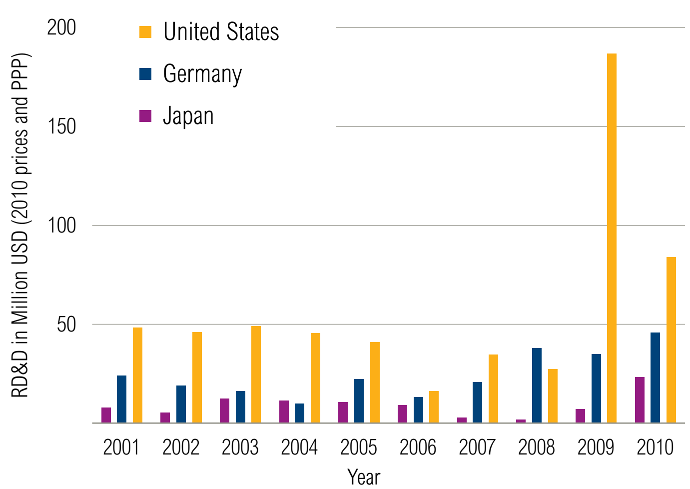
KEY POLICIES AND IMPACT ON WIND COMPETITIVENESS

Market growth has been driven by tax incentives at the federal level and renewable portfolio standards at the state level. The states play an important role in creating the conditions for a successful, competitive wind industry through renewable portfolio standards that create demand for wind power and provide some additional subsidy support through the sale of Renewable Energy Certificates[159] (RECs). These state policies have helped to direct the location and amount of wind development to date but these policies are unlikely to be able to support continued growth at the same levels as seen in the recent past.[160]

The short-lived nature of most of the federal production tax credit extensions has created a boom and bust cycle for the industry, as dips in annual installed capacity have coincided with Production Tax Credit (PTC) expirations. It is this instability that has slowed the growth of the manufacturing industry. The most recent four-year extension coincided with a significant increase in local content and the boom in assembly in the U.S. However, current uncertainty about an extension beyond 2012 is now slowing further manufacturing expansions and there are warnings about plant closures and job losses through the supply chain as orders for turbines in 2013 do not materialize.

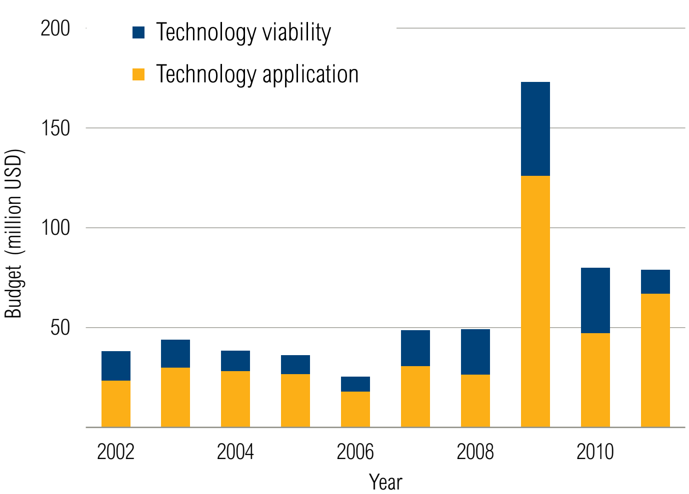
The 1603 cash grant program, approved under the 2009 American Reconstruction and Recovery Act (ARRA), provided critical support during the economic downtown, as tax credits could not be monetized by project developers and likely prevented the 2010 dip in capacity additions from worsening. Its expiration at the end of 2011 left the wind industry reliant once again on the PTC. However, the push to complete projects before the PTC expires at the end of 2012 has led to a typical burst of activity, rather than the slump in demand the subsidy change might otherwise have caused. The PTC has provided a flat level of per kWh subsidy every year it has been in place since it was initiated in 1992 and has no differentiation by wind resource quality.[161] It has been adjusted up for inflation, but not down to match falling technology costs. This has allowed the development of lower quality wind resources to continue, a shift that has been necessary as transmission to high quality wind resources has become deeply constrained.

Figure 29 | **Total Wind Energy RD&D in Millions of USD**[163]



The federal government also invests in wind research and development, including providing testing facilities to support private sector R&D efforts. Among industrialized countries reporting their R&D spending to the International Energy Agency, the United States invested by far the most in wind energy R&D (Figure 29). Programs carried out by the U.S. Department of Energy (DOE) cover areas including "electrical grid integration, wind resource assessment and forecasting, wind turbine reliability and cost, innovative technology development and improved manufacturing methods, public acceptance through education, […] responsible siting and environmental barriers [,and…] lowering the cost of offshore wind."[162] The DOE's budget has grown in recent years and benefited significantly from ARRA funding in 2009, which provided a temporary influx of short-term funding. (see Figure 30).

Figure 30 | **U.S. Department of Energy Wind Power Budget, 2002 – 2011**[164]



Japan

Key National Targets and Key Policies for Renewable Energy

Japan currently has a target of 10 percent of total primary energy supply from renewable sources by 2020.[165] This includes a target of 28 GW of solar and 5 GW of wind by this date.[166] The solar PV target was doubled from 14 GW to 28 GW in 2009, following the introduction of Prime Minister Fukuda's low-carbon vision that year, which included a pledge to install solar PV systems on 70 percent of new homes by 2020.[167]

The Japanese government has played an active role in supporting innovation for new and renewable energy supply, in collaboration with industry and academia, since the 1970s. Government-supported RD&D activities have been led by New Energy Development Organization (NEDO), a governmental agency under the Ministry of Economy, Trade and Industry (METI).[168]

The deployment of renewable energy in Japan has been primarily driven by "supply-push" policies, such as R&D and initial investment subsidies.[169] In the last decade, "demand-pull" policies have also been in introduced, starting with the Renewable Portfolio Standard (RPS) Act, in 2003, which was recently superseded by the Feed-In-Tariff (FIT) Act, enacted in July 2012. The RPS Act included a minimum renewable energy generation obligation for all power suppliers, and a renewable certificates trading scheme. However, it is questionable if the RPS accelerated the introduction of renewable energy as the target level for 2010 was less than 2 percent of the expected total electricity generation.

The core principles of Japan's national energy policy—energy security, environmental adaptability, and use of market mechanisms—do support the development and deployment of renewable energy sources in Japan. However, there was reduced incentive mechanisms for deployment of renewables in the mid-2000s in favor of nuclear power development. Since the Fukushima Daiichi nuclear power plant disaster in 2011 there has been renewed emphasis on supporting renewable energy development, as the government was forced to review the national energy policy. This has led to the introduction of policies that oblige electric utilities to allow renewable energy grid connections and guaranteed priority dispatch, except in must-run cases for other plants.[170]

Solar PV

KEY DRIVERS
Strong industrial base, globally competitive semiconductor industry, and robust innovation support, RPS requirements and solar PV targets, mandated purchase of solar PV generation at feed-in tariff rates.

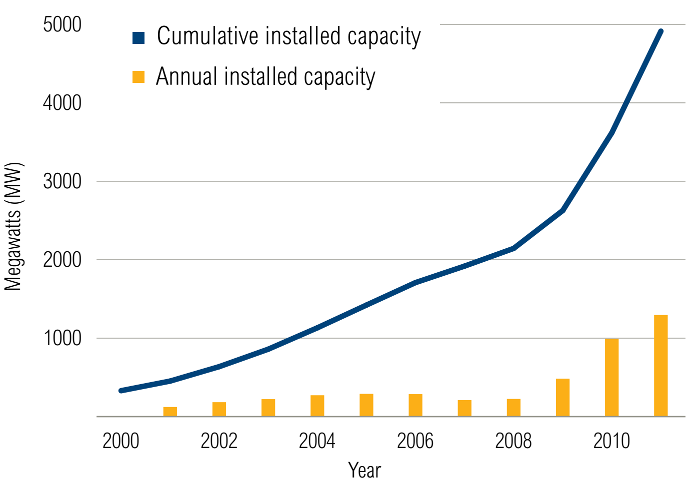
KEY CHALLENGES
High land costs and limited availability, inconsistent incentive mechanisms.

TRENDS ON MARKET SIZE AND VALUE CHAIN

Installed Capacity | Japan had a total installed capacity of 4.9 GW at the end of 2011. To date, the Japanese solar PV market has largely consisted of installations of residential PV systems due to the structure of the Japanese electricity sector, the shortage of land, and national incentives to support residential PV development. Until 2010, residential PV systems represented around 95 percent of the Japanese market,[171] although this is starting to shift with a decrease to about 80 percent in 2011.[172] Megawatt-scale projects are in the pipeline for 2012, largely driven by local utilities and private investors, in anticipation of the revamped renewable energy framework. According to the METI information sheet, there are at least 39 large solar plants equivalent to about 120 MW capacity in full or partial operation (as of February 2012), and at least 33 large solar plants equivalent to over 200 MW under construction or being planned (as of September 2011).[173]

After relatively stagnant years in 2007 and 2008 (refer to Figure 31), 2009 witnessed the highest quantity of domestic PV installations in a single year (at 484 MW), making Japan the third-largest solar PV market that year (accounting for approximately 7 percent of global solar PV capacity[174]).

Figure 31 | **Installed Solar PV Capacity for Japan, 2000 – 2011**[175]

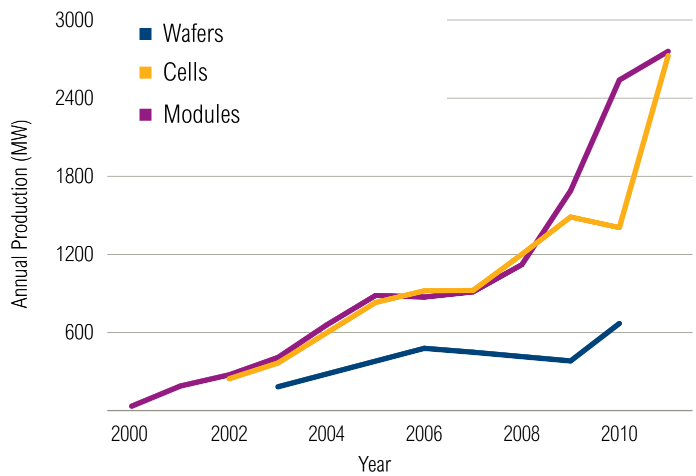


Solar PV Manufacturing | Japan has been a player in the solar PV space since the early 2000s with globally competitive players across the entire value chain, including polysilicon, ingot, wafer, cell, and module producers. This industry has been predominantly export-oriented, with higher annual manufacturing production levels than domestic installation levels every year to date. However, interestingly, the dips and increases in manufacturing production are closely mirrored by similar patterns in domestic installed capacity, just at lower overall levels (refer to Figure 33).

Japan has one producer, Tokuyama, amongst the top ten global polysilicon producers, with 3 percent of the global market.[178] However, the domestic production of silicon has remained relatively small compared to expansion of Japanese-owned silicon production in other countries and growth of silicon production in U.S., China, and Germany, due to high domestic electricity costs in Japan. For cell and module production, Japan had 3 of the top 5 solar PV players until 2006, including Kyocera and Sharp,[179] but these players have lost market share to rising Chinese competitors since then.

With the exception of polysilicon production, which saw a dip between 2009 and 2010, there has been a general increase in production of key components of the solar PV value chain since 2000. 2009 and 2010 witnessed the largest relative growth in module production (at approximately 50 percent) over previous years. This corresponds to the re-introduction of PV deployment incentives for the Japanese market and increase in global demand over that same time frame.

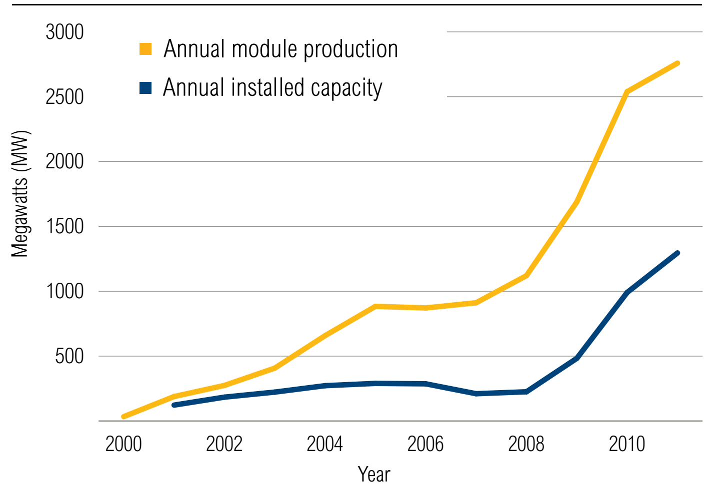
Figure 32 | **Annual Production of Wafers, Cells and Modules in Japan, 2000 – 2011**[176]



The Japanese solar PV industry has largely been dominated by a few, vertically integrated firms that bundle large portions of the value chain (including BOS components and sometimes even installation and maintenance) into their business strategies. This includes large conglomerates like Mitsubishi, Sharp, Kyocera, and JFE Steel. This type of market structure has resulted in relatively high system prices in Japan versus international markets because there has generally been less competition within all segments of the value chain including equipment, sales, and installation. [180] This is likely to change with the introduction of attractive feed-in tariffs in 2012, if there is increased competition as a result of more foreign and domestic suppliers entering the market.

A unique attribute of the Japanese market is the fact that large construction and housing companies have also become players in the solar PV value chain, largely due to the focus on the residential PV market and the nature of the Japanese construction industry, which uses pre-fabricated and standardized

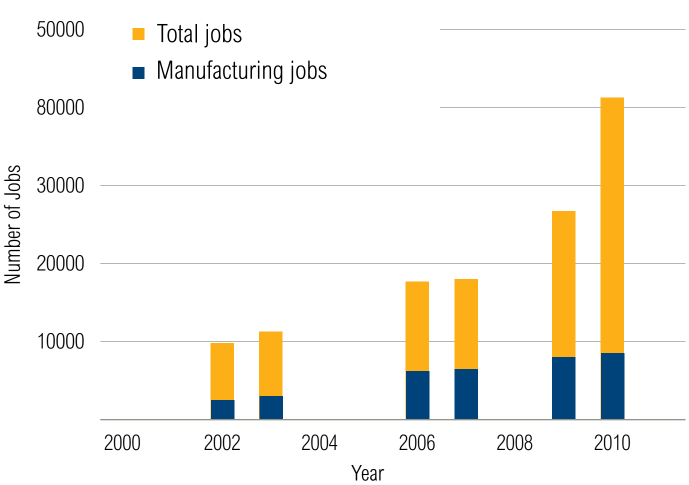
Figure 33 | **Comparing Solar PV Production to Deployment in Japan**[177]



building components that allow for the integration of solar PV modules during construction (as modules have a similar lifetime to residential homes). Some solar cell manufacturers have bought housing or construction companies, while others have forged strategic alliances with construction companies.[181]

Jobs | Although the total number of jobs in the Japanese solar PV industry has increased since 2000, the break-down of jobs between manufacturing and other jobs in the value chain is quite revealing. The total number of jobs increases most significantly following the introduction of deployment policies. The proportion of manufacturing jobs seems to remain somewhere between 21–35 percent of total jobs[182] (with the lower limit corresponding to the years in which deployment suddenly ramped up) despite the fact that the annual megawatt manufacturing capacity remains higher than the annual megawatt installed capacity. The results indicate that the activities related to domestic deployment of PV products may be the main driver for job creation in Japan. According to job estimates collected by IEA, between 2002 and 2011 Japan witnessed about a 2.2-fold increase in manufacturing jobs versus a 3.5-fold increase in jobs supporting other segments of the value chain.

Figure 34 | **Solar PV Jobs in Japan[183]**



KEY POLICIES AND IMPACTS ON SOLAR PV COMPETITIVENESS

Japan has had government-supported R&D programs for solar energy since 1974 and was the first country to implement incentive programs for the deployment of small residential solar PV in the mid-1990s.The emphasis to drive both R&D (in partnership with industry and institutes) and deployment has resulted in a competitive manufacturing industry. However, prices of installed Japanese PV systems remain high largely due to the smaller number of vertically integrated manufacturers within the industry,[184] space constraints, limits for the Japanese market to realize economies of scale, and the starts and stops in incentive programs.

Renewable energy R&D has remained a core area of focus in Japan over the past decade. In fact, although total government R&D outlays on energy fell slightly between 1996 and 2006, Japan's R&D on renewables more than doubled over that period.[185] The main R&D pillars for solar PV include new technology development, dissemination of new energy and international projects. Collaboration has relied on government invitations to specific companies and institutes in the country.

As seen through the trend of annual installed capacity (in Figure 31), higher deployment rates were seen when a feed-in tariff scheme and subsidies were in effect, with a drop in installations with the expiration of the investment subsidy scheme at end of FY2005. The next sharp increase in installations occurred in 2009, following the introduction of a new FIT scheme for solar PV systems, re-instated subsidies/grants for residential systems, mandatory purchase of surplus PV power at FIT rates, and an increase in the national solar PV target for 2020. In response to renewed government and investment subsidies and incentives for residential PV systems, over 600 local governments and municipalities started implementing their own support programs for residential PV systems as well.[186]

Since 2011 there has been a renewed emphasis on supporting renewable energy development through additional policies and incentives. The FIT Act entered into force on July 1, 2012 obligates the purchase of all renewable electricity generated[187] at fixed rates. Systems smaller than 10 kW will only sell their surplus to the grid on a net metering basis. The new FIT for solar PV electricity is amongst the world's highest levels at the equivalent of USD $0.50–0.52 per kilowatt hour (kWh) (depending on system size). It does not include a cap on capacity, and will be reviewed on an annual basis. As of 2012, utilities are also allowed to include solar in their power supply scheduling.

Although the current structure of Japan's grid infrastructure will serve as a barrier to renewable energy electricity deployment in general, due to a high level of vertical integration in the grid, high market concentration, and weak regional interconnections, increased installation of distributed solar PV should not face significant grid challenges, for the most part, as long as it is deployed near demand centers.

Wind

KEY DRIVERS

Strong industrial base and innovation support, investment subsidies for generation projects, new renewable energy policy framework announced in 2011.

KEY CHALLENGES

Social acceptance, complicated regulatory processes, vertically integrated electricity market with regional monopolies.

TRENDS IN MARKET SIZE AND VALUE CHAIN

Installed Capacity | Despite its significant potential, Japan is currently not a large user of wind power. Assessments by the ministries of the environment and of the economy estimate a technical potential of between 280 and 290 GW for onshore wind and around 1500 GW for offshore wind. Assuming a 15 year feed-in-tariff of JPY 15/kWh ($0.19/kWh), around 100 GW of additional onshore wind would be economically viable as well.[188] However, the current installed capacity in 2011 was only 2.5 GW, which means that Japan missed its national target of 3 GW set for 2010. As shown in Figure 35, the cumulative installed capacity has grown from 144 MW to 2440 MW between 2001 and 2010, with annual capacity additions between 151 MW and 405 MW. The market has fluctuated to some extent, but remained relatively small. New installations reached a historic low in 2011, after subsidy programs were cancelled in anticipation of a new feed-in-tariff scheme to be introduced in 2012.

