

Should the U.S. Support the Wind Energy Industry?

Jason Dedrick, Syracuse University
Kenneth L. Kraemer, University of California, Irvine
Greg Linden, University of California, Berkeley
jdedrick@syr.edu, kkraemer@uci.edu, glinden@berkeley.edu

Personal Computing Industry Center (PCIC)
Paul Merage School of Business
University of California, Irvine
Irvine, California 92697-4650

School of Information Studies
Syracuse University
Syracuse, NY 13244

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Executive Summary

The debate over energy policy divided the candidates in the presidential election, with President Obama defending his policies to support alternative energy and Governor Romney arguing for a policy focused on exploitation of fossil fuels in North America. With the election over, an item frequently mentioned for consideration by the lame-duck Congress as it negotiates a deal to avoid the "fiscal cliff" is the production tax credit (PTC), which supports wind energy with a small credit to energy producers for each kilowatt hour produced over ten years. Now Congress must decide whether to extend the credit or let it expire as scheduled at the end of 2012. Already, wind equipment manufacturers are laying off workers, and Obama has been joined by governors and legislators from both parties in calling for an extension, saying the PTC will protect U.S. jobs. But opponents say such credits are a waste of money and create few jobs.

It is not surprising that the debate has focused on jobs, given current unemployment rates. The number of U.S. wind industry jobs, according to our research and other estimates, is probably in the 30,000 to 55,000 range, with up to half of those jobs potentially at stake if the PTC expires. This is a significant number, especially in certain states, but not one that makes a big difference in the national employment picture. Given the estimated \$1.1 billion tax expenditure for the PTC (JCT, 2012), it is worth considering whether the cost is justified by the number of jobs involved. However, we would argue that there are other factors that should be considered beyond the number of jobs at stake.

These include the following, which we discuss in this report:

- The quality of wind jobs is relatively high. The industry employs skilled construction workers, provides decent-paying manufacturing jobs, and supports many highly paid engineers, managers, lawyers and other professionals.
- Most of these jobs are in the U.S., and are not easily moved offshore. Many are on-site jobs such as construction, development, operations, and maintenance. The very high transportation cost for wind turbines favors manufacturing domestically. In fact, the Department of Energy (2012) has stated that the domestic content (in value terms) of turbines installed in the U.S. has risen from 35% in 2005-2006 to 67% in 2011.
- The U.S. has developed a manufacturing base that includes turbines, blades, towers, gearboxes, generators and other key components as well as many of the 8,000 parts that go into a wind turbine. This has been driven by the rapid growth of domestic demand, which has drawn investment from major foreign manufacturers such as Vestas, Siemens, Nordex, ZF, ABB and others. U.S. companies such as GE have expanded production, and U.S. suppliers have also entered the industry. If the market for wind power

collapses, this momentum will be lost, factories will shut down, skilled workers will be laid off, and the U.S. wind energy industry will be set back by years.

- Wind energy costs are falling steadily as performance improves, making wind energy economically viable in a greater number of locations. In the long run, the industry will continue to grow globally, especially in places that do not have abundant alternatives. The U.S. can be a leader in developing and commercializing wind technologies, but only if the domestic market supports investment while the industry is in its intensive learning phase.
- Wind turbines are highly complex integrated systems, more like an airplane than a PC. Technologies cannot easily be developed and tested in isolation from the system, the way a hard drive can be developed separately from a PC. Having domestic manufacturing sites available to the university and other U.S.-based R&D labs working on wind innovations has the potential to accelerate the development and integration of new technologies, improving performance and further reducing the cost of wind turbines.
- Wind energy does not currently compete on a level playing field. Fossil fuels benefit from billions of dollars each year in tax preferences that, by law, will never expire. The collapse in natural gas prices that has made wind relatively unattractive for now may not last as producers rein in production. And the environmental costs of other fuels such as acid rain, greenhouse gas emissions and nuclear waste are not priced in the market in accord with any economic logic.

Governments in other countries are subsidizing their wind industries in competition with U.S. companies. The Production Tax Credit helps to level the playing field with other energy sources and other countries without favoring any particular companies or technologies. A multi-year extension would provide the wind energy industry certainty about its investment environment and allow the tax benefit to have its greatest possible impact.