Figure 35 | **Installed Wind Capacity for Japan, 2000 – 2011**[189]

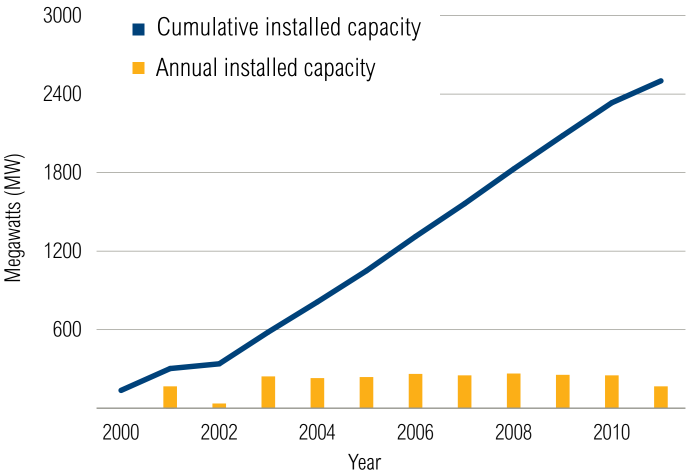
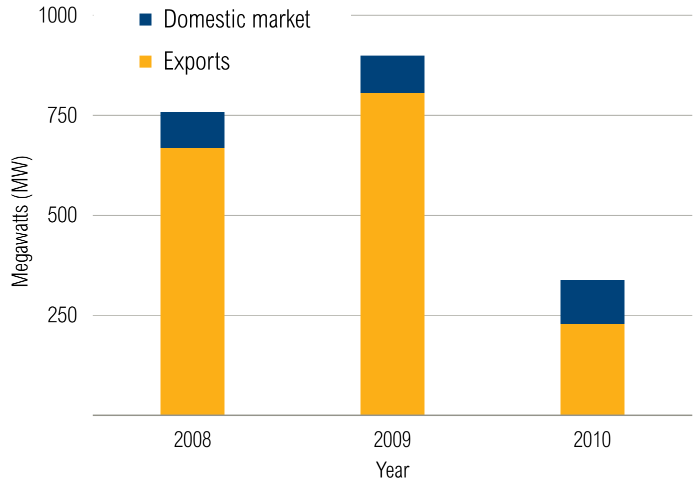


Figure 37 | **Destination of Japanese Turbine Output, 2008 – 2010**[196]



Wind Manufacturing | Japan has a number of companies manufacturing wind power equipment and the turbine manufacturing capacity in the country has increased from 0.25 GW in 2005 to 2.04 GW by the end of 2011.[190] The three largest manufacturers are Mitsubishi Heavy Industry, Japanese Steel Works, and Fuji Heavy Industry. Currently, Japanese manufacturers have a market share of around 23 percent in the domestic market.[191] Over time, this share has increased, from 6.6 percent in 2001 and 17.6 percent in 2006. Nonetheless, European and North-American manufacturers have supplied a majority of the turbines currently in operation in Japan (see Figure 36).[192]

Japanese wind power manufacturers export a large share of their production, primarily to the United States and, to a much smaller extent, to neighboring countries in Asia (see Table 5). Exports declined significantly in 2010 (see Figure 37). While Japanese manufacturers have been able to capture a slightly larger share of their small domestic market, they have lost market share abroad, as countries such as China and the United States increasingly developed their domestic wind industries and new players from China and India were able to compete in the smaller Asian markets. In 2010 and 2011, as the domestic Japanese market was shrinking, the industry was not able to make

Figure 36 | **Turbine Supplier Share in Newly Installed Capacity, 2011**[193]

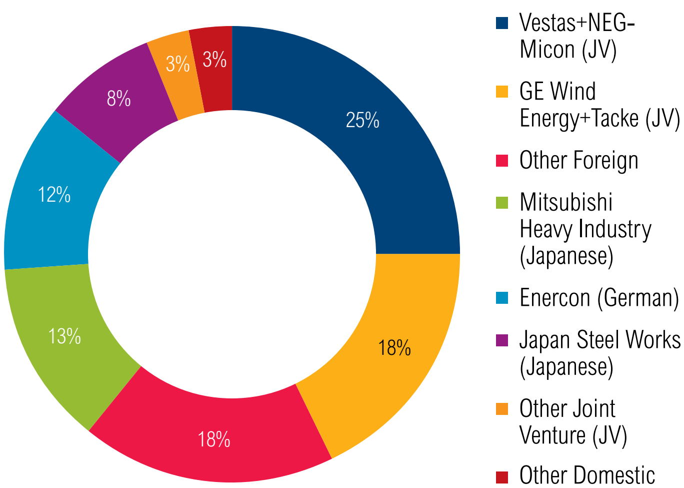
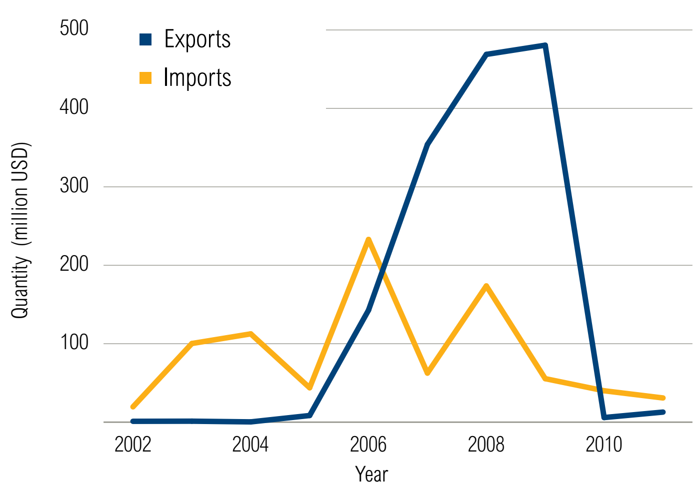


Figure 38 | **Japan: Imports and Exports of Wind Turbines, 2002 – 2011**[197]



Note: Data collected as defined under HS code 850231 (wind turbines)

Table 5 | **Japan's main trading partners for wind turbines (HS code 850231)[195]**

TOP 5 EXPORT PARTNERS 2002–2011 (US$)			TOP 5 IMPORT PARTNERS 2002–2011 (US$)		
USA	$1,432,347,533	65%	Germany	$542,437,283	62%
Bulgaria	$17,838,201	14%	Denmark	$277,545,799	32%
China	$11,170,348	7%	Spain	$34,655,685	4%
Viet Nam	$4,745,277	4%	Rep. of Korea	$5,500,870	1%
Rep. of Korea	$2,341,655	3%	India	$2,816,638	0%
Other partners	$7,744,999	6%	Other partners	$8,737,959	1%
Total	$1,476,188,013		Total	$871,694,234	

up for lost domestic sales through international exports. Without a larger and more steadily growing domestic market, it may be difficult for Japan to retain a competitive wind power manufacturing industry in the long run.

On the other hand, Japan is one of the leading suppliers of some key components of wind power generators. For example, three of the top five industrial bearings suppliers in the world are Japanese (NSK, NTN, JTEKT).[194] Japanese industries are likely to benefit from the increasing demand for wind turbines at least in the near term.

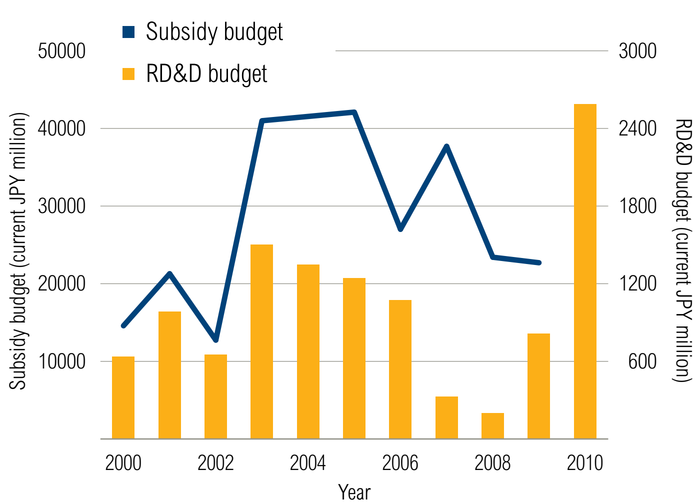
Jobs | No official job estimates exist for the entire wind energy value chain in Japan, including research, manufacturing, project development, installation, and operations and maintenance. Estimates for the employment generated in Japan's wind power manufacturing industry with its annual turnover of JPY 300 billion range from 3,000 (IEA) to 5,000 jobs (The Japan Society of Industrial Machinery Manufacturers).[198]

KEY POLICIES AND IMPACT ON WIND COMPETITIVENESS

Government support of wind power technology R&D began in 1978 under the Sunshine Program, which started in 1974 and continued until 2000, to develop new and renewable energy supply technologies following the first oil crisis. The main fields of R&D regarding wind power today are: next generation wind turbine technology, offshore wind power technology, battery back-up technology, and grid stabilization.[199] R&D of deep water offshore wind power technology is important for large-scale wind power deployment in Japan because the shallow water area in the Japanese exclusive economic zone (EEZ) and territorial waters is limited.[200] Despite its importance, it is only in 2008 that the government started supporting R&D activities on offshore wind power technology through NEDO. Grid stabilization is particularly important in Japan to integrate intermittent renewable electricity because the grid interconnectivity between regions is relatively weak throughout the country. Therefore, the development of battery technologies as well as wind power forecasting systems is crucial for successful large-scale deployment of wind power. The annual government spending on wind power research and development was relatively consistent between 2000 and 2006, but it has fluctuated significantly in recent years, from JPY200 million in 2008 ($1.7 million in 2010 dollars) to over JPY2.5 billion in 2010 ($23.2 million) (see Figure 39).

The main policies to accelerate wind power deployment have been the Renewables Portfolio Standard (RPS) and various investment subsidies. There is no specific RPS target for wind power as the RPS applies to new and renewable energy sources as a whole, but the contribution of wind energy has exceeded one-third in recent years. The largest subsidy has been distributed through

Figure 39 | **Investment Subsidies and RD&D Support Budgets for Wind Power in Japan between 2000 and 2011[201]**



the New Energy Development Support subsidy system administered by the Ministry of Economy, Trade and Industry (METI), which covers nearly 30 percent of the initial investment (Figure 39). The RPS with its relatively modest targets did not provide a strong demand-pull for wind power. In 2011, it was announced that Japan would introduce a feed-in-tariff scheme for several renewable energy sources, including wind power. This scheme entered into force on July 1, 2012 and obliges electric utilities to purchase all electricity form eligible renewable energy sources.[202]

In the anticipation of the shift to a FIT regime, the old investment subsidy regime was discontinued at the end of FY2009.[203] This helps explain the decline in new installations in 2010 and 2011 and illustrates the impacts how sudden policy changes and policy uncertainty can have on a market. With the FIT in place since July 2012, the Japanese wind market can be expected to begin building again.

One of the most important barriers to larger deployment of wind power in Japan is the structure of the electricity market with vertically integrated, regional monopoly utilities and, until recently, no clear rules for interconnection and dispatch. This has made it very difficult for wind power projects to be connected to the grid and to be able to sell their power. As part of the 2012 FIT Act, new rules are now in place that guarantee priority access to the grid for renewable energy sources.

Two additional issues are mentioned by industry experts that slow deployment in the wind industry. Compared to other countries, the regulatory requirements are higher and the permitting process thus more difficult in Japan. For example, in 2007 the new building code classified wind turbines as "buildings" imposing several new restrictions and creating uncertainty for investors, leading to a significant drop in new installations that year (see Figure 35).[204] It has also been reported that environmental impact assessments take 3 years to complete.[205] An important issue regarding the impacts of wind turbines on the ecosystem is the bird strikes involving rare raptors including Golden Eagles and Steller's Sea Eagles, which are designated as national monuments.[206] Finally, as wind turbines are still relatively rare in Japan, there may be issues around public acceptance that could be addressed by transparent and participatory planning processes.

China

Key National Targets and Key Policies for Renewable Energy

Chinese support for clean technology is largely driven by the country's pursuit of multiple avenues to increase electricity generation capacity to meet rapidly expanding demand. The first important piece of legislation for domestic renewable energy deployment was the Renewable Energy Law (enacted in 2006). The law did not move domestic deployment forward significantly in itself, but by adding a renewable energy premium and introducing medium and long-term renewable energy targets there was certainty in the market of the importance that the government was placing on renewables moving forward.[207]

Deployment has been driven primarily by government targets while support policies have been tied into broader economic development goals. However, the emphasis placed on supporting domestic deployment of technologies has been a relatively recent phenomenon, as is evidenced by the fact that targets and R&D support for utility-scale renewable energy only emerged in China's most recent 11th (FY 2006–2010) and 12th (FY 2011–2015) Five-Year Plans (FYP) for National Economic and Social Development.[208]

China's 12th FYP includes targets of 17 percent less carbon dioxide emissions and 16 percent less energy consumption per unit of GDP by 2015 in relation to levels in the base year 2010. The target for non-fossil resources in primary energy consumption is 11.4 percent by 2015 and 15 percent by 2020.[209] Specific targets for grid-connected solar PV and wind power by 2015 currently stand at 21 GW and 100 GW, respectively.[210] In addition to national targets there is also a requirement for power generators with an installed capacity of more than 5 GW to produce 8 percent of electricity from non-hydro renewable sources by 2020.[211] Since most power generators in China are large state-owned enterprises with a capacity of more than 5 GW, this impacts the quantity of electricity produced from renewables significantly.

Targets have also been put in place to encourage increased innovative activity, including a target for R&D expenditure to account for 2.5 percent of GDP. During the 11th FYP period, an estimated 15.3 percent of government stimulus funding was directed towards innovation, energy conservation, ecological improvements and industrial restructuring.[212]

Solar PV

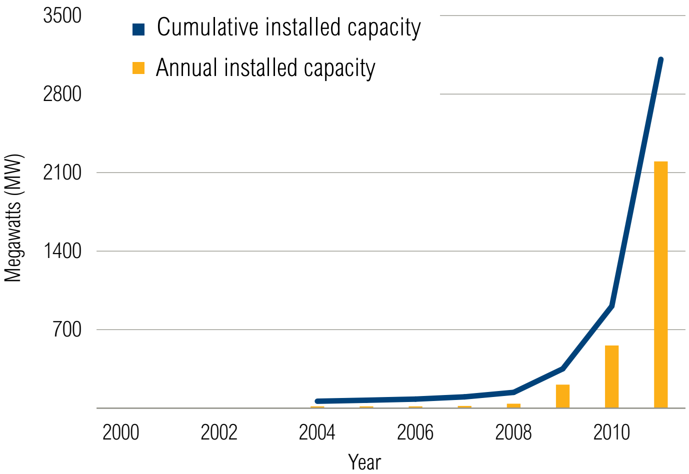
KEY DRIVERS
Growth in energy demand, industrial manufacturing base, recent aggressive solar PV deployment targets, low system costs.

KEY CHALLENGES
Manufacturing industry facing oversupply conditions, potential increases in trade barriers as importing countries react to falling prices.

TRENDS ON MARKET SIZE AND VALUE CHAIN

Installed Capacity | In the last few years the domestic market has grown exponentially (refer to Figure 40). In 2012, China is a multi-GW market, driven by various national and provincial programs. The rate of installations has consistently exceeded national targets. The 2,200 MW installed in 2011 (1.8 GW from large-scale ground mounted installations and 400 MW from rooftop projects) brought cumulative capacity to 3,093 MW. Authorities now forecast a 4 to 5 GW market in 2012, placing China in the global top three markets.[213] However, competitors are concerned that protectionist measures will mean that this market will not be accessible on a wide scale to international developers and manufacturers.

Figure 40 | **Installed Solar PV Capacity for China, 2004 – 2011**[214]



Solar PV Manufacturing | In 2009, the deployment of solar panels in China had hardly started. Yet with about 26 percent of worldwide production capacity in 2008[215] (of which 98 percent was exported), the Chinese industry was already the world's leading producer of PV cells and modules, without significant local deployment of PV systems.

There are a significant number of suppliers in each segment of the supply chain. The number of Chinese suppliers is highest in cell and module production as these segments require a lower level of technical knowledge and lower capital costs to start a production facility. In fact, China has seen exponential growth in this portion of the value chain with only 1.7 percent global market share in 2003 to nearly 50 percent of global market share for solar PV modules in 2010[217] and 60 percent of global production capacity.[218]

Recent overcapacity conditions in the global solar PV market are impacting Chinese manufacturers. It is estimated that out of 728 solar PV manufacturers, 300 have halved output or shut down entirely by the end of 2011.[219] At the same time, however, several Chinese firms have experienced positive gross margins during this same time period, including China's four key module players: Trina Solar, Yingli, JA Solar and Suntech.

Chinese module players have expanded their business into upstream and downstream activities, including polysilicon manufacturing and PV system installation. Investments in ingots and silicon production were made to hedge against volatile spot markets, but China's polysilicon industry is facing its biggest challenge since its founding, with over 80 percent of manufacturers closing down operations in 2012.[220] Of the over 40 polysilicon manufacturers in China only 6 or 7 remain operational because of the plunging prices, higher than average production costs,[221] quality concerns of domestic manufacturers, and global overcapacity in this portion of the value chain. Chinese firms continue to import about half the polysilicon utilized in the industry from overseas.[222] In fact, large Chinese players, such as Yingli Solar continue to import about 90 percent of their polysilicon needs from producers in the U.S., Germany and Korea.[223] The survivors in the industry are large diversified companies that manufacture products outside of the solar supply chain, or integrated solar PV manufacturers, such as Renesola. The introduction of government mandates on minimum production capacities, efficiency and environmental standards, along with tightened monetary policy, has driven further consolidation in the industry.

Jobs | Estimates of the direct jobs in the Chinese solar PV industry in 2007 were about 82,800.[224] A breakdown of these numbers reveals that about one-third of the employment was in module manufacturing, while the proportion of jobs in ingot, wafer and cell manufacturing combined was less than 30 percent.[225] Very few jobs had been created in the production of polycrystalline silicon materials and installation, due to the fact that most of the raw materials were imported from overseas and over 90 percent of PV products were exported to foreign markets. One would expect the proportion of jobs in installations to have increased in the last few years, due to much high annual installations, even though a breakdown of these figures is not available.

Figure 41 | **Annual Production of Wafers, Cells and Modules in China, 2000 – 2011**[216]

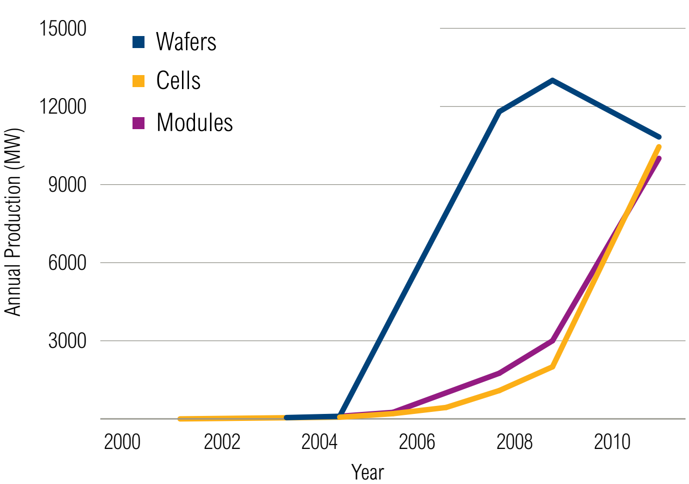
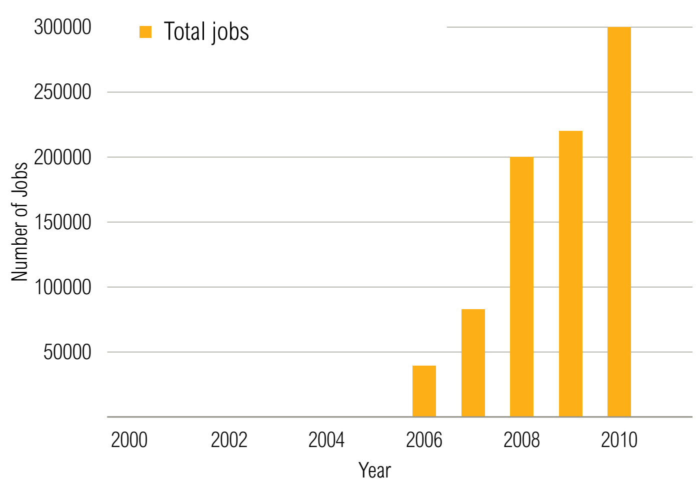


Figure 42 | **Solar PV Jobs in China**[226]



KEY POLICIES AND IMPACTS ON SOLAR PV COMPETITIVENESS

Policies and incentive mechanisms that support market deployment, domestic manufacturing, and R&D have all been introduced in China through targets that support broader economic development goals. This provides market certainty to companies, investors and developers.

Support for domestic deployment | Solar PV has played an increasingly important role in China's 12th FYP. The plan initially included a target of 15 GW of solar PV by 2015, which was raised to 21 GW by 2015 in the latest version of China's Five-Year-Plan as of July 2012, giving a clear indication to industry of the importance that the government is placing on domestic solar energy deployment.[227]

Solar PV deployment increased from 2009 onwards when the following amendments and additional programs were introduced:

- An amended law requiring power suppliers to buy electricity produced by renewable energy generators.
- Subsidies and feed-in tariffs introduced through the "golden roofs" initiative (targeting installed capacity of roof-mounted PV systems).
- Investment subsidies of 50 percent[228] of project costs through the "golden sun" program (targeting installed capacity of larger utility scale projects above 300 MW, rather than electricity production). According to the Chinese Renewable Energy Industry Association (CREIA) this program will support the commissioning of about 1 GW of large installations in 2012.
- Low-interest financing for state-backed banks such as the China Development Bank.
- Concession bidding[229] programs that award project concessions at preferential tariff rates to developers through a bidding process. This is an effective mechanism for reducing the price of installed solar PV systems while providing a generation subsidy.

However, the biggest increase in domestic installed capacity corresponded to the introduction of the national feed-in tariff in 2011 at fixed rates of RMB 1.15/kWh (US$ 0.182/kWh) for PV generation projects completed before July 1st, 2011, and RMB 1/kWh (US$ 0.158/kWh) for projects completed after that date. Some local governments that launched FIT programs before this national tariff are still complementing the national FIT with additional bonuses.

In addition to the national incentives for solar PV, provincial and local governments provide incentives and programs that vary by location and technology type.

Support for the Domestic Manufacturing Industry | The key support measure for manufacturers is access to capital through preferential loans and subsidized interest rates (the U.S. government estimates that bank interest rates are as low as 1 to 2 percent[230]), through government-supported banks, often with extended credit terms of up to 20 years.[231] In 2010, state-backed China Development bank awarded $17 billion in loans[232] to SunTech, Trina, and Yingli. In addition, tax credits and subsidies, favorable industrial policies, and the availability of low cost financing have all helped to support a robust manufacturing industry.[233]

In addition to supporting the manufacturing industry through specific policies, the way the Chinese manufacturing industry functions helps to encourage increased innovation. There is a tendency for large PV manufacturers to develop partnerships with overseas equipment suppliers, sharing know-how and feedback to improve the manufacturing process. Although this may include temporary exclusivity clauses, such partnerships make it possible for equipment suppliers to redistribute this know-how to other customers, thereby accelerating the circulation of knowledge across the industry. In addition, foreign firms set up joint ventures in China as opposed to fully owned subsidiaries, which increases the flow of know-how to Chinese actors.[234]

R&D and innovation system support | R&D for solar PV is supported through three key national programs:

- The Key Technology R&D Program, which was the country's first national R&D program to support innovation in a broad range of socioeconomic sectors, including energy.
- The High Technology Development Plan (873 Program), which is the most well-funded government innovation program to stimulate a wide range of technological fields, with renewable energy identified as a key focus of the program through China's Five-Year Plans.
- The National Basic R&D Program (973 Program), which complements the 873 Program through more basic research, with sustainable development and energy as key areas since its founding in 1998.

In addition, mandated increases in efficiency and environmental standards help to encourage increased efficiencies in manufacturing processes, which reduces costs and forces consolidation in the market. This was most recently exercised in the polysilicon industry in which new requirements for increased production capacity, lower energy consumption, and more stringent environmental standards were introduced for manufacturers in January 2012.[235]

Publicly supported low-carbon economic clusters have been developed (including a cluster of cities in Jiangsu and Hubei province), which also facilitate innovation and entrepreneurship.

It is widely believed that China's success is due to low labor costs, but labor costs are estimated to account for just 3–4 percent of the cost of making solar panels, making other factors, such as materials and cost of equipment more significant. Stuart Wenham, CTO of Suntech Power, argues that the real causes are advances in automated manufacturing technology that have improved solar cells' performance and cut costs.[236] In addition to advances in manufacturing technologies, large Chinese firms, including Suntech and Trina Solar, have also pursued aggressive recruitment strategies to hire top level managers who have been trained in industrialized countries to quickly build industry knowledge domestically.[237] Starting in 2012, provinces such as Jiangxi and Sichuan are also opening technical and vocational colleges to train domestic solar PV professionals.

Wind

KEY DRIVERS

Ambitious deployment targets, rapid deployment supported first by concession bidding and later a feed-in-tariff, targeted innovation strategy, industry-research collaboration.

KEY CHALLENGES

Interconnection and transmission challenges, lack of standards and processes to ensure quality.

TRENDS IN MARKET SIZE AND VALUE CHAIN

Installed Capacity | China's wind power potential is very large. The commercial onshore potential is estimated between 1,000 and 4,000 GW, with an additional 500 GW of offshore potential. Since 2009, China has been the largest wind power market in the world, adding more capacity each year than any other country. In 2010, China also became the country with the largest total installed capacity (see Figure 43).[238]

Total installed capacity in China was 62364 MW at the end of 2011. Between 2006 and 2009, installed capacity had doubled each year in China. Since 2010, growth in annual installations has slowed down and stabilized around 18 GW in 2011 (see Figure 44). Wind power provided around 1.5 percent of China's electricity demand in 2011.[240]

Figure 43 | **Cumulative Installed Wind Capacity, 2001 – 2011**[239]

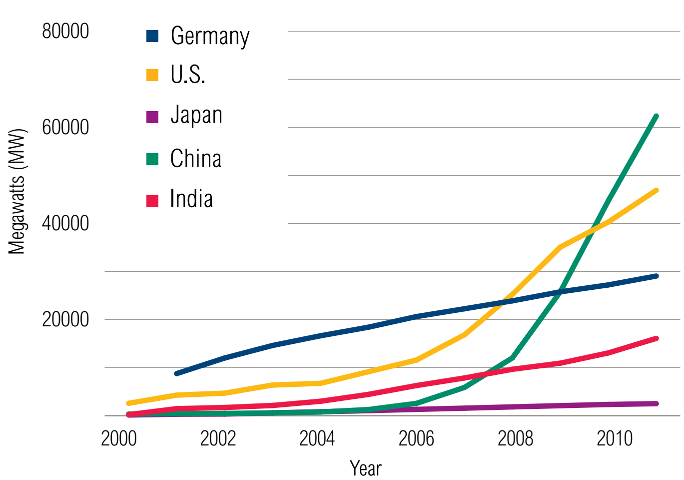
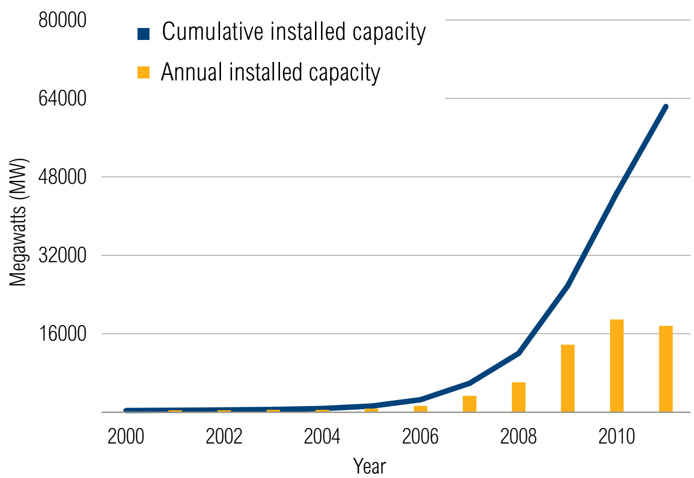


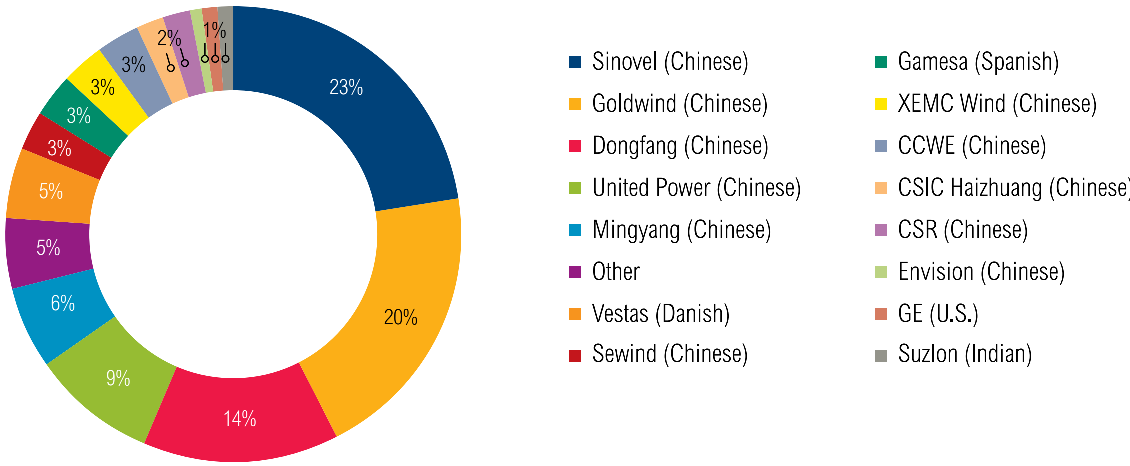
Figure 44 | **Installed Wind Capacity for China, 2001 – 2011**[241]



Wind Manufacturing | When China began installing wind turbines, most of the equipment was imported from the leading global manufacturers. Due to the large size of the Chinese market and local content requirements enforced by the authorities through 2009, most international manufacturers set up assembly and production facilities in China. At the same time, a domestic-owned industry developed quickly. The turbine manufacturing capacity in China has increased exponentially from 0.78 GW in 2005 to over 70 GW in 2011.[242] In 2010, Chinese manufacturers had a market share of at least 85 percent on the domestic market (see Figure 45).[243] Four Chinese manufacturers (Sinovel, Goldwind, United Power, Mingyang) were among the global top ten in 2011.[244] While the first years of rapid growth in installations saw the emergence of many small manufacturing companies, there are now trends toward industry consolidation giving more importance to the large players such as Sinovel and Goldwind.

The Chinese wind industry is predominantly focused on the domestic market. In 2011, Chinese exports of wind power generating equipment were only 27 percent of German exports in the same time period.[246] Nonetheless, the leading Chinese manufacturers are beginning to pursue a more active export strategy and exports have been growing in recent years. Since 2008, China has been a net exporter (see Figure 46). Chinese manufacturers export to all continents (see Table 6). Often, the project development subsidiaries of the large Chinese turbine manufacturers develop the projects, using financing from Chinese investors or banks.

Figure 45 | Top 15 Chinese Wind Turbine Manufacturers and Their Share in New Installations in 2010[245]

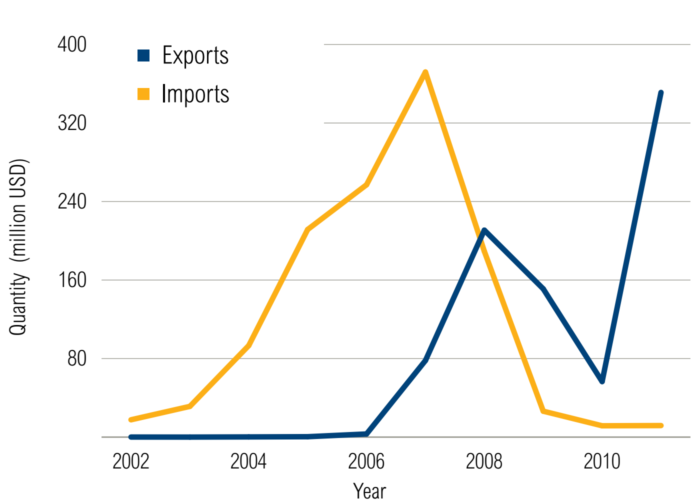


Jobs | Estimates of the employment generation in the Chinese wind industry vary between 80,500 and 297,000 jobs.[249] A break down provided in the "Study on Low Carbon Development and Green Employment in China"[250] shows that in 2010, about half of the employment was in manufacturing, while the other half was in installation, operations and maintenance. While the total output of the wind manufacturing industry has not declined, employment has been reduced. This is most likely due to the consolidation of the industry and improving productivity.

KEY POLICIES AND IMPACT ON WIND COMPETITIVENESS

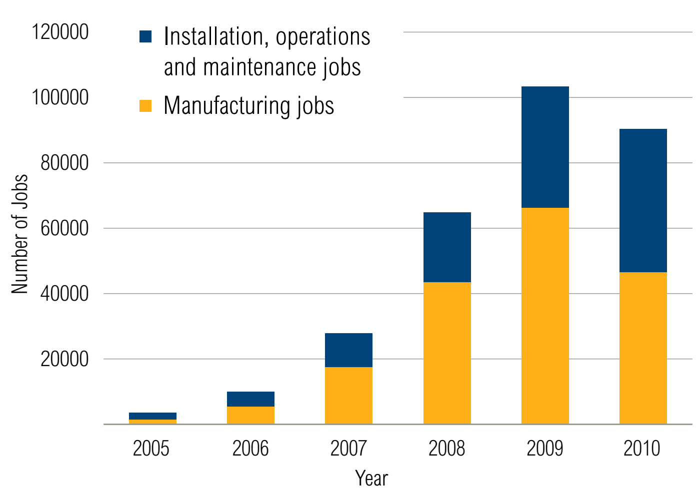
Market Creation | The spectacular growth in wind deployment has been driven by clear targets for the expansion of non-fossil fuel electricity, including specific targets for wind in national five-year economic development plans. In the context of the 12th five-year plan that entered into force in 2011, the wind energy target was increased to 100 GW of installed capacity by 2015.

Figure 46 | China: Imports and Exports of Wind Turbines, 2002 – 2011[247]



Note: Data collected as defined under HS code 850231 (wind turbines)

Figure 47 | Wind Power Jobs in China[251]



The second key driver includes the concession bidding[252] mechanism that was introduced in 2003 to accelerate the deployment of wind power. This provided the industry with a degree of certainty about the market size over the coming years. For each concession, the developer was determined based on the offered power rate and the share of local content. The winning bid price was guaranteed for 15 years. In July 2009, the support policy was changed from the bidding mechanism to feed-in tariffs, differentiated by four classes of wind resource areas.[253]

Explicit Support for Domestic Industry | China's wind power manufacturing has grown in parallel with the market. This was explicitly encouraged through a local content requirement that mandated a 70 percent share of local content for all wind concessions. It has been argued that the requirement might not have been necessary as most international manufacturers would have located some of their production in China anyway, due to the size and attractiveness of the market.[254] This requirement was dropped in 2009 but by that point, there was a strong Chinese wind industry, and the local content has not dropped below 70 percent since.[255]

China has also provided easy access to financing at attractive conditions for new wind power manufacturers, along with a subsidy of 600 RMB/kW for the first 50 MW-size wind turbines produced by a company as well as an import tax exception for raw materials and components needed by wind power manufacturers.

Innovation Support and R&D | The Chinese government made a strategic decision to develop the wind power industry and implemented a comprehensive innovation strategy to get there. Wind power is included in the National Mid- and Long-Term Science and Technology Development Plan for 2006–2020. Research and Development are supported both through national basic R&D program (known as the 973 Program) and the national high technology program (863 Program). Issues addressed in these programs include wind resource evaluation, wind turbine aerodynamics, wind power systems, sea wind access, and wind power applications.[256] Nine key laboratories and research centers focused on wind power bring together researchers from the industry and research institutes, so that research findings can be rapidly put into practice and networks of experts can emerge. In 2010, the government invested US$1.3 billion in clean energy R&D, including wind.[257]

Addressing grid and quality issues | China's wind energy policy has focused strongly on increasing capacity and on building a domestic industry. Initially, little attention was being paid to ensuring that projects were being connected to the grid and that the grid infrastructure was able to handle large amounts of wind power.[258] For the past few years, up to a third of Chinese wind capacity was not connected to the grid at any given time. The government is taking steps to address this issue, including a new approval requirement for wind farms at the central level, to ensure that local grid expansion can be planned. In addition, the government is now encouraging wind energy project development in lower wind speed regions that are closer to load centers, rather than relying on the large, remote wind bases alone that require the construction of new transmission lines. [259]

In the early years of wind power deployment there were also reports of technical difficulties with turbines and projects not achieving the projected capacity factors. A new series of standards, certification requirements, regulations for wind farms, as well as a grid code with specific standards for wind projects are being put in place to address these issues.[260]

Table 6 | **China's main trading partners for wind turbines (HS code 850231)[248]**

TOP 5 EXPORT PARTNERS 2002–2011 (US$)			TOP 5 IMPORT PARTNERS 2002–2011 (US$)		
USA	$326,804,040	38%	Spain	$456,451,763	37%
Other partners	$320,435,547	38%	Italy	$315,544,735	26%
India	$55,913,368	7%	Denmark	$187,057,320	15%
Australia	$54,283,139	6%	Germany	$175,943,529	14%
Denmark	$53,318,378	6%	Australia	$49,829,687	4%
Argentina	$40,744,301	5%	Other partners	$36,897,058	3%
Total	$851,498,773		Total	$1,221,724,092	

India

Key National Targets and Key Policies for Renewable Energy

In 1992, India was the first country in the world to create a ministry devoted solely to the promotion of non-conventional and renewable energy sources, though convention fossil fuels continued to dominate the national energy strategy. Current renewable energy development India has largely been guided by the National Action Plan on Climate Change (NAPCC), which was launched in June 2008 and contains an aspirational target of 15 percent electricity consumption from renewable energy sources by 2020.[261] NAPCC laid the foundation for the Jawaharlal Nehru National Solar Mission (JNNSM), which sets out ambitious targets for solar capacity and outlines a framework for developing holistic policy support including R&D, manufacturing development, and market deployment.

At the national level renewable energy generation is encouraged through a combination of incentive mechanisms which include tax incentives, generation based incentives, capital subsidies, and feed-in tariffs for some technologies such as solar. Unlike many countries, feed-in tariffs in India are not adjusted for inflation on an annual basis.[262] In addition to these incentive mechanisms there is also a Renewable Portfolio Obligations (RPOs)[263] scheme with a tradable renewable energy certificates mechanism,[264] which is implemented at the state level but not enforced by all states. Some state RPOs include a minimum amount of solar and/or wind electricity while others are technology neutral.

State level incentives have played a more important role in determining where domestic renewable energy deployment and manufacturing facilities are established, primarily through a combination of attractive feed-in tariffs and tax benefits.

The Indian government also publishes official targets for renewable energy deployment in the national Five-Year Plans. By the end of the 11th Plan (2007/08–2011/12) the target of power from renewable energy sources (excluding large hydro) was 4.4 percent and this was increased to 5.4 percent in the 12th Five-Year Plan (2012/13–2017/18).[265] The NAPCC, on the other hand, enshrines a much more ambitious target of 15 percent of renewable energy by 2020.[266]

Although all renewable sources except for biomass plants above 10 MW have dispatch priority,[267] grid strength and integration represent major hurdles for renewable energy deployment since transmission losses in the grid system were as high as 25 percent of all electricity generation in 2009.[268]

Box 1 | **India's Key Solar Targets**

SOLAR TECHNOLOGY	PHASE 1 (2010–13)	PHASE 2 (2013–17)	PHASE 3 (2017–22)
Grid-connected	1,000 – 2,000 MW	4,000 – 10,000 MW	20,000 MW
Off-grid	200 MW	1,000 MW	2,000 MW

*Targets are stated as technology neutral, so there is no specific solar PV target; although approximately 500 MW of PV and 500 MW of CSP were targeted for Phase I.