Introduction

“We will put Americans to work in new jobs that pay well and can’t be outsourced - jobs building solar panels and wind turbines; constructing fuel-efficient cars and buildings; and developing the new energy technologies that will lead to even more jobs, more savings, and a cleaner, safer planet in the bargain,” President-elect Obama, January 8, 2009.

http://change.gov/newsroom/entry/dramatic_action/

“You can’t drive a car with a windmill on it.” Mitt Romney, 2012

<http://www.youtube.com/watch?v=nVvvZ64c9Gs>

The debate over energy policy involves many issues, from prices paid by consumers to dependence on foreign sources, to the impact of different energy sources on the environment. In the recent election and ongoing debate over energy policy, the discussion of alternative energy sources such as wind power has been framed by its supporters as a jobs issue, with the Obama administration and others favoring continued subsidies to the wind industry to sustain and create

jobs. Meanwhile, the Romney campaign called for an end to wind energy subsidies, but argued that his plans to increase fossil fuel production would create millions of American jobs. We present our findings on jobs in the wind industry in this report, but we also argue that wind energy needs to be looked at in a broader long-term context that considers U.S. technological leadership and the development of a manufacturing base in the emerging clean energy industries.

Although the price of wind energy continues to fall as companies develop new generations of larger, more efficient turbines, wind energy remains more expensive than competing energy sources, especially with natural gas prices having dropped significantly following huge growth in shale-gas production. Consequently, demand for wind power in the short-term is partly dependent on government support and/or on regulations that require renewable energy use.

In the U.S., the main federal policy tool to promote the industry is the Production Tax Credit (PTC), which was first adopted during the George H.W. Bush administration as part of the Energy Policy Act of 1992. Currently, the PTC pays wind operators 2.2 cents per kilowatt hour of production during their first 10 years in operation, and has contributed to rapid growth in the industry. However, Congress has repeatedly allowed the PTC to expire prior to renewal, which has undermined the predictability required for planning long-term investments such as wind farm development. This has led to an unfortunate stop-and-start investment pattern and possibly limited the growth of domestic wind energy below its potential. In years when the credit had expired, the level of new wind capacity collapsed when compared to the previous year's total: by 93% in 2000, 73% in 2002, and 77% in 2004 (AWEA, 2012b). This on-off pattern is detrimental to the wind industry supply chain, since ramp-up and ramp-down costs of manufacturing capacity are high, and companies are deterred from making long-term investments.

Wind energy accounts for about 3% of electricity generation in the U.S., and it is growing fast. In recent years, wind energy installations have been the second largest source of new electricity-generating capacity after natural gas (DOE, 2012: 5), demonstrating the importance of wind in satisfying growth in demand. Total U.S. installed wind capacity has increased more than seven times over eight years, from 6,700 megawatts (MW) in 2003 to 49,916MW in 2011 (AWEA, 2012a). Another 12,000MW is expected to be online by the end of 2012. Global capacity grew six-fold in the same period from 39,431MW to 237,669MW (GWEC, 2012). However, the continued expansion of U.S. capacity is far from certain, given the lack of clear policy direction and the low price of natural gas.

Barring Congressional action, the current PTC will expire at the end of 2012, once again creating market uncertainty and prompting manufacturers of wind turbines and components to lay off workers. Given the potential for an impact on employment, it is important to develop a deeper understanding of the number, type and location of jobs in the industry.

There are already various estimates of wind energy jobs in the U.S. and worldwide. The American Wind Energy Association (AWEA) estimated that 75,000 U.S. jobs were directly or indirectly associated with the wind industry in 2011, about 25% of which were in manufacturing (AWEA, 2012a). By comparison, the European Wind Energy Association (EWEA) estimated that there were 238,154 people working directly or indirectly in the wind industry in Europe in 2010 (EWEA, 2012).

The methodologies behind these estimates typically rely on multipliers for a large share of the headcount, or are simply not disclosed. We set out to apply a method that we have successfully used in the electronics industry (Linden, Dedrick, and Kraemer, 2011) to count the actual jobs required to produce wind energy, from the planning stage through factories to wind farm maintenance.

One aspect of the debate about jobs in the U.S. wind industry is whether more will be created in the U.S. or overseas. Unlike many industries, in which offshore activity has grown while the number of U.S. jobs declines, the trend in wind energy has been towards greater domestic content in U.S. wind installations. The percent of the U.S. wind industry's components manufactured in the U.S. increased from 35% in 2005-2006 to about 67% in 2011 as firms in the supply chain invested more in developing local capacity (DOE, 2012: 23)¹. However, four of the top ten turbine manufacturers are now Chinese companies, who are likely to enter the U.S. market more aggressively as their own market is saturated. An Indian company, Suzlon, has 5% of the U.S. market (DOE, 2012: iv), with no production in the U.S. So far, Chinese suppliers mainly compete in providing towers for U.S. turbines, but many Western companies are now producing in China and could supply the U.S. with components made by low-wage workers if the U.S. market becomes too small to justify investment.