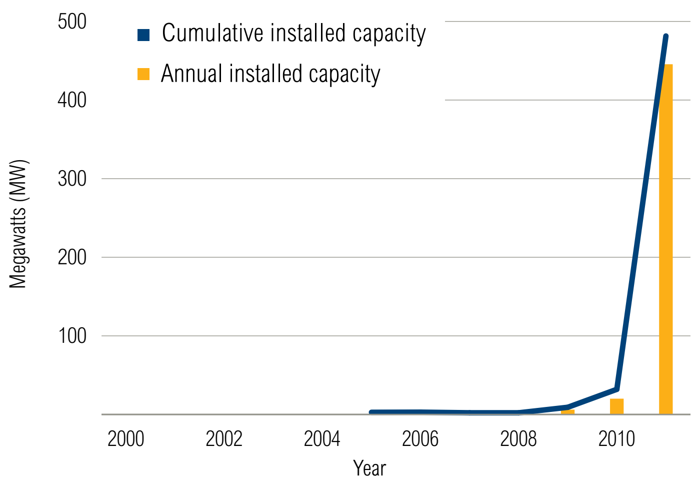
Source: JNSM document.

Solar PV

TRENDS IN MARKET SIZE AND VALUE CHAIN

Installed Capacity | The relatively nascent solar industry is beginning to take shape in India, with about 500 MW of capacity installed by the end of 2011, of which 446 MW were installed in 2011 alone.[269] Although this represents a significant jump for India over previous years, this quantity is dwarfed in comparison to the annual installations of China, the U.S., Germany, and Japan in 2011 which ranged from 1,295 MW (Japan)[270] to 7,500 MW (Germany)[271] in the same year.

Figure 48 | **Installed Solar PV Capacity for India, 2000 - 2011**[272]

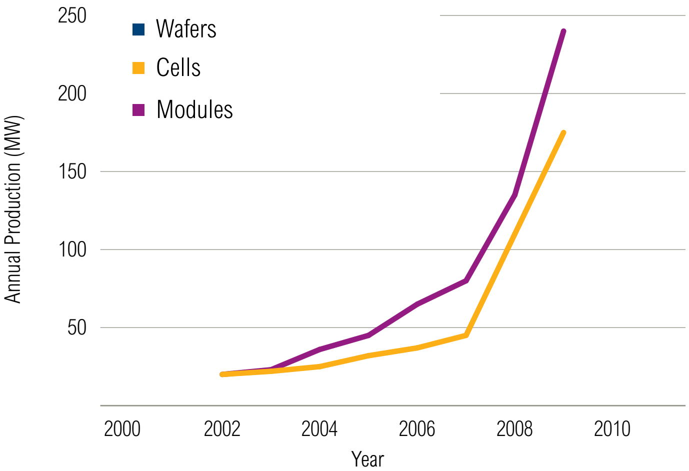


Solar PV Manufacturing | India's solar PV manufacturing industry consists primarily of cell and module production, with much of this coming online in the last two years according to industry estimates.[273] There has been a relatively steady increase in annual manufacturing capacity since 2002, with a more accelerated rate since 2007. Manufacturing was established before the push for domestic deployment started in 2009. The country has been a net exporter of solar PV technology, with exports accounting for about 66 percent of cumulative domestic PV production till 2009. Solar PV cells are the main export products with the German market alone accounting for nearly half Indian-manufactured solar PV exports.[274]

According to Ministry of New and Renewable Energy (MNRE), approximately 90 companies operate in the solar PV manufacturing segment.[276] Around 15 companies manufacture PV cells, 20 manufacture PV modules, and 50 companies assemble and supply solar-based systems (including both PV-based and thermal-based systems).[277]

Solar PV manufacturing's narrow focus on cells and modules has resulted in a largely fragmented industry. The bulk of India's solar PV industry is dependent on imports of critical raw materials and components, including polysilicon, ingots, and wafers. This not only exposes Indian PV manufacturers to foreign exchange fluctuations but means that the only avenue for cost reduction potential is through production yields of cells and modules. Competitors in other countries are able to pursue vertical integration to reduce margins.[278] Smaller manufacturing production capacity also limits the ability to achieve economies of scale, challenging the cost reduction potential within the domestic industry.

Figure 49 | **Annual Production of Wafers, Cells and Modules in India, 2002 - 2011**[275]



Jobs | There is a lack of information on employment numbers in the solar PV industry in India. The only estimates available are from Ministry of New and Renewable Energy (MNRE). They have estimated that there were about 112,000 jobs in the solar PV industry in 2009[279] and they suggest that approximately 50 percent of the value chain can be attributed to solar cells and modules.[280] Although solar manufacturing has the potential to generate jobs, this may not be the optimal route for short-term job and value creation, given the resource- and investment-intensive requirements of this segment of the value chain and some of the inherent challenges that India faces, as outlined in the following section.

KEY POLICIES AND IMPACTS ON SOLAR PV COMPETITIVENESS

The Indian government has used a phased approach to develop the solar industry, with an initial push for domestic manufacturing followed by the focus on deployment through progressively more ambitious solar PV targets. Although there are a number of national incentives (as outlined below), state level incentives such as feed-in tariffs have played a more significant role in influencing where solar PV development has taken place.[281] The first significant incentive for solar PV manufacturing was the introduction of the Special Incentive Package (SIPS) in 2007, which included subsidies, tax incentives, and duty exemptions for investments over US$200 million. This helped to push a five-fold increase cell and module manufacturing capacity in 2007,[282] although manufacturing production itself did not see as drastic of an increase.

The big push for domestic installations came with the launch of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2009.[283] The objective of the JNNSM is to establish India as a global leader in solar energy by creating policy conditions for competitive manufacturing and rapid deployment. To encourage deployment, the national government introduced policies to support installations through subsidies and loans and power generation through FITs and solar-specific RPOs. After an initial introduction of a generation based incentive program and fixed national FIT, with a cap on installation, the government now allocates projects through an auction to developers who offer to supply power at the lowest tariffs. This has been an effective mechanism to drive down solar PV prices in the domestic market. This auction approach is also being followed in most states, except Gujarat and Maharashtra, which continue to offer fixed feed-in tariffs. The Indian government has also introduced local content requirements to support and boost the development of a domestic manufacturing base for silicon cells and modules.

Although India had a similar strategy to China's development strategy for solar PV, with the development of an export-oriented manufacturing industry, followed by the development of a domestic installation industry, India has not seen close to the level of growth as China, largely due to a number of additional challenges in the Indian market context.

A mix of state and national policies has contributed to a largely fragmented market. Solar PV manufacturers face systemic limitations, such as underdeveloped infrastructure (lack of continuous power and water supply) and a relatively high cost of capital, which slows both manufacturing investments and investments in solar PV deployment projects. India also has a complex regulatory system for permitting and land clearances, which has caused delays in establishing facilities. Although manufacturing facilities have developed in clusters, inadequate national standardization has led to the development of disorganized clusters of manufacturers catering to various, differing specifications in the market.

Solar PV developers also face significant challenges due to high lending rates and perceived risk from domestic banks, dispatching and payment uncertainties from state-owned utilities, land acquisition complexities, and lack of clarity on who pays for "last mile" infrastructure for grid connectivity.

The local content requirements that were introduced to support solar PV manufacturing have contributed to growth in production capacity for domestic crystalline silicon cells and modules, but not the use of these components in the domestic market, which was the intention of the policy. The high cost of domestic financing makes it more attractive for domestic developers to use imported thin film technologies as it can give them access low-cost international financing (9–10 percent interest for 15–18 year time horizons versus 11–13 percent for only 10 years).[284] Attractive import duties make importing solar cells more economical for Indian module manufacturers than buying from Indian cell producers, who face a 12.8 percent duty on component imports. In addition, zero import duty on completely built modules has put imported thin film technologies at a cost advantage. This has resulted in domestic installations shifting towards imported thin film (50 percent of batch 1 projects use thin film which is much greater than the proportion typically seen in the global PV market of only 17 percent; batch 2 projects use even more thin film because of increased local content requirements for domestic crystalline cells and modules).[285] In addition, the local content requirement drives up project costs by prohibiting access to cheap solar components and technology from abroad, and can slow the rate of solar installation until infrastructure for local manufacturing is established.

Indian manufacturers are looking to develop the upstream portion of the domestic solar value chain. Domestic manufacturers, such as Bhaskar Silicon, Lanco Solar, and Euro Multivision, are venturing into expanding their businesses through the production and processing of polysilicon. However, it is unclear whether this would provide a competitive advantage to the Indian solar PV industry since the manufacture of these upstream components is energy and capital-intensive, and facilities take a longer time to establish. In addition, India's R&D efforts focus on producing polysilicon with direct electricity consumption of less than 125kWh/kg, whereas in China the maximum energy use for operating facilities already has a target of 60kWh/kg as of the end of 2011,[286] which is significantly lower and puts Chinese manufacturers at an advantage at the outset.

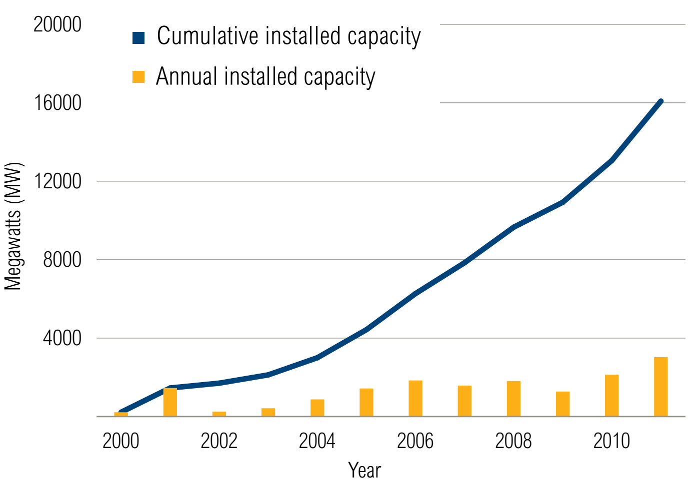
Despite the market distortions created by the local content requirement and the challenges solar PV project developers face, the two rounds of auctions conducted under the National Solar Mission have driven prices for grid-connected solar down to as low as Rs.7.49 ($0.15) per kilowatt-hour, reducing the subsidy burden and bringing utility-scale solar PV within range of grid-connected diesel generation.[287] India witnessed the largest growth (of 52 percent) in clean energy investments of any significant economy in the world in 2011, from $6.8 billion in 2010 to $10.3 billion in 2011. Much of this growth constituted a seven-fold increase in funding for grid-connected solar projects,[288] despite high lending rates in India. The private sector has played an important role in driving these investments and India is increasingly becoming a favored destination for venture capital and private equity financing. A number of state-backed funding sources have also emerged, including IREDA, PFC, REC, National Bank for Agriculture and Rural Development.[289]

On-Shore Wind

TRENDS IN MARKET SIZE AND VALUE CHAIN

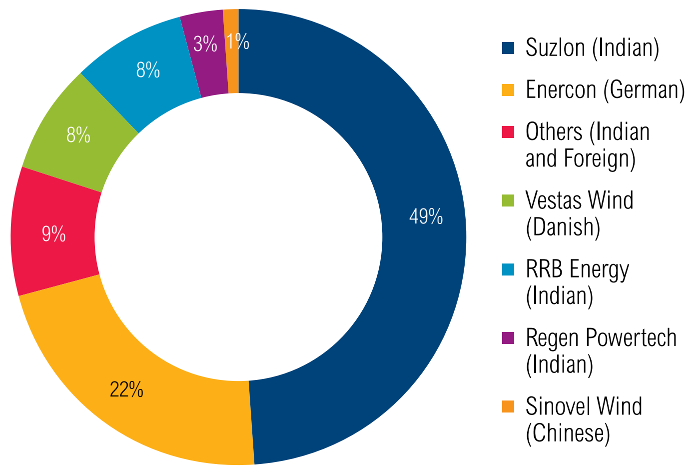
Installed Capacity | The wind power market in India began its initial growth in the mid-1990s and saw resurgence again in the early 2000s. By 2011 India had the fifth largest installed wind capacity base globally.[290] There has been a steady increase in new installations over the past six years, ranging between 1.5 GW and 3 GW annually[291] (see Figure 50).

Figure 50 | **Installed Wind Capacity for India, 2001 - 2011[292]**



Wind Manufacturing | India has built a strong wind manufacturing industry, with over 7.5 GW of manufacturing capacity on line by the end of 2010.[293] There were a total of 20 wind turbine manufacturers in the Indian market in 2010, up from 15 the previous year, with the entrance of new international wind turbine manufacturers.[294] India's major domestic wind turbine manufacturer, Suzlon, a leading global manufacturer, continues to maintain the majority share of the Indian market, but increasing competition from other players has forced a shift from 58.7 percent of newly installed capacity in 2008 to 48.8 percent in 2010.[295]

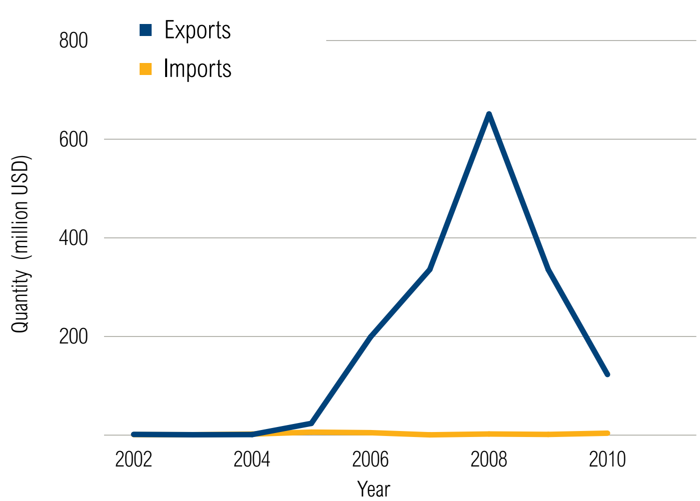
Figure 51 | **Turbine Supplier Share in Newly Installed Capacity, 2010[296]**



Manufacturing capacity has grown over 400 percent from 0.9 GW in 2005 to 4.6 GW in 2011, making India the fifth largest producer of wind turbines, with 4 percent of total production capacity, at the end of 2011.[297] However, capacity appears to far exceed actual production with manufacturers, maintaining reserve capacity in India to meet any surge in demand domestically and in export markets.[298]

While imports have remained low and relatively consistent, exports of wind equipment from India increased rapidly from 2005 to 2008, but have experienced a sharp drop since then, in line with the global equipment glut (refer to Figure 52 and Table 7).

Figure 52 | **India: Imports and Exports of Wind Turbines, 2002 - 2011[299]**



Note: Data collected as defined under HS code 850231 (wind turbines)

Table 7 | **India's main trading partners for wind turbines (HS code 850231)[300]**

TOP 5 EXPORT PARTNERS 2002–2011 (US$)			TOP 5 IMPORT PARTNERS 2002–2011 (US$)		
USA	$953,942,620	57%	Germany	$14,262,706	61%
Australia	$243,882,231	15%	China	$3,347,317	14%
Brazil	$225,944,891	14%	Spain	$1,537,880	7%
Portugal	$92,044,156	6%	Denmark	$797,658	3%
Spain	$63,563,212	4%	Singapore	$765,898	3%
Other partners	$92,390,941	6%	Other partners	$2,634,413	11%
Total	$1,671,768,051		Total	$23,345,872	

Until recently wind turbine manufacturers in India have provided complete turnkey solutions to investors in generation projects. Under this business model, wind turbine manufacturers have been a full service provider, manufacturing turbines, acquiring land permits and buying land for wind projects, installing turbines and providing operations and maintenance.

Jobs | There is a lack of information on employment numbers in the wind industry in India. MNRE estimates that there were 42,000 jobs in 2009[301] but the breakdown of jobs along the value chain is not available, making analysis of jobs difficult in the Indian context, particularly as manufacturing capacity is significantly larger than actual annual production.

KEY POLICIES AND IMPACTS ON WIND COMPETITIVENESS

Policy at both the federal and the state-level has played an important role in creating the demand that has driven growth in the wind industry.

Key national-level policies for manufacturing | The two large increases in manufacturing capacity have coincided with the introduction of key, stable policies with a time horizon of at least 3 years. The first increase in 2006 coincided with establishment of the renewable portfolio obligations and national renewable energy targets. The second, in 2009, coincided with both the aggressive renewable energy targets in the 2008 National Action Plan on Climate Change and the creation of generation based incentives, essentially a kWh premium for projects built between 2010 and the end of 2012.

Key national-level policies for deployment | On the national level three major incentives have supported the deployment market: accelerated depreciation, tax reductions and exemptions, and generation-based incentives. In the last four years, the government has moved away from solely relying on subsidy schemes that rewarded developers for installing wind capacity (through accelerated depreciation of up to 80 percent and tax holidays of 10 years) to mechanisms that incentivize generation capacity (through feed-in tariffs, generation based incentives, and renewable energy certificates). National feed-in tariffs are applied above any existing state feed-in tariffs.

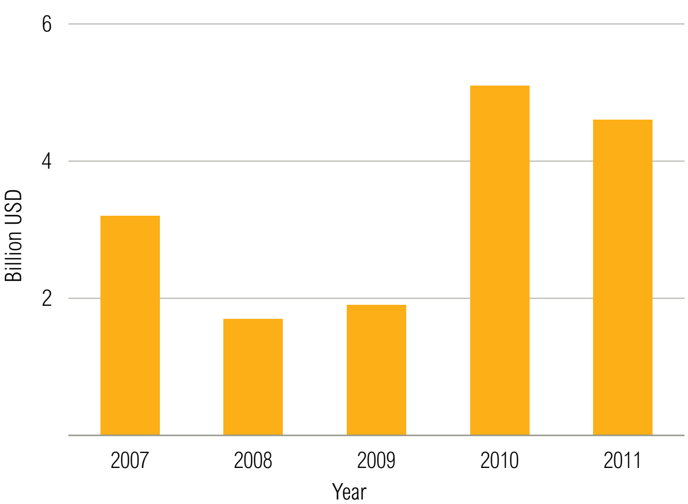
In March 2012, the federal level generation-based incentive program for wind expired and the federal government reduced accelerated depreciation allowances for wind projects from 80 percent to 15 percent of capital. This is expected to reduce the annual deployment rate going forward.

Key state policies | State policies and regulations have also played a critical role in the development of the wind industry in India. State level feed-in tariffs are a key mechanism for driving development but the level, duration, and structure of these tariffs vary by state and hence influence where projects are installed. In addition, state level tax incentives play a key role in determining where manufacturers locate facilities because tax incentives vary widely from state to state. Union territories[302] have awarded the most generous incentives to date, which is where most manufacturing facilities are located. Labor costs, quality of workforce, and access to ports are also factors in the decision of manufacturing facility location and hence wind industry clusters have tended to develop in more industrialized states with attractive tax incentives, like Maharashtra and Tamil Nadu.[303]

Rules for foreign equipment suppliers | Local rules make it very difficult to import completed wind turbines into India. Components can be imported and assembled in India, but all turbines installed in the Indian market have to be certified by the Centre for Wind Energy Technology (C-WET), a research and development institute within MNRE, to be eligible for grid connectivity and incentives. This certification process can take up to a year. In addition, foreign manufacturers are required to establish a local manufacturing facility and provide after sales services to be approved by C-WET.

Significant private sector investment has been flowing into the Indian wind power industry, up to US$4 billion to $5 billion dollars annually in the last two years (Figure 53).

Figure 53 | **Private Sector New Financial Investment in Wind Power in India, 2007 - 2011**[304]



ANNEX 2: SOLAR PV INDUSTRY VALUE CHAIN

VALUE CHAIN SEGMENT		APPROX. NUMBER / TYPES OF GLOBAL PLAYERS	KEY CHARACTERISTICS
Upstream (Research & Development, Key Input Materials, and Manufacturing)	R&D	Integrated solar firms, component suppliers, government-sponsored/ national labs	Mostly in-house at integrated solar firms and component suppliers
	Polysilicon Production	Global supply dominated by 10 suppliers[305] (52% of supply from 7 OECD firms and 18% from 3 Chinese firms), but many new entrants, estimated 70 suppliers[306] globally → shift from 2 years ago when industry dominated by 8 OECD firms	High entry barriers - Very capital and energy intensive production processes (Depreciation and interest contributes ~48%, and energy ~13% of manufacturing costs[307]), long learning curves to achieve desired cost structure, and long lead times of about two years[308] to establish facilities ■ Large scale production facilities required for economies of scale ■ Once manufacturing established, difficult to relocate facilities ■ Business strategies targeted toward competitiveness for global supply chain
	Other Materials		■ Glass, aluminum etc. needed for panels and other components ■ Can often leverage existing domestic manufacturing industries
	Wafer manufacturing	Around 250[309] companies globally: integrated solar firms, silicon suppliers, wafer-module manufacturers	Relatively high entry barriers -significant capital expenditures, need for high performance manufacturing equipment, high energy needs, significant manufacturing experience required for optimal manufacturing efficiency, and good customer relationships with global solar cell producers ■ Wafer's conversion efficiency, physical properties, and production cost contribute to solar cell's cost per watt of electricity generation
	Cell manufacturing	Highly fragmented - More than 350[310] companies globally: Pure cell manufacturers, wafer-module manufacturers, cell-system manufacturers, integrated solar firms	Relatively low entry barriers ■ High upfront capital investments needed for production facilities ■ Business strategies factor local and global demand markets, therefore consolidation due to rapid decrease in technology costs ■ Highly automated production processes so facilities can be established and/or relocated relatively quickly (~3 months), but larger facilities offer cost-competitiveness for global markets
	Module manufacturing	Highly fragmented: More than 400 companies globally[311]: wafer-module manufacturers, cell-system manufacturers, integrated solar firms	Very low entry barriers, with lowest capital investments; but seeing some consolidation ■ Less technical, more labor intensive manufacturing processes ■ Facilities can be established and/or relocated quickly (~1 month) ■ Modules are the heaviest and most fragile of solar components (due to glass, wiring, encapsulation), which makes importation from foreign markets less economic

ANNEX 2: SOLAR PV INDUSTRY VALUE CHAIN (CONT.)

VALUE CHAIN SEGMENT		APPROX. NUMBER / TYPES OF GLOBAL PLAYERS	KEY CHARACTERISTICS
Upstream (Research & Development, Key Input Materials, and Manufacturing)	BOS components manufacturing (Production of inverters, mounting structure, batteries and other electronic equipment)	Highly fragmented: Mostly sourced from external suppliers	Low barriers to entry for most components ■ Inverters primarily supplied from EU-based firms and a few Chinese suppliers, therefore still highly consolidated industry, but many new entrants emerging with shifts in PV markets to North America and Asia ■ For other BOS components many competitors at domestic level, and often possible to leverage capabilities of firms supplying other segments, however these are also easily transportable ■ Commodity prices have a large impact on the costs of BOS components ■ Facilities for BOS components can be established and/or relocated relatively quickly
Downstream (PV Development and installation services) ■ More global cell and module suppliers are moving into this part of value chain ■ Business strategies factor local demand markets	System design/ System integration/Project development	Integrated solar firms, system integrators and external service firms	Design of rooftop and field installations/Final manufacturing of BOS components/Development of larger scale projects ■ More specialized technical skills/expertise required for resource assessments
	System installation and construction work (engineering, procurement, construction)	Local providers of construction and installation services; local EPC contractors	■ Can leverage domestic players from other construction industries, especially for large scale PV EPC projects ■ Taps into specialized local electrical and engineering firms
	O&M	Integrated solar firms, system integrators, external service firms	■ Low O&M requirement ■ Fixed year service periods could create opportunity for large scale project segment
	Financing	Integrated solar firms and project developers with banks and other financial services providers	

ANNEX 3: ON-SHORE WIND INDUSTRY VALUE CHAIN[312]

VALUE CHAIN SEGMENT		APPROX. NUMBER / TYPES OF GLOBAL PLAYERS	KEY CHARACTERISTICS
Upstream (Research & Development, Key Input Materials, and Manufacturing)	R&D	■ Whole Turbine Design ■ Component Design	Service; mostly OEM in-house; some specialist R&D/IP services providers
	Key Materials	Cast Iron	Used for several key components (approx. 15-20 tonnes per installed MW); overwhelmingly external suppliers; European and Chinese firms are important
		Forgings	Used for several key components (approx. 10 tonnes per installed MW); solely external suppliers; Chinese and Korean firms are important
		Reinforcement Fibers	Used in blades, e.g. glass fibers, carbon fibers, woven and stitched fabrics, pre-impregnated glass; solely external suppliers
	Components Manufacturing	Towers	Ranges from 50-110m and weighs up to 280-300 tonnes, depending on tower classification. Usually ships in units no larger than 70 tonnes; some OEM in-house; mostly external suppliers
		Blades and Hub	Blades vary in length up to 60m. Each blade and hub shipped separately, with combined weight up to 45 tons; mostly OEM in-house; one major external supplier with global presence (LM Glasfiber); new entrants
		Gearboxes	Most wind turbine gearboxes are produced by a small number of large established external suppliers (Winergy), Hansen, and Bosch-Rexroth, with their own global production operations; a significant number of new players in Asia
		Generators	Most wind turbine generators are produced in-house by OEM producers or by large suppliers of a broad portfolio of electrical machinery; China has seen the entry of a large number of new suppliers in recent years
		Large Bearings	Several types of bearings are a critical part of the several moving components of a wind turbine (gearbox, main shaft, yaw, pitch, and generator). All bearings are produced by large-scale external bearing suppliers with own global operations
		Power Converters	Converts wind power into power grid frequency and voltage; mostly OEM in-house but some from external suppliers
	Turbine Manufacturing	Final Turbine Assembly	Solely OEM in-house

ANNEX 3: ON-SHORE WIND INDUSTRY VALUE CHAIN[312] (CONT.)

VALUE CHAIN SEGMENT		APPROX. NUMBER / TYPES OF GLOBAL PLAYERS	KEY CHARACTERISTICS
Downstream (Wind Power Production)	Turbine Deployment	Turbine Marketing/Sales	Service; solely OEM in-house
		Wind Park Site Assessment	Service; external wind assessment consultancies
		Financing	Service; large number of external banks and financial firms
		Transport/Logistics	Service; OEMs relying on external providers of logistics services
		Wind Park Construction	Service; external providers of construction services
	Post-Deployment Services	Wind Park Operation and Maintenance	Service; OEMs, independent power producers (IPPs), and external utility companies
		Repowering and Grid Connections and Wind Power Sales	Service; OEMs, independent power producers (IPPs), and external utility companies

ENDNOTES

1. International Energy Agency (IEA), World Energy Outlook 2011 (Paris: IEA, 2011), 178, 193.
2. Nathalie Girouard et al., Energy, OECD Green Growth Studies (Paris, France: Organisation for Economic Co-Operation and Development, n.d.).
3. Nathalie Girouard et al., Energy, OECD Green Growth Studies (Paris: Organisation for Economic Co-Operation and Development, n.d.).
4. System prices include all of the hardware required to produce electricity and feed it into the grid, including PV modules, inverters that convert DC current of the modules into AC current, storage batteries and all installation and control components. Additionally installation costs are included, though operations and maintenance costs over the life of the system are excluded. (Lothar Wissing, National Survey Report of PV Power Applications in Germany 2011, IEA Co-operative Programme on Photovoltaic Power Systems Task 1 Germany Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), July 2012), http://www.iea-pvps.org/index.php?id=95&eID=dam_frontend_push&docID=1234.)
5. By "policy stability", this report is considering the time horizons incorporated in government goal setting, for instance China and India's five-year plans and renewable energy goals into the mid-2020's, and the time horizon placed on a policy. The Germany and Chinese feed-in-tariffs have no pre-set expiration date, while the U.S. PTC has usually been in effect for only one to two years at a time.
6. See, for example: Oliver Wyman, "Oliver Wyman study 'Wind Power 2020: Boom-Market Service': The underestimated profit machine," (Munich: Oliver Wyman, 8 November 2010), http://www.oliverwyman.com/pdf_files/PR_OliverWyman_WindPower2020.pdf
7. Renewable energy industries include the businesses throughout the supply chains that are involved in making, financing, and installing renewable energy equipment such as solar panels and wind turbines, as well as those involved in generating electricity, such as the operations and maintenance companies. Taken together these businesses make up the solar PV or on-shore wind industries in countries and globally.
8. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), 13, http://www.map.ren21.net/GSR/GSR2012_low.pdf.
9. United Nations Environment Programme and Bloomberg New Energy Finance, Global Trends in Renewable Energy Investment 2011, 2011, 25, http://www.unep.org/pdf/BNEF_global_trends_in_renewable_energy_investment_2011_report.pdf.
10. United Nations Environment Programme and Bloomberg New Energy Finance, Global Trends in Renewable Energy Investment 2012, (2012), 12, http://fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012final.pdf
11. International Energy Agency (IEA), World Energy Outlook 2011 (Paris: IEA, 2011), 178.
12. International Energy Agency (IEA), World Energy Outlook 2011 (Paris: IEA, 2011), 193.
13. Pew Charitable Trusts, Global Clean Power: A $2.3 Trillion Opportunity,(Washington: Pew, 2010), 18,23.
14. Becky Beetz, "PV oversupply issues will see 60 GW capacity come offline by 2015," PV Magazine: Photovoltaic Markets & Technology (27 June 2012), http://www.pv-magazine.com/news/details/beitrag/pv-oversupply-issues-will-see-60-gw-capacity-come-offline-by-2015_100007498/#axzz22DbmFIUT; Shyam Mehta. Greentechsolar, "The Global PV Manufacturing Landscape in 2012 and Beyond: A Brave New World," (31 July 2012), http://www.greentechmedia.com/articles/read/the-global-pv-manufacturing-landscape-in-2012-and-beyond-a-brave-new-world/
15. This is so much the case that the key variable that differs between the three future scenarios estimated in the IEA's annual energy outlook is public policies to drive the transition to a low-carbon energy system. See International Energy Agency, World Energy Outlook 2011 (Paris, France: IEA, 2011).
16. Mahesh Sugathan et al., Fostering Low Carbon Growth: The Case for a Sustainable Energy Trade Agreement (Geneva: International Centre for Trade and Sustainable Development, November 2011), http://ictsd.org/downloads/2012/05/fostering-low-carbon-growth-the-case-for-a-sustainable-energy-trade-agreement1.pdf.
17. Bloomberg New Energy Finance, Crossing the Valley of Death: Solutions to the Next Generation Clean Energy Project Financing Gap, White Paper (Bloomberg New Energy Finance, Clean Energy Group, June 2010), http://bnef.com/WhitePapers/view/29; Jacob Funk Kirkegaard et al., Toward a Sunny Future? Global Integration in the Solar PV Industry, PIIE WRI Working Paper (Washington, DC: Peterson Institute for International Economics and World Resources Institute, May 2010), http://www.wri.org/publication/toward-a-sunny-future
18. Robert Bryce, The High Cost of Renewable Electricity Mandates, Energy Policy & the Environment Report, Feb. 2012, http://www.manhattan-institute.org/html/eper_10.htm
19. Nathalie Girouard et al., Energy, OECD Green Growth Studies (Paris: Organisation for Economic Co-Operation and Development, n.d.)
20. International Centre for Trade and Sustainable Development, "China-US Sparring over Renewable Energy Intensifies," Bridges 16, no. 21 (May 30, 2012), http://ictsd.org/i/news/bridgesweekly/134029/; Joanna I. Lewis and Ryan H. Wiser, "Fostering a Renewable Energy Technology Industry: An International Comparison of Wind Industry Policy Support Mechanisms," Energy Policy 35, no. 3 (March 2007): 1844–1857, http://www.sciencedirect.com/science/article/B6V2W-4KJ7541-1/2/4ebbd16928e5688b5a504a610fd8ad35.
21. Birgit Marshal, "Chef der Deutschen Energie-Agentur 'Die Bürger könnten viel mehr Strom sparen'," Rheinische Post (Düsseldorf, June 19, 2012), http://www.rp-online.de/wirtschaft/finanzen/die-buerger-koennten-viel-mehr-strom-sparen-1.2876697; Abigail Ho, "Gov't Urged to Delay Wind, Solar Projects," Philippine Daily Inquirer (Manila, September 12, 2011), http://business.inquirer.net/18441/gov%E2%80%99t-urged-to-delay-wind-solar-projects.
22. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), 13, http://www.map.ren21.net/GSR/GSR2012_low.pdf
23. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012), 14.
24. The Pew Charitable Trusts, Who's Winning the Clean Energy Race? 2011 Edition, 14 (Washington: Pew, 2012), http://www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/FINAL_forweb_WhoIsWinningTheCleanEnergyRace-REPORT-2012.pdf

25. International Energy Agency, CO2 Emissions from Fuel Combustion Highlights, IEA Statistics (Paris, France: International Energy Agency, 2011), http://www.iea.org/co2highlights/CO2highlights.pdf.

26. Morgan Bazilian et al., "Reconsidering the Economics of Photovoltaic Power," Bloomberg New Energy Finance White Paper, May 16, 2012, 3-4, www.bnef.com/WhitePapers/download/82

27. Becky Beetz, "PV oversupply issues will see 60 GW capacity come offline by 2015," PV Magazine: Photovoltaic Markets & Technology (27 June 2012), http://www.pv-magazine.com/news/details/beitrag/pv-oversupply-issues-will-see-60-gw-capacity-come-offline-by-2015_100007498/#axzz22DbmFIUT

28. Ethan Zindler, "Overcapacity and new players keep wind turbine prices in the doldrums", Bloomberg New Energy Finance, (06 Mar 2012), http://bnef.com/PressReleases/view/196

29. Ibid.

30. The current solar PV equipment over-supply and the emerging over-supply in the wind industry do make manufacturing capacity a potentially overstated measure of economic activity. However, actual production is both very dynamic from quarter to quarter and data is impossible to uncover for private firms. This working paper has highlighted cases where a large idle manufacturing capacity should be considered before drawing conclusions.

31. Letha Tawney et al., Two Degrees of Innovation - How to Seize the Opportunities in Low-carbon Power, WRI Working Paper (Washington, DC: World Resources Institute, 2011), http://pdf.wri.org/working_papers/two_degrees_of_innovation.pdf

32. Cédric Philibert, "Renewable Energy Policy and Climate Policy Interactions," in Climate and Electricity Annual (Paris: International Energy Agency, 2011), 35-42.

33. Nathalie Girouard et al., Energy, OECD Green Growth Studies (Paris: Organisation for Economic Co-Operation and Development, n.d.); United Nations Department of Economic and Social Affairs (UN DESA), The Great Green Technological Transformation, World Economic and Social Survey (New York: UN DESA, 2011), http://www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf

34. According to statistics from German Solar Industry Association (BSW Solar), the ratio of exports for the industry increased from 14 percent to 47 percent and for suppliers from 30 percent to 79 percent from 2004 to 2009. BSW Solar, Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik), (August 2010), www.solarwirtschaft.de/fileadmin/content_files/Faktenblatt_PV_BSW_Dez.pdf

35. Council on Energy, Environment and Water (CEEW) and Natural Resources Defense Council (NRDC), Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1 of India's National Solar Mission, (NRDC/CEEW April 2012), 6.

36. Japan Photovoltaic Energy Association (JPEA) Q3 Press Releases: (February 2010), accessed at: http://www.jpea.gr.jp/pdf/pub_st03.pdf, (February 2012), accessed at: http://www.jpea.gr.jp/pdf/t120215.pdf; Hiroyuki Yamada and Osamu Ikki National Survey Report of PV Power Applications in Japan 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2012).

37. "2011 Chinese Overseas and Industry Development Report," (2011年中国及海外太阳能光伏产业发展报告), http://wenku.baidu.com/view/a95718f77c1cfad6195fa7c4.html;, China Electronic Materials Industry Association (中国电子材料行业协会 经济技术管理部),"2011 Chinese Solar and Silicone Material Industry Research Report," (2011年中国太阳能电池及硅材料行业调研报告), http://wenku.baidu.com/view/f02cb948e518964bcf847cd1.html; Renewable Energy Policy Network for the 21st Century (REN21), Renewables Global Status Report 2006 Update, (Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute, 2006).

38. India Semiconductor Association (ISA), Solar PV Industry 2010 : Contemporary scenario and emerging trends, (ISA May 2010), 33, http://www.isaonline.org/documents/ISA_SolarPVReport_May2010.pdf; Ministry of New and Renewable Energy (MNRE), Government of India, Annual Reports 2005 – 2011, http://mnre.gov.in/mission-and-vision-2/publications/annual-report-2/.

39. According to statistics from German Solar Industry Association (BSW Solar), the ratio of exports for the industry increased from 14 percent to 47 percent and for suppliers from 30 percent to 79 percent from 2004 to 2009. BSW Solar, Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik), (August 2010), www.solarwirtschaft.de/fileadmin/content_files/Faktenblatt_PV_BSW_Dez.pdf

40. International Energy Agency Co-operative Programme on Photovoltaic Power Systems (IEA PVPS), National Survey Report for Germany, Reports for 2002 - 2011, http://www.iea-pvps.org/; German Solar Industry Association (BSW-Solar), Statistische Zahlen der deutschen, Solarstrombranche (Photovoltaik), August 2010, www.solarwirtschaft.de/fileadmin/content_files/Faktenblatt_PV_BSW_Dez.pdf; German Solar Industry Association (BSW-Solar), Statistic Data on the German Solar Power (Photovoltaic) Industry, June 2012, http://www.solarwirtschaft.de/fileadmin/media/pdf/BSW_facts_solarpower_en.pdf.

41. India is not included in this comparison because comparable figures for average system prices was not available/accessible.

42. Council on Energy, Environment and Water (CEEW) and Natural Resources Defense Council (NRDC), Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1 of India's National Solar Mission, (NRDC/CEEW April 2012), 9.

43. Jacob Funk Kirkegaard et al., Toward a Sunny Future? Global Integration in the Solar PV Industry, PIIE WRI Working Paper (Washington, DC: Peterson Institute for International Economics and World Resources Institute, May 2010), 39, http://www.wri.org/publication/toward-a-sunny-future

44. German Solar Industry Association (BSW Solar), Statistic Data on the German Solar Power (Photovoltaic) Industry, June 2012, http://www.solarwirtschaft.de/fileadmin/media/pdf/BSW_facts_solarpower_en.pdf; China Electronic Materials Industry Association (中国电子材料行业协会 经济技术管理部),"2011 Chinese Solar and Silicone Material Industry Research Report," (2011年中国太阳能电池及硅材料行业调研报告), http://wenku.baidu.com/view/f02cb948e518964bcf847cd1.html; Kristen Ardani and David Feldman, National Survey Report of PV Power Applications in the United States 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (June 2012); Hiroyuki Yamada and Osamu Ikki National Survey Report of PV Power Applications in Japan 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2012). Refer to Table 1 for data sources for average installed solar system price per Watt.