We are estimating the industry's employment in a way that allows us to look more closely at the quality as well as quantity of jobs associated with U.S. wind installations. Quality includes both the wages paid and the extent to which jobs are subject to competition from imports or offshoring sourcing. Our method, which is based on the method used in our earlier studies of Global Value Chains in the electronics sector, allows us to identify value chain segments and types of jobs that are the least likely to be transferred offshore.

Our findings address two important questions:

1. What is the quantity, quality and location of jobs supported by wind energy installations in the U.S.?
2. What are the broader impacts of wind energy on U.S. technology leadership and the U.S. manufacturing base?

¹ Domestic content is the fraction of total equipment-related wind turbine costs produced in the U.S.

Wind Energy Jobs in the Global Value Chain

A modern wind turbine, as used in utility-scale wind farms, stands over 300 feet tall, weighs 150-350 tons, has over 8,000 parts and components, and can cost upwards of \$3 million. Wind farms range in size from a few turbines to hundreds, and take several years to develop and build. A turbine can operate for twenty years or more, but requires ongoing maintenance. The process of developing, constructing and operating a wind farm, and manufacturing the turbines for that farm, involves hundreds of jobs. In order to have a basis for estimating the number of wind jobs in the U.S., and to predict job growth or decline under different scenarios, we have estimated the number and types of jobs in a 100MW wind farm, which would have between 50 to 65 turbines (the average turbine size is now just under 2MW).

To estimate the number and type of the jobs in the U.S. wind industry, we have been interviewing more than two dozen companies at various stages of the industry value chain to measure representative factory and farm employment over the life cycle of a wind farm project. This includes employment at wind energy companies and contractors, and counts only wind-specific jobs in companies operating in multiple industries (e.g., companies making gears or bearings for a wide variety of industrial applications). Although we have not yet finished estimating some corporate support jobs, we are presenting our preliminary estimates of the employment directly linked to wind farms in order to help illuminate the policy debate. The results are presented in Table 1.

Table 1. Estimated Jobs for a 100MW Wind Farm and for the U.S. Wind Economy in 2011

	Jobs embedded in hypothetical 100MW wind farm	% of total	Estimated U.S. wind energy jobs in 2011	% of total
Development	21*	4%	1,428	5%
Manufacturing (Parts & Assembly)	391	75%	17,281	59%
Construction & Trucking	99*	19%	6,732	23%
Operations & Maintenance	8	2%	3,992	13%
Total	519		29,433	

* The wind farm employment for Development and Construction are reported in “job-years” because these activities span more than a single 12-month period. A single job that lasts two years counts as two job-years.

NOTE: The 100MW employment figures do not correct for imports; the jobs are “embedded” in the farm, but could be located anywhere. The U.S. estimates in the right-hand columns reflect an assumption that 35% of parts were imported.

Source: Authors’ calculation; see Appendix for details.

As the left-hand side of Table 1 shows, the most jobs required for developing a wind farm are in manufacturing and assembling the parts – primarily blades, towers, and nacelles (in which most of the moving parts are located). The manufacturing activity, which may happen locally, overseas, or some combination of these, accounts for 75% of the jobs “embedded” in a wind farm. The next biggest source of jobs is in construction, including the transportation of the very large parts between the factory and the wind farm site (19%). The development of a site, which requires permitting, reviewing engineering data, and satisfying legal requirements, can take several years; it employs relatively few people, but they are highly-skilled. Maintenance is a small but long-lived element of the employment picture; some wind turbines have been kept in service almost 30 years.

The values for Development and Construction, which each last longer than 12 months, were converted to a single count of full-time equivalent positions. The development process (legal, regulatory, contracting and other activities) for a site can take as long as five years, with most of the activity close to the time the farm is actually constructed. Construction of a wind farm typically lasts about 18 months. We took the total hours for these two activities and converted them to “job-years” on the basis of 1,920 hours per year.

To calculate the right-hand side of Table 1, which shows our estimate of the industry’s total U.S. employment in 2011, we multiplied the 100MW values for Development, Manufacturing, and Construction by the number of 100MW-equivalent farms that were installed that year (68), while we multiplied Operations jobs by the number of 100MW-equivalent farms nationwide at year-end (499). We subtracted 35% of manufacturing jobs to reflect the fact that many parts are still imported, yielding a grand total of 29,433 jobs.²

This is not an exhaustive count of all the jobs created by the industry. We have not yet estimated, for example, the jobs required to build the electrical substation that every wind farm needs in order to be connected to the electrical grid.

More importantly, though, because the first stage of our research has focused primarily on the jobs required for each new farm rather than the entire national headcount, we have not yet included many employees of wind energy companies, from building maintenance workers to R&D engineers, who may not be directly involved in the supply chain for a specific farm, but would nonetheless not have their jobs in the absence of a healthy wind energy sector. We believe there are at least a thousand more U.S. employees involved with sales, research, management, and support who are not yet reflected in our data.

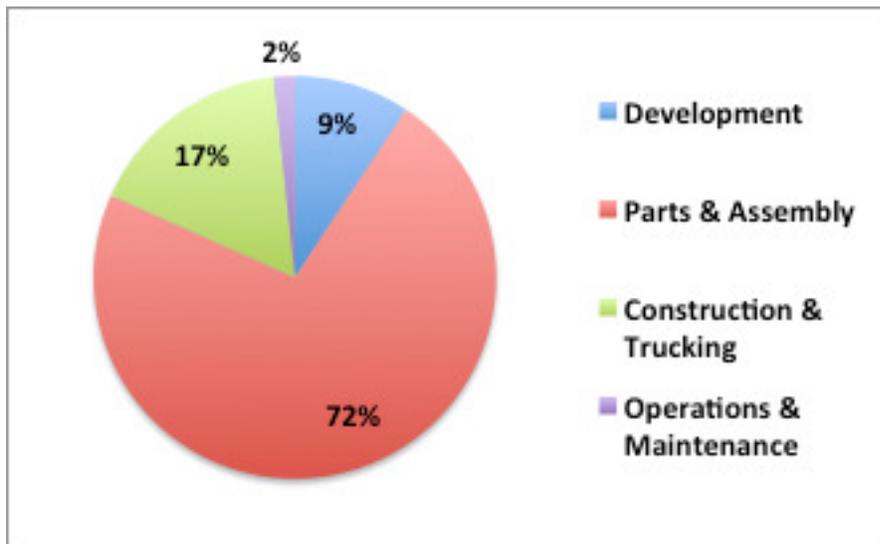
² Our estimate is considerably below the American Wind Energy Association’s estimate of 75,000 in 2011. We have not yet been able to obtain information needed to analyze why there is such a large difference. A study by Navigant Consulting that was released by the AWEA estimated 53,000 direct and indirect wind energy jobs in 2011 plus an additional 19,000 “induced” jobs derived by applying an economic multiplier to the industry-specific jobs for a grand total of 72,000 (Navigant Consulting, 2011). Our estimates do not include any induced jobs.

It is not just the number of jobs, but the quality and wage rates that matter as well (Figure 1).³ Returning to the job count for a representative 100MW wind farm, the associated wages, excluding benefits, total \$21,665,503 if all were paid at U.S. wage rates (see Appendix Table 2 for details). Benefits would add anywhere from 12% to 40% to this amount.

The proportions in the breakdown of wages by activity are different than the percentages on the right-hand side of Table 1, which reflect only the headcount. The biggest difference is Development, which accounts for 5% of overall employment but 9% of the corresponding wage bill because the lawyers and other professionals required for this work earn \$50,000 to \$150,000 a year.

Manufacturing and assembly of equipment accounts for 72% of the wage bill, and pays between \$12 and \$24 an hour for production workers. The manufacturing sector also employs engineers and managers who receive \$75,000 to \$150,000 per year. Construction and trucking account for 17% of the wage bill. Construction jobs pay around \$18-25 an hour, but construction managers can earn well over \$100,000.

Figure 1. Breakdown of Total Wage Bill for a Representative 100MW Wind Farm by Activity



We also compared our results to those from our previous research in the electronics industry (Linden, Dedrick, and Kraemer, 2011).⁴ Compared to portable electronics such as the iPod, the

³ The wage rates used, from a combination of industry interviews for some and Bureau of Labor Statistics for others, are representative but will vary greatly from one location to another.

⁴ The results aren't exactly comparable because the electronics study, which estimated employment for the production of iPods as of 2006, covered all activities, including manufacturing and sales, worldwide. The percentage of offshore non-professionals, which includes retail workers, is higher than if we considered only U.S.

wind industry provides the U.S. economy with a larger share of total employment (76% versus 34%) and a broader mix of jobs across production, professional and non-professional categories (Table 2). In place of the thousands of jobs in retail and distribution attributable to iPod sales in 2006, the wind energy sector in 2011 provides factory jobs that use the education and skills of middle class blue-collar workers.