45. Lothar Wissing on behalf of German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), National Survey Report of PV Power Applications in Germany 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (July 2012); Lothar Wissing on behalf of German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), National

Survey Report of PV Power Applications in Germany 2010, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2011); Kristen Ardani and David Feldman, National Survey Report of PV Power Applications in the United States 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (June 2012); Katie Bolcar and Kristen Ardani, National Survey Report of PV Power Applications in the United States 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2011); Hiroyuki Yamada and Osamu Ikki National Survey Report of PV Power Applications in Japan 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2012); Masamichi Yamamoto and Osamu Ikki, National Survey Report of PV Power Applications in Japan 2010, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (June 2011); China Electronic Materials Industry Association (中国电子材料行业协会 经济技术管理部),"2011 Chinese Solar and Silicone Material Industry Research Report," (2011年中国太阳能电池及硅材料行业调研报告), http://wenku.baidu.com/view/f02cb948e518964bcf847cd1.html.

46. Council on Energy, Environment and Water (CEEW) and Natural Resources Defense Council (NRDC), Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1of India's National Solar Mission, (NRDC/CEEW April 2012), 9.

47. Ibid, 7.

48. Ministry of New and Renewable Energy (MNRE), Government of India, Annual Reports 2005 – 2011, http://mnre.gov.in/mission-and-vision-2/publications/annual-report-2/.

49. Marc Roca and Stefan Nicola, "Germany Plans Record Cuts in Solar Subsidies to Limit Boom," Bloomberg (23 February 2012), http://www.bloomberg.com/news/2012-02-23/germany-cuts-solar-energy-subsidies-to-curb-installations-boom.html; Nilima Choudhury, "Update: China cuts solar subsidies by up to 22% for PV projects," PV-Tech, (23 February 2012), http://www.pv-tech.org/news/china_cuts_solar_subsidies_by_22.3_for_pv_projects

50. Hiroyuki Yamada and Osamu Ikki National Survey Report of PV Power Applications in Japan 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2012), http://www.iea-pvps.org/.

51. Modules are made up of several solar cells that are further bundled together to create panels. When panels are installed with electronics such as an inverter and begin generating electricity, they form a solar system. The price of an installed system is important to the homeowner or utility that will use it to generate and sell electricity. The price of the module is important to the manufacturer who will bundle it into a panel, and ultimately to the installer or project developer, who wants to keep supply costs low in order to preserve the margin when selling on to the customer.

52. Solar Energy Industries Association (SEIA), U.S. Solar Market Insight: 2011 Year-in-Review, (Washington, DC: SEIA, 2012) http://www.seia.org/research-resources/us-solar-market-insight-report-2011-year-review; Japan Photovoltaic Energy Association (JPEA), http://www.jpea.gr.jp/pdf/qlg2010_eng.pdf; Lothar Wissing on behalf of German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), National Survey Report of PV Power Applications in Germany 2010, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2011). Refer to Table 2 for data sources for average module price per Watt.

53. Lothar Wissing on behalf of German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), National Survey Report of PV Power Applications in Germany 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (July 2012); Lothar Wissing on behalf of German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), National Survey Report of PV Power Applications in Germany 2010, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2011); Kristen Ardani and David Feldman, National Survey Report of PV Power Applications in the United States 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (June 2012); Katie Bolcar and Kristen Ardani, National Survey Report of PV Power Applications in the United States 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2011); Hiroyuki Yamada and Osamu Ikki National Survey Report of PV Power Applications in Japan 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2012); Masamichi Yamamoto and Osamu Ikki, National Survey Report of PV Power Applications in Japan 2010, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (June 2011); China Electronic Materials Industry Association (中国电子材料行业协会 经济技术管理部), "2011 Chinese Solar and Silicone Material Industry Research Report," (2011 年中国太阳能电池及硅材料行业调研报告), http://wenku.baidu.com/view/f02cb948e518964bcf847cd1.html

54. Council on Energy, Environment and Water (CEEW) and Natural Resources Defense Council (NRDC), Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1of India's National Solar Mission, (NRDC/CEEW April 2012), 20.

55. Becky Stuart, "Importance of PV module quality to increase," PV Magazine: Photovoltaic Markets & Technology, (18 March 2011), http://www.pv-magazine.com/news/details/beitrag/importance-of-pv-module-quality-to-increase_100002460/#axzz22Up5WzYb

56. New Energy and Industrial Technology Development Organization (NEDO), "PV 2030+" (太陽光発電ロードマップ), http://www.nedo.go.jp/content/100116421.pdf

57. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), 27, http://www.map.ren21.net/GSR/GSR2012_low.pdf

58. Ryan Wiser and Mark Bolinger, 2011 Wind Technologies Market Report (U.S. Department of Energy, August 2012), http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf.

59. Global Wind Energy Council, Online Country Profiles, available at http://www.gwec.net/

60. Jacob Funk Kirkegaard et al., "It Should Be a Breeze: Harnessing the Potential of Open Trade and Investment Flows in the Wind Energy Industry," PIIE WRI Working Paper (Washington, DC: Peterson Institute for International Economics and World Resources Institute, December 2009), http://pdf.wri.org/working_papers/it_should_be_a_breeze.pdf

61. Merritt Brown, "MAINTENANCE," Wind Systems, July 2010, http://windsystemsmag.com/article/detail/128/maintenance.

62. Bloomberg New Energy Finance (BNEF). Data provided by BNEF analysts on 17 July 2012. These data numbers vary quite significantly by source. Numbers included in this graphic are numbers provided by BNEF for final turbine assembly capacity, which is significantly higher than turbine production levels.

63. By “policy stability”, this report is considering the time horizons incorporated in government goal setting, for instance China and India’s five-year plans and renewable energy goals into the mid-2020’s, and the time horizon placed on a policy. The Germany and Chinese feed-in-tariffs have no pre-set expiration date, while the U.S. PTC has usually been in effect for only one to two years at a time.
64. Database of State Incentives for Renewables & Efficiency (DSIRE), Renewable Electricity Production Tax Credit, http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F
65. Ryan Wiser and Mark Bolinger, 2011 Wind Technologies Market Report, (United States Energy Department, 14 August 2012, 3, http://www.windpoweringamerica.gov/pdfs/2011_annual_wind_market_report.pdf
66. Ibid., 23.
67. Ibid., 69.
68. Mark Jaffe, “Failing Wind Market Leads to Job Cuts at Vestas Pueblo Factory,” The Denver Post, August 13, 2012, http://www.denverpost.com/breakingnews/ci_21302515/failing-wind-market-leads-job-cuts-at-vestas; NAW Staff, “LM Wind Power Announces U.S. Layoffs Amid PTC Uncertainty,” North American Windpower, August 6, 2012, http://nawindpower.com/e107_plugins/content/content.php?content.10234.
69. Calculated based on German Federal Ministry for the Environment (BMU) , Kurz- und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt, (BMU 2011), http://erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/ee_arbeitsmarkt_bf.pdf, tables 2-2 and 2-11
70. Bloomberg New Energy Finance. Data provided by BNEF analysts on 17 July 2012
71. Ryan Wiser and Mark Bolinger, 2011 Wind Technologies Market Report, (United States Energy Department, 14 August 2012)3, http://www.windpoweringamerica.gov/pdfs/2011_annual_wind_market_report.pdf.
72. Bloomberg New Energy Finance, Q1 2012 Clean Energy Policy & Market Briefing (Bloomberg New Energy Finance, April 18, 2012).
73. Andrew S.David, Wind Turbines: Industry and Trade Summary. United States International Trade Commission, Office of Industries, Publication ITS-02, (June 2009), 29, http://www.usitc.gov/publications/332/ITS-2.pdf
74. See, for example: Oliver Wyman, “Oliver Wyman study ‘Wind Power 2020: Boom-Market Service’: The underestimated profit machine,” (Munich: Oliver Wyman, 8 November 2010), http://www.oliverwyman.com/pdf_files/PR_OliverWyman_WindPower2020.pdf
75. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/
76. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), “The Energy Concept and its accelerated implementation,” Resolutions and Measures, Transformation of the energy system, (October 2011), http://www.bmu.de/english/transformation_of_the_energy_system/resolutions_and_measures/doc/48054.php
77. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Renewable Energy Sources Act (EEG) 2012 (As of: January 2012), http://www.erneuerbare-energien.de/english/renewable_energy/acts_and_ordinances/eeg/eeg_2012/doc/47883.php.
78. Die Bundesregierung, “Efficient, state-of-the-art energy technologies based on research and innovation, http://www.hightech-strategie.de/en/200.php
79. Fraunhofer, Standorte in Deutschland, http://www.fraunhofer.de/de/institute-einrichtungen.html
80. Fraunhofer, Das Fraunhofer-Geschaftsmodell, http://www.fraunhofer.de/de/ueber-fraunhofer/geschaeftsmodell.htm
81. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), Table R5, p 101 , http://www.map.ren21.net/GSR/GSR2012_low.pdf
82. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2011: Global Status Report, (Paris: REN21 Secretariat, 2011),12, http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf
83. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), http://www.erneuerbare-energien.de/inhalt/45919/2720/
84. Stephen Lacey, “Germany Installed 3 GW of Solar PV in December—The U.S. Installed 1.7 GW in all of 2011,” Renewable Energy World.com, (12 January 2012), http://www.renewableenergyworld.com/rea/news/article/2012/01/germany-installed-3-gw-of-solar-pv-in-december-the-u-s-installed-1-7-gw-in-all-of-2011
85. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), http://www.erneuerbare-energien.de/inhalt/45919/2720/ http://www.erneuerbare-energien.de/inhalt/45919/2720/; German Solar Industry Association (BSW-Solar), Statistic Data on the German Solar Power (Photovoltaic) Industry, June 2012, http://www.solarwirtschaft.de/fileadmin/media/pdf/BSW_facts_solarpower_en.pdf.
86. Insa Wrede, “Chinese exports crushing German solar industry,” Deutsche Welle (16 June 2012), http://www.dw.de/dw/article/0,,16031596,00.html
87. International Energy Agency Co-operative Programme on Photovoltaic Power Systems (IEA PVPS), National Survey Report for Germany, Reports for 2002 - 2011, http://www.iea-pvps.org/; German Solar Industry Association (BSW-Solar), Statistische Zahlen der deutschen, Solarstrombranche (Photovoltaik), August 2010, www.solarwirtschaft.de/fileadmin/content_files/Faktenblatt_PV_BSW_Dez.pdf; ;German Solar Industry Association (BSW-Solar), Statistic Data on the German Solar Power (Photovoltaic) Industry, June 2012, http://www.solarwirtschaft.de/fileadmin/media/pdf/BSW_facts_solarpower_en.pdf.
88. International Energy Agency Co-operative Programme on Photovoltaic Power Systems (IEA PVPS), National Survey Report for Germany, Reports for 2002 - 2006, http://www.iea-pvps.org/; German Solar Industry Association (BSW-Solar), Statistische Zahlen der deutschen, Solarstrombranche (Photovoltaik), August 2010, www.solarwirtschaft.de/fileadmin/content_files/Faktenblatt_PV_BSW_Dez.pdf.
89. Balance-of-system (BOS) components refer to all the solar PV system components, except for the modules. BOS components include module mounting structures, wiring, switchgears, and the inverter which converts the direct current (DC) electricity produced by the semiconducting material to the alternate current (AC) needed for the electricity grid.
90. European Photovoltaic Industry Association (EPIA), Homepage, http://www.epia.org/; Thilo Grau, Monin Huo, and Karsten Heuhoff, “Survey of Photovoltaic Industry and Policy in Germany and China,” Climate Policy Initiative Report (Berlin: CPI, March 2011), 15, http://climatepolicyinitiative.org/wp-content/uploads/2011/12/PV-Industry-Germany-and-China.pdf
91. Christoph Moller, “Creditors give the go-ahead for continuation,” Q.Cells News, 18 July 2012, http://www.q-cells.com/en/press/article/QCELLS-Creditors-give-the-go-ahead-for-continuation.html
92. Solar Millennium, Homepage, http://www.solarmillennium.de/

93. According to IHS Emerging Energy Research data, Germany had 42 percent share of the global inverter market in 2010.

94. Becky Stuart, "Importance of PV module quality to increase," PV Magazine: Photovoltaic Markets & Technology, (18 March 2011), http://www.pv-magazine.com/news/details/beitrag/importance-of-pv-module-quality-to-increase_100002460/#axzz22Up5WzYb

95. Gordon, Kate, Julian Wong, and JT Mclain. Center for American Progress, "Out of the Running? How Germany, Spain, and China Are Seizing the Energy Opportunity and Why the United States Risks Getting Left Behind." (March 2010), 9, http://www.americanprogress.org/wp-content/uploads/issues/2010/03/pdf/out_of_running.pdf

96. BSW Solar, Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik), (August 2010), www.solarwirtschaft.de/fileadmin/content_files/Faktenblatt_PV_BSW_Dez.pdf; German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Renewably employed: Short and long-term impacts of the expansion of renewable energy on the German labour market, (Berlin: BMU, July 2011), http://www.erneuerbare-energien.de/files/english/pdf/application/pdf/broschuere_erneuerbar_beschaeftigt_en_bf.pdf

97. German Solar Industry Association (BSW-Solar), Statistische Zahlen der deutschen, Solarstrombranche (Photovoltaik), August 2010, http://www.solarwirtschaft.de/fileadmin/content_files/Faktenblatt_PV_BSW_Dez.pdf; Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Renewably Employed, July 2011, http://www.erneuerbare-energien.de/files/english/pdf/application/pdf/broschuere_erneuerbar_beschaeftigt_en_bf.pd; BMU, "Pressedienst Nr 036/12," (Berlin, March 6, 2012) http://www.bmu.de/pressemitteilungen/aktuelle_pressemitteilungen/pm/pdf/48528.pdf.

98. Henning Wicht, "German Solar Installations Undergo end-of-Year Resurgence, Straining Supply Chain," Press Release, 3 October 2011, http://www.isuppli.com/Photovoltaics/News/pages/German-Solar-Installations-Undergo-End-of-Year-Resurgence,-Straining-Supply-Chain.aspx

99. R. Deshmukh, et al., "Analysis of International Policies in the Solar Electricity Sector: Lessons for India," (Prayas India, Lawrence Berkeley National Laboratory, January 2011),12, ies.lbl.gov/solar_electricity_sector; Thilo Grau, Monin Huo, and Karsten Heuhoff, "Survey of Photovoltaic Industry and Policy in Germany and China," Climate Policy Initiative Report (Berlin: CPI, March 2011), 23- 25, http://climatepolicyinitiative.org/wp-content/uploads/2011/12/PV-Industry-Germany-and-China.pdf

100. Thilo Grau, Monin Huo, and Karsten Heuhoff, "Survey of Photovoltaic Industry and Policy in Germany and China," Climate Policy Initiative Report (Berlin: CPI, March 2011), http://climatepolicyinitiative.org/wp-content/uploads/2011/12/PV-Industry-Germany-and-China.pdf

101. German Trade and Invest (GTAI), "Photovoltaic R&D in Germany", (August 2011), http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Fact-sheets/Energy-environmental/fact-sheet-photovoltaic-r-d.pdf

102. International Energy Agency, Energy Technology RD&D 2011 edition, http://wds.iea.org/

103. Arne Jungjohann and Bjorn Jahnke, "Europe: Creating Jobs with Renewable Energies" (Washington: Heinrich Boll Stiftung, May 19, 2009), http://boell.org/web/139-270.html

104. German Federal Ministry of Education and Research, "Bekanntmachung," http://www.bmbf.de/en/furtherance/15069.php

105. J.P. Molly, "Status der Windenergienutzung in Deutschland," Presentation for Deutsches Windenergie Institut (DEWI GmbH), http://www.dewi.de/dewi/fileadmin/pdf/publications/Statistics%20Pressemitteilungen/Statistik_2011_Folien.pdf

106. Ibid; German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), "Development of renewable energy sources in Germany 2011," March 2012, http://erneuerbare-energien.de/files/english/pdf/application/pdf/ee_in_deutschland_graf_tab_en.pdf

107. DEWI (2012): Status der Windenergienutzung in Deutschland - Stand 31.12.2011, available at http://www.dewi.de/dewi/fileadmin/pdf/publications/Statistics Pressemitteilungen/Statistik_2011_Folien.pdf

108. Bloomberg New Energy Finance. Data provided by BNEF analysts on 17 July 2012.

109. Calculated based on German Federal Ministry for the Environment (BMU), Kurz- und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt, (BMU 2011), http://erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/ee_arbeitsmarkt_bf.pdf, tables 2-2 and 2-11.

110. Bundesverband WindEnergie e.V., Presentation "Windindustrie in Deutschland – Inlandsmarkt und Exportgeschaft," http://www.wind-energie.de/sites/default/files/attachments/press-release/2011/deutsche-windindustrie-maerkte-erholen-sich/windindustrie-deutschland-inlandsmarkt-und-exportgeschaeft.pdf; German Wind Energy Association (BWE), "Windindustrie trotzt Wirtschaftskrise," 23 July 2009, http://www.wind-energie.de/presse/pressemitteilungen/2009/windindustrie-trotzt-wirtschaftskrise; J.P. Molly, "Ermittlung der deutschen Wertschopfung im weltweiten Windenergiemarkt fur 2007," Presentation for Deutsches Windenergie Institut (DEWI GmbH), http://www.dewi.de/dewi/fileadmin/pdf/publications/Statistics%20Pressemitteilungen/30.06.08/Statistik_1HJ_2008.pdf

111. DEWI (2012): Status der Windenergienutzung in Deutschland - Stand 31.12.2011, available at http://www.dewi.de/dewi/fileadmin/pdf/publications/Statistics Pressemitteilungen/Statistik_2011_Folien.pdf

112. Bundesverband WindEnergie and VDMA (2009): Die deutsche Windindustrie im Weltmarkt, available at http://www.dewi.de/dewi/fileadmin/pdf/publications/Statistics%20Pressemitteilungen/folien_bwe_vdma.pdf; Bundesverband WindEnergie and VDMA (2011): Windindustrie in Deutschland –Inlandsmarkt und Exportgeschäft, available at http://www.wind-energie.de/sites/default/files/attachments/press-release/2011/deutsche-windindustrie-maerkte-erholen-sich/windindustrie-deutschland-inlandsmarkt-und-exportgeschaeft.pdf; Bundesverband WindEnergie and VDMA (2012): Produktionsvolumen und Export der Windindustrie in Deutschland 2011, available at http://www.wind-energie.de/sites/default/files/attachments/press-release/2012/deutscher-markt-fuer-windenergieanlagen-waechst-stabil-weltmarkt-stellt-windindustrie-vor-grosse/2012-08-01-praesentation-produktionsvolumen.pdf.

113. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/. Note that internationally harmonized data in Figure 21 contains a much smaller set of exports (entire turbines or generating sets), whereas Figure 20 includes most components as well.

114. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/

115. Marlene O'Sullivan, et al., "Employment from renewable energy in Germany: expansion and operation – now and in the future, first report on gross employment," (Berlin: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 14 March 2012), http://erneuerbare-energien.de/files/english/pdf/application/pdf/ee_bruttobeschaeftigung_en_bf.pdf

116. Bundesverband WindEnergie e.V., Presentation “Windindustrie in Deutschland – Inlandsmarkt und Exportgeschaft,” http://www.wind-energie.de/sites/default/files/attachments/press-release/2011/deutsche-windindustrie-maerkte-erholen-sich/windindustrie-deutschland-inlandsmarkt-und-exportgeschaeft.pdf. Please note that break-down of jobs not available for 2000 - 2003.

117. E.ON owns the largest wind farm in the United States and is the fifth largest “managing owner” of U.S. wind capacity, see http://www.awea.org/learnabout/publications/factsheets/upload/2010-Annual-Market-Report-Rankings-Fact-Sheet-May-2011.pdf

118. Bundesverband WindEnergie: Number of employees in the wind sector, available at http://www.wind-energie.de/en/infocenter/statistiken/deutschland/number-employees-wind-sector; Bundesverband WindEnergie and VDMA (2011): Windindustrie in Deutschland –Inlandsmarkt und Exportgeschäft, available at http://www.wind-energie.de/sites/default/files/attachments/press-release/2011/deutsche-windindustrie-maerkte-erholen-sich/windindustrie-deutschland-inlandsmarkt-und-exportgeschaeft.pdf; Bundesministerium fuer Umwelt, Naturschutz und Reaktorsicherhiet (2012): Gross employment from renewable energy in Germany in 2011, available at http://www.erneuerbare-energien.de/files/english/pdf/application/pdf/ee_bruttobeschaeftigung_en_bf.pdf. Note: No breakdown for manufacturing available prior to 2004 and for 2011.

119. KFW, Key Renewable energies programme-standard, http://www.kfw.de/kfw/en/Domestic_Promotion/Our_offers/Renewable_energy.jsp#KfWRenewableEnergiesProgramme-Standard

120. KFW, Erneuerbare Energien ausbauen, http://energiewende.kfw.de/erneuerbare_energien_ausbauen.html

121. International Energy Agency, Energy Technology RD&D 2011 edition, http://wds.iea.org/

122. Fraunhofer, Energy and living: Wind power, http://www.fraunhofer.de/en/research-topics/energy-living/wind-power.html, Fraunhofer Network for Wind Energy, http://www.energie.fraunhofer.de/de/dokumente/medien-windenergie/fraunhofer-network-for-wind-energy.pdf

123. See, for example, Renewable energy Hamburg, http://en.erneuerbare-energien-hamburg.de/wind-energy.html, Windcomm schelesig-holstein, http://www.windcomm.de/Seiten/en/home/home.php; Wind Energy Agency (WAB),http://www.wab.net/index.php?option=com_content&view=article&id=327&Itemid=27&lang=en; EnergieRegion.NRW, http://www.energieregion.nrw.de/windkraft/page.asp?RubrikID=13377; , Wind power cluster, http://www.windpowercluster.com/; Cluster Energietechnik, http://energiecluster-bb.de/?page_id=1695.

124. Database of State Incentives for Renewables & Efficiency (DSIRE), Quantitative RPS Data Project , accessed May 2012, http://www.dsireusa.org/rpsdata/index.cfm

125. Richard J. Campbell, “China and the United States – A Comparison of Green Energy Programs and Policies,” (Washingon, DC: Congressional Research Service, 14 June 2010),14, http://www.fas.org/sgp/crs/row/R41287.pdf

126. Solar Energy Industries Association (SEIA), U.S. Solar Market Insight: 2011 Year-in-Review, (Washington, DC: SEIA, 2012) http://www.seia.org/research-resources/us-solar-market-insight-report-2011-year-review

127. Kristen Ardani and David Feldman, National Survey Report of PV Power Applications in the United States 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (June 2012).

128. International Energy Agency Co-operative Programme on Photovoltaic Power Systems (IEA PVPS), National Survey Report for the United States, Reports for 2002 - 2006, http://www.iea-pvps.org/; Solar Energy Industries Association (SEIA), U.S. Solar Market Insight: 2011 Year-in-Review, (Washington, DC: SEIA, 2012), http://www.seia.org/research-resources/us-solar-market-insight-report-2011-year-review.

129. Michaela Platzer, “U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support,” (Washington, DC: Congressional Research Service, 2012), 11, http://www.fas.org/sgp/crs/misc/R42509.pdf

130. Ibid, 7

131. GTM Research for Solar Energy Industries Association (SEIA), “U.S. Solar Energy Trade Assessment 2011: Trade Flows and Domestic Content for Solar Energy-Related Goods and Services in the United States,” (Washington, DC: SEIA, 2011).

132. Thin film are the second generation of solar PV technologies that have thin layers of PV materials deposited on low-cost substrates like glass, stainless steel, or plastic.

133. Bloomberg New Energy Finance. Data provided by BNEF analysts on 17 July 2012.

134. Crystalline silicon are first generation solar PV technologies that dominate the global market because of high conversion efficiency in converting sunlight into electrical energy. They are cut from silicon ingot, casting, or grown ribbon.

135. Joanna Lewis, “China’s Competitive Advantage in the Solar Industry: How Advantageous is it Really?,” ChinaFAQs: The Network for Climate and Energy Information, (3 October 2011), http://www.chinafaqs.org/blog-posts/chinas-competitive-advantage-solar-industry-how-advantageous-it-really

136. Conversation with industry expert from IHS Emerging Energy Research, March 2012

137. National Solar Jobs Census 2011, The Solar Foundation (Oct. 2011), 13, http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF_JobsCensus2011_Final_Compressed.pdf

138. Ibid. The census includes jobs in the solar sector beyond just solar PV.

139. Ibid (for 2010 and 2011 jobs data); International Energy Agency Co-operative Programme on Photovoltaic Power Systems (IEA PVPS), National Survey Report for the United States, Reports for 2002 and 2003, http://www.iea-pvps.org/; Solar Energy Industries Association (SEIA) estimates as reported in US Solar Industry Year In Review Reports, http://www.seia.org/research-resources/us-solar-market-insight. Note: the methodologies used to derive the figures differ by source so they cannot be considered completely comparable. Also, breakdown of jobs is only available for some years.

140. Detailed information on individual state incentives and policies can be accessed through the Database of State Incentives for Renewables & Efficiency (DSIRE), Quantitative RPS Data Project , accessed May 2012, http://www.dsireusa.org/rpsdata/index.cfm

141. Solar Energy Industries Association (SEIA), U.S. Solar Market Insight: 2011 Year-in-Review, (Washington, DC: SEIA, 2012), 22, http://www.seia.org/research-resources/us-solar-market-insight-report-2011-year-review.

142. Jesse Jenkins et al., Beyond Boom and Bust: Putting Clean Tech on a Path to Subsidy Independence (The Breakthrough Institute, April 2012), http://thebreakthrough.org/blog/Beyond_Boom_and_Bust.pdf.

143. Solar Energy Industries Association (SEIA), “US Solar Industry Year in Review 2009”, April 15, 2010, http://www.slideshare.net/SEIA/us-solar-industry-yearinreview-2009

144. Phillip Brown and Molly F. Sherlock, “ARRA Section 1603 Grants in Lieu of Tax Credits for Renewable Energy: Overview, Analysis, and Policy Options,” (Washington: Congressional Research Service, February 2011), http://assets.opencrs.com/rpts/R41635_20110208.pdf

145. Database of State Incentives for Renewables & Efficiency (DSIRE), Business Energy Investment Tax Credit, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1

146. Solar Energy Industries Association (SEIA), U.S. Solar Market Insight: 2011 Year-in-Review, (Washington, DC: SEIA, 2012), 3, http://www.seia.org/research-resources/us-solar-market-insight-report-2011-year-review)

147. Brett Prior and Carolyn Campbell, “Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry,” (presented at GTM Research webinar on 9 February, 2012).

148. Bloomberg New Energy Finance

149. Michaela Platzer, “U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support,” (Washington, DC: Congressional Research Service, 2012), 26-27, http://www.fas.org/sgp/crs/misc/R42509.pdf

150. Global Wind Energy Council, Online Country Profile United States, available at http://www.gwec.net/

151. Bloomberg New Energy Finance

152. American Wind Energy Association (AWEA), “Wind Turbine Manufacturing and Supply Chain,” (Washington, DC: AWEA), http://www.awea.org/learnabout/publications/upload/Manufacturing-SupplyChain_1-pager.pdf

153. American Wind Energy Association (AWEA), “U.S. Wind Industry: Market Update,” (Washington, DC: AWEA, May 2011), http://www.awea.org/learnabout/publications/factsheets/upload/U-S-Wind-Industry-Market-Update-Factsheet-May-2011.pdf.

154. Ryan Wiser and Mark Bolinger, 2011 Wind Technologies Market Report, (United States Energy Department, 14 August 2012), 22, http://www.windpoweringamerica.gov/pdfs/2011_annual_wind_market_report.pdf.

155. International Energy Agency (IEA), IEA Wind: 2010 Annual Report, (Paris: IEA, July 2011), http://ieawind.org/index_page_postings/IEA%20Wind%202010%20AR_cover.pdf; American Wind Energy Association, U.S. Wind Industry Year-End 2010 Market Report, January 2011, 166, http://www.awea.org/learnabout/publications/upload/4Q10_market_outlook_public.pdf.

156. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/. Data for 2004 is unavailable.

157. Ibid.

158. Navigant Consulting, Inc., “Impact of the production tax credit on the US Wind Market,” prepared for American Wind Energy Association, December 12, 2011, http://www.awea.org/learnabout/publications/reports/upload/AWEA-PTC-study-121211-2pm.pdf

159. Renewable Energy Certificates (RECs) represents the property rights to the environmental, social, and other non-power qualities of renewable electricity generation and are sold separately from the underlying physical electricity associated with a renewable-based generation source.

160. Ryan Wiser and Mark Bolinger, 2011 Wind Technologies Market Report, (United States Energy Department, 14 August 2012, 55, http://www.windpoweringamerica.gov/pdfs/2011_annual_wind_market_report.pdf.

161. Database of State Incentives for Renewables & Efficiency (DSIRE), Renewable Electricity Production Tax Credit, http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F

162. International Energy Agency (IEA), IEA Wind 2010 Annual Report, (Paris: IEA, July 2011), 168, http://ieawind.org/index_page_postings/IEA%20Wind%202010%20AR_cover.pdf.

163. International Energy Agency, Energy Technology RD&D 2011 edition, IEA Data Services, available at http://wds.iea.org

164. United States, Department of Energy, Office of Budget, http://www.cfo.doe.gov/crorg/cf30.htm.

165. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012), 38.

166. Reegle, Country Energy Profile for Japan, http://www.reegle.info/countries/japan-energy-profile/JP#energy_framework

167. Ibid.

168. New Energy and Industrial Technology Development Organization (NEDO), “Nedo’s Role,” http://www.nedo.go.jp/english/introducing_mis_poli.html

169. Renewables Japan Status Report 2011 (ISEP, 2011, Japanese only).

170. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012)

171. European Photovoltaic Industry Association (EPIA), Global Market Outlook for Photovoltaics until 2016, (Brussels: EPIA, May 2012), 31, http://files.epia.org/files/Global-Market-Outlook-2016.pdf.

172. Masamichi Yamamoto, “National Survey Report of PV Power Applications in Japan 2010,” (Kawasaki City, Japan: International Energy Agency, June 2011).

173. Ministry of Economy, Trade and Investment (METI), http://www.meti.go.jp/committee/chotatsu_kakaku/001_07_01.pdf, in Japanese.

174. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2010: Global Status Report, (Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute, 2008), 19, http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf

175. International Energy Agency Co-operative Programme on Photovoltaic Power Systems (IEA PVPS), National Survey Report for Japan, Reports for 2002–2011, http://www.iea-pvps.org/index.php?id=93&tx_damfrontend_pi1=&tx_damfrontend_pi1[catPlus]=&tx_damfrontend_pi1[catEquals]=&tx_damfrontend_pi1[catMinus]=&tx_damfrontend_pi1[catPlus_Rec]=65&tx_damfrontend_pi1[catMinus_Rec]=&tx_damfrontend_pi1[treeID]=201&tx_damfrontend_pi1[id]=146.

176. Ibid (for wafers and cells data); Japan Photovoltaic Energy Association (JPEA) Q3 Press Releases: (February 2010), accessed at: http://www.jpea.gr.jp/pdf/pub_st03.pdf, (February 2012), accessed at: http://www.jpea.gr.jp/pdf/t120215.pdf (for module data)

177. Japan Photovoltaic Energy Association (JPEA) Q3 Press Releases: (February 2010), accessed at: http://www.jpea.gr.jp/pdf/pub_st03.pdf, (February 2012), accessed at: http://www.jpea.gr.jp/pdf/t120215.pdf; Hiroyuki Yamada and Osamu Ikki National Survey Report of PV Power Applications in Japan 2011, International Energy Agency Co-operative Programme on Photovoltaic Power Systems, (May 2012).

178. Brett Prior and Carolyn Campbell, “Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry,” (Boston: GTM Research, January 2012), http://www.greentechmedia.com/research/report/polysilicon-2012-2016/

179. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2007: Global Status Report, (Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute, 2008), http://www.ren21.net/Portals/97/documents/GSR/RE2007_Global_Status_Report.pdf

180. Yutaka Yamamoto, "Rooftops and Residential: Solar Power in Japan," (Suntech Blog, 28 February 2012), http://blog.suntech-power.com/2012/suntech-explains/rooftops-and-residential-solar-power-in-japan
181. European Commission Joint Research Centre, PV Status Report 2011, (Ispra, Italy: Institute for Energy, July 2011), 72 – 76, http://re.jrc.ec.europa.eu/refsys/pdf/PV%20reports/PV%20Status%20Report%202011.pdf
182. International Energy Agency (IEA), Photovoltaic Power Systems Programme National Survey Reports, http://www.iea-pvps.org/index.php?id=93
183. International Energy Agency Co-operative Programme on Photovoltaic Power Systems (IEA PVPS), National Survey Report for Japan, Reports for 2002–2011, http://www.iea-pvps.org/index.php?id=93&tx_damfrontend_pi1=&tx_damfrontend_pi1[catPlus]=&tx_damfrontend_pi1[catEquals]=&tx_damfrontend_pi1[catMinus]=&tx_damfrontend_pi1[catPlus_Rec]=65&tx_damfrontend_pi1[catMinus_Rec]=&tx_damfrontend_pi1[treeID]=201&tx_damfrontend_pi1[id]=146Note: No surveys were conducted in 2000, 2001, 2004, 2005 and 2008.
184. Yutaka Yamamoto, "Rooftops and Residential: Solar Power in Japan," (Suntech Blog, 28 February 2012), http://blog.suntech-power.com/2012/suntech-explains/rooftops-and-residential-solar-power-in-japan
185. Reegle, Country Energy Profile for Japan, http://www.reegle.info/countries/japan-energy-profile/JP#energy_framework
186. Masamichi Yamamoto, "National Survey Report of PV Power Applications in Japan 2010," (Kawasaki City, Japan: International Energy Agency, June 2011).
187. Includes wind, solar, small hydro (<30 MW), geothermal and biomass that does not affect existing industrial processes such as pulp and paper production.
188. Izumi Ushiyama, "Wind Power Development in Japan," (Japan Wind Energy Association, March 2012), http://jref.or.jp/en/images/pdf/20120309/9March_REvision2012_session2_ushiyama.pdf
189. Global Wind Energy Council, Online Country Profiles, available at http://www.gwec.net/.
190. Bloomberg New Energy Finance
191. NEDO (2012), Nihon ni okeru fuuryoku hatsuden no joukyou (日本における風力発電の状況 ページ3/7 "The situation of wind power generation in Japan"), page 3/7. New Energy and Industrial Technology Development Organization, Kawasaki, Kanagawa, Japan. http://www.nedo.go.jp/library/fuuryoku/state/1-03.html, accessed on 29 August 2012.
192. JWPA (2012). 2011 nenmatsu no fuuryokuhatsuden dounyuuryou to 2012 nen3 gatsumatsu no suitei dounyuuryou (2011年末の風力発電導入量と 2012年3 月末の推定導入量"Wind power: installed capacity as of end-2011 and estimated installed capacity as of end-March 2012"). Japan Wind Power Association, Tokyo, Japan. http://jwpa.jp/pdf/30-12dounyuujisseki2011graph.pdf, accessed on 29 August 2012.
193. Ibid.
194. Boston Strategies, "Industrial Power Transmission Equipment 2012 Q1," (Boston: Boston Strategies), http://ogpnetwork.com/clients/documents/2012%20Q1%20Power%20Transmission%20-%20Bearings.pdf
195. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/
196. Note: Only turbines greater than 1 MW are included in this statistic. Source: Turbomachinery Society of Japan.
197. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/
198. IEA Wind 2010 Annual Reports: Japan. IEA Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). http://www.ieawind.org/countries/japan.html accessed on June 29, 2012); The Japan Society of Industrial Machinery Manufacturers, Fuuryokuhatsuden kanrenkiki sangyou ni kansuru chousa kenkyuu (Survey research regarding wind power generation machinery industries, in Japanese), 2012.
199. IEA Wind, Annual Reports: 2000-2010. Prepared for Japan under IEA Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). http://www.ieawind.org/countries/japan.html.
200. Tetsuya Kogaki, National Institute of Advanced Industrial Science and Technology (AIST), IEA WIND Annual Report for Japan: 2010, http://www.ieawind.org/annual_reports_PDF/2010/Japan.pdf.
201. IEA Wind, Annual Reports: 2000-2010. Prepared for Japan under IEA Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). http://www.ieawind.org/countries/japan.html (source for subsidy data); International Energy Agency (IEA), "RD&D statistics," (Paris: International Energy Agency), http://www.iea.org/stats/rd.asp. accessed 29 June, 2012 (source for RD&D budget).
202. Includes wind, solar, small hydro (<30 MW), geothermal, and biomass that does not affect existing industrial process such as pulp and paper production. Net-metering system will continue for residential PV systems below 10 kW.
203. Izumi Ushiyama, "Wind Power Development in Japan," (Japan Wind Energy Association, March 2012), http://jref.or.jp/en/images/pdf/20120309/9March_REvision2012_session2_ushiyama.pdf
204. Hikaru Matsumiya, "Chapter 20: Japan," Annual Report 2007, (Paris: IEA Wind, 2008), http://www.ieawind.org/annual_reports_PDF/2007/Japan.pdf
205. Izumi Ushiyama, "Wind Power Development in Japan," (Japan Wind Energy Association, March 2012), http://jref.or.jp/en/images/pdf/20120309/9March_REvision2012_session2_ushiyama.pdf
206. International Energy Agency (IEA) WIND TASK 28. Social Acceptance of Wind Energy Projects "Winning hearts and minds" Country Report for Japan.
207. Richard J. Campbell, "China and the United States – A Comparison of Green Energy Programs and Policies," (Washington, DC: Congressional Research Service, 14 June 2010), http://www.fas.org/sgp/crs/row/R41287.pdf
208. "The Five-Year Plan for National Economic and Social Development, or the Five-Year Plan, mainly aims to arrange national key construction projects, manage the distribution of productive forces and individual sector's contributions to the national economy, map the direction of future development, and set targets." Source: http://english.gov.cn/2006-04/05/content_245556.htm
209. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012).
210. The National Energy Administration, "Renewable Energy Development in the 12th Year Plan released," (8 August 2012), http://www.nea.gov.cn/2012-08/08/c_131767651.htm
211. Gordon, Kate, Julian Wong, and JT Mclain. Center for American Progress, "Out of the Running? How Germany, Spain, and China Are Seizing the Energy Opportunity and Why the United States Risks Getting Left Behind." (March 2010), 32, http://www.americanprogress.org/wp-content/uploads/issues/2010/03/pdf/out_of_running.pdf

212. Steven Sun, Hongbin Qu and Garry Evans, “China’s next 5-year plan: What it means for equity markets,” (HSBC Global Research, October 2 2010), http://www.research.hsbc.com/midas/Res/RDV?p=pdf&key=DRpq0Zsciy&n=279532.PDF

213. European Photovoltaic Industry Association (EPIA), Global Market Outlook for Photovoltaics until 2016, (Brussels: EPIA, May 2012), 31, http://files.epia.org/files/Global-Market-Outlook-2016.pdf

214. China Electronic Materials Industry Association (中国电子材料行业协会 经济技术管理部),“2011 Chinese Solar and Silicone Material Industry Research Report,” (2011年中国太阳能电池及硅材料行业调研报告), http://wenku.baidu.com/view/f02cb948e518964bcf847cd1.html; Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), 101, http://www.map.ren21.net/GSR/GSR2012_low.pdf.