Table 2. Estimated Headcount for U.S. Installation Wind Jobs (2011) and Worldwide iPod Jobs (2006), by Job Type

	Production	Non-professional	Engineering, professional, managerial	Total
Wind jobs				
U.S.	22,139	2,423	4,871	29,433
Non-U.S.	6,819	976	1,464	9,259
% U.S.	76%	71%	77%	76%
iPod jobs				
U.S.	30	7,789	6,101	13,920
Non-U.S.	19,160	4,825	3,265	27,250
% U.S.	0%	62%	65%	34%

Source: Wind industry numbers are the authors' calculations, as described in the Appendix. The iPod job numbers are from Linden, Dedrick, and Kraemer (2011).

Unlike electronics, where the trend has been towards moving manufacturing offshore over the last 30 years, the wind industry has seen a steady shift toward U.S. manufacturing, with domestic content growing from 35% to 67% since 2005, as noted above (DOE, 2012: 23) even as the industry has grown dramatically in size. The domestic manufacturing share could grow even further, as many components are made by European companies that have started production in the U.S. recently. For instance, when German gearbox and drivetrain manufacturer ZF decided to enter the wind industry, it built a plant in Gainesville, GA to supply the U.S. market because importing from Europe would require extra inventory and longer lead times (Umberson, 2012).

There is a strong incentive to manufacture in the U.S., as the cost of transportation can be up to 20% of total cost for large items that require special equipment and even police escorts to move. But there is no guarantee that domestic production will dominate imports if the market continues to be as volatile as it has been under the stop-and-start policies of recent years.

sales, as in our present study of wind energy. However, most iPods were sold in the U.S. in 2006, so the distortion may not be large.

Public Policy Towards Wind Energy

The chief policy instrument for promoting wind industry momentum is the Production Tax Credit (PTC), which cost the U.S. Treasury \$1.1 billion in 2011 (JCT, 2012), but political support has become erratic. The PTC, which was first put in place in 1992, has been allowed to lapse before being renewed three times--2000, 2004 and 2008--and it is scheduled to lapse again at the end of 2012. This pattern of repeated expiration and short-term renewal of the PTC causes a boom–bust cycle in wind power farm investment in the U.S., with declines of more than 70% in the “lapse” years.

In the past, the PTC, coupled with a number of state-level mandates for the use of renewable energy sources, has stimulated rapid growth of domestic demand, which has drawn investment from major foreign manufacturers such as Vestas, Siemens, Nordex, ZF, ABB and others. U.S. turbine makers such as GE and Clipper also expanded production.

U.S. companies in the materials, foundry services, electrical equipment, and other sectors have also become suppliers to the wind industry. Over the last decade, the U.S. has developed a manufacturing base of over 500 companies that produce blades, towers, gearboxes, generators and other key components, as well as many of the 8,000 other parts that go into a wind turbine. Wind companies are located in 44 states, of which 38 have utility-scale wind installations, the type that we analyze in this report.⁵

The U.S. is the second largest wind market in the world after China. This is due in large part to our abundant wind potential, and this potential is being realized more rapidly as a result of the PTC and related state government policies that also help to create demand.

A renewal of five years or more, with a gradual phase-out in outlying years, would create certainty for the industry and allow the tax benefit to have its greatest possible impact. But if investors believe that the PTC is unlikely to be extended for more than a year at a time, its impact will be greatly reduced. The evaluation and development of a potential wind farm site requires several years. One-year renewals of the PTC are not adequate to stimulate investment that has such a long time horizon. At best, a one-year renewal is likely to keep a few projects that were already underway from being cancelled.

The wind industry will eventually have to stand on its own, but the time has not yet come. In a market that properly priced the cost of negative externalities, such as carbon emissions, air pollution, and radioactive waste, wind might already be economically competitive without any tax credits. But such policies are not under consideration.

⁵ http://www.awea.org/learnabout/industry_stats/index.cfm, accessed September 1, 2012.

Wind energy will not require subsidies indefinitely. By comparison, fossil fuels benefit from billions of dollars in tax preferences each year, and these tax benefits have no expiration date (CBO, 2012).