215. Renewable Energy Policy Network for the 21st Century (REN21), Renewables: Global Status Report, 2009 Update (Paris: REN21 Secretariat, 2009), 15, http://www.ren21.net/Portals/97/documents/GSR/RE_GSR_2009_Update.pdf

216. “2011 Chinese Overseas and Industry Development Report,” (2011年中国及海外太阳能光伏产业发展报告), http://wenku.baidu.com/view/a95718f77c1cfad6195fa7c4.html; Renewable Energy Policy Network (REN21), Renewables 2005 Global Status Report. (Washington, DC: Worldwatch Institute, 2005), 17, Renewables Global Status Report 2006 Update (Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute), 7, accessed at: http://www.ren21.net/REN21Activities/Publications/GlobalStatusReport/tabid/5434/Default.aspx (source for solar PV cells and modules for 2004 and 2005); GTM Research for Solar Energy Industries Association (SEIA), “U.S. Solar Energy Trade Assessment 2011: Trade Flows and Domestic Content for Solar Energy-Related Goods and Services in the United States,” (Washington, DC: SEIA, 2011), 20 & 22, http://www.seia.org/research-resources/us-solar-energy-trade-assessment-2011(source for solar PV cells and wafers for 2010).

217. Melanie Hart, “What does the solar trade dispute mean? Shining a light on US-China Clean Energy Cooperation,” (ThinkProgress: Climate Progress, 9 February 2012), http://thinkprogress.org/climate/2012/02/09/422282/solar-trade-us-china-clean-energy-cooperation/

218. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2011 Global Status Report, (Paris: REN21 Secretariat, July 2011), 41, http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf. Note: This figure includes production in mainland China and Taiwan.

219. “Renewable energy country attractiveness indices”, Ernst & Young, (February 2012), Issue 32, 18, http://www.ey.com/GL/en/Industries/Oil---Gas/Oil_Gas_Renewable_Energy_Attractiveness-Indices

220. Vivian L, “China Solar: Who Survives China’s Polysilicon Shakeout?”, (Greentech: Solar, 12 April 2012), http://www.greentechmedia.com/articles/read/china-solar-who-survives-chinas-polysilicon-shakeout/

221. China Research & Intelligence (CRI), Research Report on China’s Polysilicon Industry, 2012, (CRI, May 2012)

222. Vivian L, “China Solar: Who Survives China’s Polysilicon Shakeout?”, (Greentech: Solar, 12 April 2012), http://www.greentechmedia.com/articles/read/china-solar-who-survives-chinas-polysilicon-shakeout/

223. Ibid.

224. China Electronic Materials Industry Association (中国电子材料行业协会 经济技术管理部),“2011 Chinese Solar and Silicone Material Industry Research Report,” (2011年中国太阳能电池及硅材料行业调研报告), http://wenku.baidu.com/view/f02cb948e518964bcf847cd1.html.

225. Institute for Urban and Environmental Studies (IUE) and Chinese Academy of Social Sciences (CASS), Study on Low Carbon Development and Green Employment in China, (Beijing: IUE and CASS, 2010), http://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---ilo-beijing/documents/publication/wcms_155390.pdf

226. China Electronic Materials Industry Association (中国电子材料行业协会 经济技术管理部),“2011 Chinese Solar and Silicone Material Industry Research Report,” (2011年中国太阳能电池及硅材料行业调研报告), http://wenku.baidu.com/view/f02cb948e518964bcf847cd1.html.

227. PVMarketresearch.com, “China PV Market Set to Boom as Government Raises 2015 Installation Target to 21GW,” 16 July 2012, http://www.pv-marketresearch.com/press-release/China_PV_Market_Set_to_Boom_as_Government_Raises_2015_Installation_Target_to_21GW/5

228. This is even higher at 70 percent for projects in remote, rural areas.

229. Concessions are allocated to bidders through Power Purchase Agreements (PPAs) for a 25-year time horizon. Prices at which electricity is delivered to the grid are set based on the initial bids, and fixed for a guaranteed period, usually 10 years.

230. United Steelworks (USW), “United Steelworks’ Section 301 Petition Demonstrates China’s Green Technology Practices Violate WTO Rules,”(Pittsburgh, PA: USW), assets.usw.org/releases/misc/section-301.pdf

231. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012).

232. Conversation with IHS Emerging Energy Research experts, March 2012

233. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012), 111-113.

234. Arnaud de la Tour, Matthieu Glachant, Yann Meniere, “Innovation and international tech transfer: case of Chinese PV industry”Energy Policy 39 (2011): 761 – 770, http://www.sciencedirect.com/science/article/pii/S0301421510008013.

235. Liu Yiyu, “Entry standards for polysilicon plants rise,” China Daily, 16 February 2011, http://www.chinadaily.com.cn/bizchina/2011-02/16/content_12025081.htm.

236. Devin Bullis, “Chinese Solar Companies Thrive on Manufacturing Innovations,” Technology Review, 6 July 2011, http://www.technologyreview.com/business/37954/

237. Arnaud de la Tour, Matthieu Glachant, Yann Meniere, “Innovation and international tech transfer: case of Chinese PV industry” Energy Policy 39 (2011): 761 – 770, http://www.sciencedirect.com/science/article/pii/S0301421510008013

238. Global Wind Energy Council (GWEC), Global Wind Report: Annual market update 2011, (Brussels: GWEC, March 2012), http://www.gwec.net/fileadmin/documents/NewsDocuments/Annual_report_2011_lowres.pdf.

239. Global Wind Energy Council, Online Country Profiles, available at http://www.gwec.net/

240. Global Wind Energy Council (GWEC), Global Wind Report: Annual market update 2011, (Brussels: GWEC, March 2012), http://www.gwec.net/fileadmin/documents/NewsDocuments/Annual_report_2011_lowres.pdf

241. Global Wind Energy Council, Online Country Profile China, available at http://www.gwec.net/

242. Bloomberg New Energy Finance. Data provided by BNEF analysts on 17 July 2012.

243. International Energy Agency (IEA), IEA Wind 2010 Annual Report, (Paris: IEA, 2011), 71, http://ieawind.org/index_page_postings/IEA%20Wind%202010%20AR_cover.pdf

244. Global Wind Energy Council (GWEC), Global Wind Report: Annual market update 2011, (Brussels: GWEC, March 2012), 30, http://www.gwec.net/fileadmin/documents/NewsDocuments/Annual_report_2011_lowres.pdf http://www.gwec.net/fileadmin/documents/NewsDocuments/Annual_report_2011_lowres.pdf, page 30.

245. IEA Wind: 2010 Annual Report, July 2011, 71, http://ieawind.org/index_page_postings/IEA%20Wind%202010%20AR_cover.pdf

246. According to the UN COMTRADE database, Germany exported $1,211,812,497 worth of wind power generating sets (HS code 850231), while China exported $351,154,168.

247. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/

248. Ibid.

249. 80,500 is the lowest number in a range of estimates in the "Study on Low Carbon Development and Green Employment in China", while the Chinese Wind Energy Association reports 297,000 jobs in its report to the IEA Wind Program. REN21's Global Status Report estimates 150,000 jobs.

250. Institute for Urban and Environmental Studies (IUE) and Chinese Academy of Social Sciences (CASS), Study on Low Carbon Development and Green Employment in China, (Beijing: IUE and CASS, 2010), http://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/---ilo-beijing/documents/publication/wcms_155390.pdf

251. Ibid, 60.

252. Concessions are allocated to bidders through Power Purchase Agreements (PPAs) for a 25-year time horizon. Prices at which electricity is delivered to the grid are set based on the initial bids, and fixed for a guaranteed period, usually 10 years.

253. International Energy Agency (IEA), IEA Wind 2010 Annual Report, (Paris: IEA, 2011), 70,http://ieawind.org/index_page_postings/IEA%20Wind%202010%20AR_cover.pdf.

254. Jacob Funk Kirkegaard et al., "It Should Be a Breeze: Harnessing the Potential of Open Trade and Investment Flows in the Wind Energy Industry," PIIE WRI Working Paper (Washington, DC: Peterson Institute for International Economics and World Resources Institute, December 2009), http://pdf.wri.org/working_papers/it_should_be_a_breeze.pdf

255. Ibid, 21; AFP, "China scraps limits on foreign wind turbine parts", 11 January 2010, http://www.google.com/hostednews/afp/article/ALeqM5iUix-FRiXbLQhdojIrIlvefqaHzA

256. International Energy Agency (IEA), IEA Wind 2010 Annual Report, (Paris: IEA, 2011), 68, 71-13, http://ieawind.org/index_page_postings/IEA%20Wind%202010%20AR_cover.pdf

257. Frankfurt School of Finance &Management, Global Trends in Renewable Energy Investment 2012, (Frankfurt am Main: UNEP Collaborating Centre and Frankfurt School of Finance & Management, 2012), http://fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012final.pdf

258. Letha Tawney, Ruth Greenspan Bell, and Micah S. Ziegler, High Wire Act: Electricity Transmission Infrastructure and its Impact on the Renewable Energy Market (Washington, D.C.: World Resources Institute, April 2011), http://www.wri.org/publication/high-wire-act.

259. Global Wind Energy Council (GWEC), Global Wind Report: Annual market update 2011, (Brussels: GWEC, March 2012), 31-32, http://www.gwec.net/fileadmin/documents/NewsDocuments/Annual_report_2011_lowres.pdf

260. Ibid.

261. Prime Minister's Council on Climate Change, Government of India, "National Action Plan on Climate Change," 30 June 2008, pmindia.nic. in/Climate%20Change.doc.

262. Ibid.

263. RPOs are analogous to Renewable Portfolio Standards (RPSs) that have been introduced in other countries.

264. The national certificate scheme and feed-in tariffs offered at the state level are mutually exclusive, with power producers either choosing to sell power under feed-in tariffs or availing of the national certificate scheme.

265. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012), 119.

266. Prime Minister's Council on Climate Change, Government of India, "National Action Plan on Climate Change," 30 June 2008, pmindia.nic.in/Climate%20Change.doc.

267. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012), 119.

268. Ibid, 118.

269. Ministry of New and Renewable Energy (MNRE), Government of India, "Annual Report 2011 – 12", http://mnre.gov.in/file-manager/annual-report/2011-2012/EN/index.htm.

270. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), p 101 , http://www.map.ren21.net/GSR/GSR2012_low.pdf

271. German Solar Industry Association (BSW-Solar), "Statistic data on the German Solar power (photovoltaic) industry," (June 2012), http://www.solarwirtschaft.de/fileadmin/media/pdf/BSW_facts_solarpower_en.pdf.

272. Ministry of New and Renewable Energy (MNRE), Government of India, Annual Reports 2005 – 2011, http://mnre.gov.in/mission-and-vision-2/publications/annual-report-2/. Note: Data represents installed grid-connected solar power capacity. Break-down of solar PV is not available.

273. Becky Stuart, "PV module production in India could hit 6 GW," PV Magazine: Photovoltaic Markets & Technology, (21 December 2011), http://www.pv-magazine.com/news/details/beitrag/pv-module-production-in-india-could-hit-6-gw-by-2015_100005312/#axzz22DbmFIUT

274. India Semiconductor Association (ISA), Solar PV Industry 2010 : Contemporary scenario and emerging trends, (ISA May 2010), 33, http://www.isaonline.org/documents/ISA_SolarPVReport_May2010.pdf.

275. Ibid; Becky Stuart, "PV module production in India could hit 6 GW," PV Magazine: Photovoltaic Markets & Technology, (21 December 2011), http://www.pv-magazine.com/news/details/beitrag/pv-module-production-in-india-could-hit-6-gw-by-2015_100005312/#axzz22DbmFIUT (2011 estimates). Note: No data available for 2010.

276. Ibid.

277. Ministry of New and Renewable Energy (MNRE), Government of India, "Annual Report 2011 – 12", http://mnre.gov.in/file-manager/annual-report/2011-2012/EN/index.htm.

278. Trina Solar, "Vertical Integration, the path to success in a competitive market," pe Power & Energy, Issue 1, http://www.nextgenpe.com/article/Vertical-Integration-the-path-to-success-in-a-competitive-market/

279. Hugo Lucas and Rabia Ferroukhi et. al, IRENA, 2011, IRENA Working Paper: Renewable Energy Jobs: Status, Prospects & Policies, 17. The estimates include direct jobs and projections for indirect jobs generated.

280. Council on Energy, Environment and Water (CEEW) and Natural Resources Defense Council (NRDC), Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1of India's National Solar Mission, (NRDC/CEEW April 2012),18.

281. Priya Barua, "India Solar: the Dawn of an Emerging Market", IHS Emerging Energy Research, Asia Pacific Renewable Power Advisory (ID# APRP 825-100810), August 10, 2010.

282. Bloomberg New Energy Finance

283. Ministry of New and Renewable Energy (MNRE), Government of India, "Jawaharlal Nehru National Solar Mission:Towards Building SOLAR INDIA", 30 June 2008, http://www.mnre.gov.in/file-manager/UserFiles/mission_document_JNNSM.pdf .

284. Council on Energy, Environment and Water (CEEW) and Natural Resources Defense Council (NRDC), Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1of India's National Solar Mission, (NRDC/CEEW April 2012), 12

285. Ibid, 21.

286. European Commission Joint Research Centre, PV Status Report 2011, (Ispra, Italy: Institute for Energy, July 2011), 81, http://re.jrc.ec.europa.eu/refsys/pdf/PV%20reports/PV%20Status%20Report%202011.pdf

287. Council on Energy, Environment and Water (CEEW) and Natural Resources Defense Council (NRDC), Laying the Foundation for a Bright Future: Assessing Progress Under Phase 1of India's National Solar Mission, (NRDC/CEEW April 2012), 9.

288. Angus McCrone, "India saw Record $10.3bn Clean Energy Investment in 2011, February 2, 2012," Bloomberg New Energy Finance News Release, 2 February 2012, accessed 13 July 2012, http://www.bnef.com/PressReleases/view/186

289. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012).

290. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), Table R5, p 104 , http://www.map.ren21.net/GSR/GSR2012_low.pdf

291. International Energy Agency (IEA), Medium-Term Renewable Energy Market Report 2012 (Paris: IEA, 2012), 115.

292. Global Wind Energy Council, Online Country Profiles, available at http://www.gwec.net/

293. Shantanu Jaiswal, "Tough Road Ahead for New Turbine Makers in India," India Wind Research Note, Bloomberg New Energy Finance, 25 February 2011, 1, www.bnef.com

294. Ibid.

295. Ibid, 9.

296. Shantanu Jaiswal, "Tough Road Ahead for New Turbine Makers in India," India Wind Research Note, Bloomberg New Energy Finance, 25 February 2011, 2, www.bnef.com

297. Bloomberg New Energy Finance. Data provided by BNEF analysts on 17 July 2012.

298. Shantanu Jaiswal, "Tough Road Ahead for New Turbine Makers in India," India Wind Research Note, Bloomberg New Energy Finance, 25 February 2011, www.bnef.com

299. HS code 850231 (generating sets, wind-powered), UN COMTRADE database, available at http://comtrade.un.org/db/

300. Ibid.

301. Hugo Lucas and Rabia Ferroukhi et. al, IRENA, 2011, IRENA Working Paper: Renewable Energy Jobs: Status, Prospects & Policies, 17. The estimates include direct jobs and projections for indirect jobs generated

302. There are seven Union Territories in India, including National Capital Territory of Delhi. A Union Territory is an administrative region that does not have an elected government, but is governed by the Federal government.

303. Ibid.

304. Ashish Sethia, "India: At the $10bn Inflection Point?" slide 6, (presentation at the Bloomberg New Energy Finance Global Analysts Day, Washington D.C., 23 March 2012)

305. Brett Prior and Carolyn Campbell, "Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry," (presented at GTM Research webinar on 9 February, 2012)

306. European Commission Joint Research Centre, PV Status Report 2011, (Ispra, Italy: Institute for Energy, July 2011), http://re.jrc.ec.europa.eu/refsys/pdf/PV%20reports/PV%20Status%20Report%202011.pdf

307. Brett Prior and Carolyn Campbell, "Polysilicon 2012-2016: Supply, Demand & Implications for the Global PV Industry," (presented at GTM Research webinar on 9 February, 2012)

308. Michaela Platzer, "U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support," (Washington, DC: Congressional Research Service, 2012), 6, http://www.fas.org/sgp/crs/misc/R42509.pdf.

309. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), Table R5, p 50, http://www.map.ren21.net/GSR/GSR2012_low.pdf

310. European Commission Joint Research Centre, PV Status Report 2011, (Ispra, Italy: Institute for Energy, July 2011), 26, http://re.jrc.ec.europa.eu/refsys/pdf/PV%20reports/PV%20Status%20Report%202011.pdf

311. Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2012: Global Status Report, (Paris: REN21 Secretariat, 2012), Table R5, p 50 , http://www.map.ren21.net/GSR/GSR2012_low.pdf

312. Jacob Funk Kirkegaard et al., "It Should Be a Breeze: Harnessing the Potential of Open Trade and Investment Flows in the Wind Energy Industry," PIIE WRI Working Paper (Washington, DC: Peterson Institute for International Economics and World Resources Institute, December 2009), 39, http://pdf.wri.org/working_papers/it_should_be_a_breeze.pdf.

ACKNOWLEDGMENTS

This paper has benefitted from the expertise and review of numerous colleagues. The authors would particularly like to thank our partners in the Open Climate Network, particularly Takeshi Kuramochi of IGES; Hannah Forster, Verena Graichen, and Johanna Cludius of the Oko Institute; Wang Ke, Cui Xueqin, and Chen Yiying of Renmin University of China; and Neha Pahuja, Siddha Mahajan, and Arnab Bose at TERI for their invaluable contributions as collaborators, with tireless hours spent in collecting national policy information, market data and in helping to shape the country narratives. We would also like to thank the following colleagues at WRI for providing their guidance, support, and expertise, in helping to shape and complete this working paper: Jennifer Morgan, Taryn Fransen, Janet Ranganathan, James Bradbury, Nate Aden, Siddarthan Balasubramania, and Ailun Yang. This paper also benefitted greatly from the substantive inputs of the following reviewers: David Tomberlin, Davida Wood, Bharath Jairaj, Luke Schoen, Mary Sotos, and Lauren Zelin. Steve Sawyer (GWEC); Michael Wilshire, Ethan Zindler, and Jenny Chase (BNEF), Reese Tisdale and Thomas Maslin (IHS Emerging Energy Research), Jessica Isaacs (formerly AWEA), and Philip Brown (Congressional Research Service) for their valuable market expertise and for sharing relevant industry reports and data. Kevin Lustig and Tom Damassa for helping to develop the accompanying dynamic data explorer tool: www.openclimatenetwork.org/data. Milap Patel, Jennifer Hatch, and Wendi Bevins for their help with data collection and research inputs. Nathan Kommers for editing this paper. Hyacinth Billings, Nick Price, and Dave Cooper for their invaluable help with the graphic design and the production process. Finally, we are grateful to our funders, including ClimateWorks Foundation and Oak Foundation, who generously supported this work. All conclusions are the authors' own, and we take full responsibility for any errors.

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The World Resources Institute (WRI) is a global environmental and development think tank that goes beyond research to create practical ways to protect the Earth and improve people's lives. We work with governments, companies, and civil society to build practical solutions to urgent environmental challenges. WRI's transformative ideas protect the Earth and promote development because sustainability is essential to meeting human needs and fulfilling human aspirations for the future.

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