In young industries such as wind, where manufacturing costs fall with experience and technology is steadily advancing, support can help the industry reach the point where it is fully competitive with established energy sources, such as nuclear and fossil fuels. Support for domestic demand through the PTC and state-level renewable energy mandates raises the level of local production and jobs, and leads to faster learning and greater competitiveness against producers in other countries.

However this virtuous cycle also works in reverse. If domestic demand falls steeply, manufacturing declines and learning slows. If the expiration of the PTC leads to a large contraction in demand, capabilities will be lost, factories will shut down, skilled workers will be laid off, and the U.S. industry will be set back by years. The U.S. will have to either rebuild the industry at considerable cost, or buy wind turbines and parts from countries such as Brazil and China, increasing the U.S. trade deficit in wind equipment.

So far this year there have been announced layoffs of about 2,000 workers as manufacturers adjust to the lack of new projects and possible end of the PTC. As work on projects being completed in 2012 wraps up, further layoffs in manufacturing and construction are likely. Clipper Windpower has announced it is laying off 32% of its 550 workers, mainly in manufacturing (Stinson, 2012). Vestas, a European turbine manufacturer has announced 500 layoffs in Colorado and may cut up to 1,600 jobs (Morales and Efstathiou, 2012). Vestas is also closing its R&D operations in the U.S, and Siemens has announced layoffs of 600 wind industry workers (Johnson, 2012).

The cutbacks extend to the supply chain. LM Wind Power and Katana Summit each announced layoffs of over 300 workers making wind components (Lacey, 2012; Johnson, 2012). According to company documents, the German gearbox maker ZF's decision to manufacture in the U.S. was based on volume assumptions for the U.S. market with the PTC in place. With the PTC expiring, new hires have been put on hold (Umberson, 2012). A European bearing manufacturer that we interviewed said that it had considered production in the U.S., but hesitated due to the uncertainty over the PTC.

According to one industry study, the number of wind energy jobs in the U.S. could fall by half if the PTC is not extended (Navigant, 2011). Using our estimates of total employment, a loss of 50% would be around 15,000 jobs (versus the 37,000 figure being used by AWEA). By contrast, when new wind installations declined by 50% from 2009 to 2010, total employment only fell by about 10%, perhaps because the industry expected renewed growth after the financial crisis. But if the PTC is not renewed, the economics of wind power will be different going forward, and the industry will have to adjust its capacity to produce at a level that can be sustained without

subsidies. Navigant estimated that annual installations without a PTC would be 4-5 GW per year as compared with the nearly 7 GW that was installed in 2011, the year used for our estimate. It is likely that employment would decline more than proportionally as lower demand reduces investments by suppliers and leaves more of the market to imports.

By extending the PTC, the U.S. would avoid the contraction of manufacturing and be in a competitive position to grow and export wind energy parts and equipment to other countries. U.S. wind exports increased from \$15 million in 2007 to \$149 million in 2011 (DOE, 2012) and has the potential for continued growth, especially in nearby markets which can be supplied by U.S. factories. Moreover, wind turbine costs are falling steadily even as generating efficiency improves, making wind energy economically viable in a greater number of locations around the world. The U.S. can be a leader in developing and commercializing wind technologies, but only if the domestic market supports the necessary investment.

A stronger U.S. manufacturing base for wind energy is also desirable for innovation. Wind turbines are highly complex integrated systems, more like an airplane than a PC. Technologies for individual components cannot easily be developed and tested in isolation from the entire system, in contrast with the way a hard drive can be developed separately from a PC.

Wind turbines are semi-custom products. Turbine makers usually have a small number of different platforms, which must be optimized for different markets where local transport, wind, altitude and land availability may dictate turbine weight, size, or functionality. A turbine developed for the low altitude, high wind, and limited land availability in Denmark will not be efficient for the higher altitudes and lower winds in California. While turbine design can be done anywhere, a great deal of physical development, testing and optimization must be done close to production where there can be frequent interaction between development and manufacturing. The proximity of manufacturing to R&D has the potential to accelerate the development and integration of new technologies, improving performance and reducing the cost of wind turbines, thereby contributing to industry leadership by U.S. firms.

Although the PTC is not a jobs bill, we evaluated the cost-benefit ratio when looking at jobs alone. The amount of credit earned per year by a 100MW wind farm is the product of the number of hours in a year (8,760), the capacity factor, which is the actual output as a percentage of nominal capacity (33% is the national average [DOE, 2012: vii]), and the size of the credit (currently \$0.022 per kilowatt hour). Multiplying these values together yields an annual cost of \$6,359,760 per 100MW installed, or a cumulative \$63,597,600 over the 10-year life of the credit.

Next we calculate the corresponding number of “job-years”. Table 1 shows 519 job-years per 100MW wind farm, but two adjustments must be made for the PTC calculation. First, we subtract 35% of the manufacturing jobs because of offshore production, which reduces the amount from 391 to 254. Then we multiply the Operations & Maintenance jobs by a

conservative 20-year lifespan for a wind turbine, which raises it from 8 jobs to 160 job-years. The revised net total for domestic job-years at a 100MW wind farm is 534.

Dividing the total 10-year cost of the credit by the corresponding job-years works out to \$119,097, paid out over 10 years to the power producer, for each job-year of demand created by a new wind farm. So if the PTC were just a jobs program, it would be an expensive one. But the PTC, as we have explained above, is much more.

A multi-year extension of the PTC is critical for maintaining the industry's momentum. In a stable policy environment, we could expect to see domestic content and the share of U.S. jobs in the wind energy value chain continue on their recent growth path. We estimate that a multi-year extension of the PTC could easily add several thousand jobs in the U.S. while speeding the U.S. toward greater competitiveness with foreign suppliers of wind power equipment.

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Appendix: Methodology

Our estimates are based primarily on detailed interviews with at least two companies at each stage of the wind energy value chain, from site development to maintenance. Interviewed companies were asked to provide the number of employees, the associated output, and the breakdown of employment by job category and wages. When a factory was a subsidiary of a larger company, we included a prorated share of headquarters employment wherever possible.

Where wages were provided as a range, the midpoint was used for estimates. Benefit ratios were obtained whenever possible, but our results are currently reported without benefits included because the interviewed companies reported a wide range of benefit ratios. In a few cases where wages were not provided by the interviewee, we used wages from comparable companies or the Bureau of Labor Statistics (BLS). Our findings are not sensitive to changes in these numbers.

We used the interview results to estimate industry averages, so our results should not be taken as representing the activity of any specific company.

Although we extended this interview-based method to some of the key upstream inputs, such as steel, we used a different method for some components that relied on Census of Manufacturing data. For these other inputs, we compared their cost in the industry's bill of materials with the total sales for the corresponding six-digit NAICS code from the Census of Manufacturing for 2010. We then applied this ratio to the employment data for that NAICS code to estimate the number of jobs and then obtained wage estimates from BLS data. This NAICS/BLS estimation method was used for inputs amounting to just under half the value of the bill of materials for a wind turbine.

Using the job estimates derived by one or the other of these two methods, we calculated employment and wages involved in planning, building, and maintaining a "typical" 100 megawatt (MW) wind farm, abstracting from the issue of imports (Appendix Tables 1 and 2). Utility-scale wind farms installed in 2011 ranged from 30MW to 250MW. For the development and construction activities that last more than 12 months, we compressed multi-year employment into "job-years". For example, a construction job that lasts 18 months is reported as having 1.5 jobs associated with a 100MW wind farm unit.

To estimate the total industry employment in 2011 for operations and maintenance, we multiplied our 100MW value (8 jobs) by 499 to account for the maintenance component of the 49.9 gigawatt (GW) national installed base at the end of 2011. Then we multiplied the other

categories by 68 to capture the jobs associated with the 6.8 GW that had been added during 2011, but took away 35% of the parts and assembly jobs to account for foreign content.⁶

For convenience, we also provide Appendix Table 3, which reports the quotient of the headcount in Table 1 and the wages in Table 2 for each activity-job pair. Each cell contains the representative annual salary (before benefits) for an activity-job pair, but actual salaries vary considerably by location.

Appendix Table 1. Embedded Labor in a Hypothetical 100MW Wind Farm

Item or Activity	Direct Labor	Indirect Labor	Managers	Engineers	Other Professional
Development*	0	0	0	0	21
Nacelle assembly	34	18	1	3	0
Blade set	59	10	1	2	0
Tower	67	6	1	1	0
Tower steel	8	2	0	0	0
Gears	17	0	1	1	9
Nacelle housing	10	3	1	0	0
Blade fiberglass and resin	21	3	0	1	0
Hub/Castings	9	0	0	0	2
Generator	8	0	1	1	5
Converter	6	0	0	1	2
Control system	7	0	1	4	2
Yaw/Pitch	9	0	1	1	2
Nacelle Other	12	0	2	4	4
Controller/ Transformer	20	0	1	4	3
Parts & Assembly Sub-Total	287	42	11	22	29
Construction*	68	0	0	0	2
Trucking	27	1	1	0	0
Construction & Trucking Sub-Total	95	1	1	0	2
Operations & Maintenance	6	1	1	0	0

⁶ The 35% factor is slightly more conservative than the most recent Department of Energy estimate of a 33% import share (DOE, 2012: 23).

Column Totals	388	44	13	22	52
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*Development and Construction are expressed in "job-years", the number of FTEs equivalent to the total hours that in practice would be worked over more than a 12-month period.

Appendix Table 2. Embedded Wages in a Hypothetical 100MW Wind Farm (all at U.S. wages rates and without benefits)

Item or Activity	Direct Labor	Indirect Labor	Managers	Engineers	Other Professional
Development*	\$0	\$0	\$0	\$0	\$2,023,200
Nacelle assembly	\$961,891	\$699,638	\$96,058	\$228,192	\$0
Blade set	\$1,377,485	\$212,122	\$92,506	\$154,982	\$0
Tower	\$2,199,744	\$389,952	\$124,992	\$74,995	\$0
Tower steel	\$255,437	\$71,539	\$0	\$0	\$0
Gears	\$735,706	\$0	\$122,496	\$99,994	\$414,163
Nacelle housing	\$243,840	\$94,013	\$50,304	\$0	\$0
Blade fiberglass and resin	\$837,120	\$230,400	\$0	\$59,520	\$0
Hub/Castings	\$362,880	\$0	\$0	\$0	\$142,080
Generator	\$399,360	\$0	\$97,920	\$61,440	\$432,000
Converter	\$213,120	\$0	\$0	\$0	\$130,560
Control system	\$241,920	\$0	\$115,200	\$207,360	\$153,600
Yaw/Pitch	\$319,680	\$0	\$97,920	\$57,600	\$130,560
Nacelle Other	\$546,048	\$0	\$211,200	\$268,800	\$345,600
Controller/ Transformer	\$768,000	\$0	\$97,920	\$230,400	\$213,120
Parts & Assembly Sub-Total	\$9,462,231	\$1,697,664	\$1,106,516	\$1,443,283	\$1,961,683
Construction*	\$2,337,024	\$0	\$0	\$0	\$168,307
Trucking	\$978,221	\$31,258	\$91,642	\$0	\$0
Construction & Trucking Sub-Total	\$3,315,245	\$31,258	\$91,642	\$0	\$168,307
Operations & Maintenance	\$95,002	\$0	\$0	\$0	\$84,154
Column Totals	\$12,872,478	\$1,728,922	\$1,198,158	\$1,443,283	\$4,237,344

*Development and Construction are expressed in "job-years", the number of FTEs equivalent to the total hours that in practice would be worked over more than a 12-month period.

Appendix Table 3. Representative Annual Salaries for Jobs Associated With a Hypothetical 100MW Wind Farm

Item or Activity	Direct Labor	Indirect Labor	Managers	Engineers	Other Professional
Development	--	--	--	--	\$96,343
Nacelle Assembly	\$28,291	\$38,869	\$96,058	\$76,064	--
Blade set	\$23,347	\$21,212	\$92,506	\$77,491	--
Tower	\$32,832	\$64,992	\$124,992	\$74,995	--
Tower steel	\$31,930	\$35,770	--	--	--
Gears	\$43,277	--	\$122,496	\$99,994	\$46,018
Nacelle housing	\$24,384	\$31,338	\$50,304	--	--
Blade Fiberglass and resin	\$39,863	\$76,800	--	\$59,520	--
Hub/Castings	\$40,320	--	--	--	\$71,040
Generator	\$49,920	--	\$97,920	\$61,440	\$86,400
Converter	\$35,520	--	--	--	\$65,280
Control System	\$34,560	--	\$115,200	\$69,120	\$76,800
Yaw/Pitch	\$35,520	--	\$97,920	\$57,600	\$65,280
Nacelle Other	\$45,504	--	\$105,600	\$67,200	\$86,400
Controller/Transformer	\$38,400	--	\$97,920	\$57,600	\$71,040
Construction	\$34,368	--	--	--	\$84,154
Trucking	\$36,230	\$31,258	\$91,642	--	--
O&M	\$38,400	\$49,920	\$84,154	--	--

Notes: "--" in a cell means that no jobs were reported in that category for the activity.

All values were calculated by dividing Table 2 cells by the corresponding Table 1 cells.

Values represent salaries or hourly wages converted at 1,920 paid hours per year.

All values are before benefits, which range from 12% to 40% among our sample firms.