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"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/

Alternative energy is being promoted by the current administration, as well as many opinion leaders as part of a future economy based on green technologies and sustainable energy sources. Supporters see the potential to slow global warming, reduce U.S. dependence on unpredictable foreign energy sources, and create millions of jobs in the U.S. Bestselling author Thomas Friedman (2008) has called for a green revolution and raised concerns that other countries will leave the U.S. behind in the critical energy technologies of the 21st century.

However, there are skeptics who believe that the potential of alternative energy has been overstated and that government subsidies will simply distort investment decisions. In terms of the job potential of alternative energy, they point out that the wind and solar industries are global in nature, with companies from the U.S., Europe and Asia participating in the supply chain, and manufacturing spread around the world. It is possible that much of the wealth and employment associated with alternative energies will end up outside the U.S. According to one source, 84% of the $1 billion in clean energy grants given out under the 2009-2010 economic stimulus plan went to foreign companies (Choma, 2009).

In order to understand the potential for creating economic value from alternative energy, there is a need for detailed empirical research on the global structure of those industries. As one step in this direction, we have conducted research aimed at answering the question: Who captures value in the global wind energy industry supply chain? [1]

[1] There are a number of potential measures of value that are important to firms, countries, workers, shareholders and others. These include jobs, wages and profits. In this case, we focus on financial value in the form of profits to firms. In future work we hope to analyze other measures, as we have done for the electronics industry.

Background

Wind energy accounts for about two percent of electricity generation in the U.S., but is growing fast, with installed capacity increasing from 6,700 MW in 2003 to 40,180MW in 2010 (Kirkegaard et al., 2009 and GWEC, 2011). Global capacity grew from 39,431MW to 194,390MW in the same period.

In 2010, China passed the U.S. with the largest installed base of wind generation capacity (Table 1). Asia is now a larger market than Europe or North America, and is expected to pass Europe in installed capacity by 2013. Investment in new capacity at the country level varies quite a bit over time, driven to in part by government subsidies that make wind energy more competitive with alternatives fuel sources.

These subsidies sometimes favor domestic producers, who also have local knowledge and connections that gives them an advantage in their home markets, so that the fortunes of wind turbine manufacturers are related to domestic subsidies and demand. Thus the growth of wind capacity in Asia, and China in particular, points to a shift on the supply side as well. Already, two of the top five turbine manufacturers (Sinovel and Goldwind) and four of the top ten are Chinese companies. Their success is based mainly on supplying the domestic market, but they are now expanding into international markets (GWEC, 2011).

Table 1. Installed and new wind capacity 2010: Top 5 countries

	Installed capacity (MW) end of 2010	New installation in 2010
China	42,287	16,500
USA	40,180	5,115
Germany	27,214	1,493
Spain	20,676	1,516
India	13,065	2,139

Source: Global Wind Energy Council, 2011

The wind industry value chain

Wind turbine manufacturing and transportation account for about 75% of the cost of a modern wind farm, with the rest going to local costs such as construction, grid connections, site development etc. (Kirkegaard, et al., 2009). Wind turbines consist of upwards of 8,000 parts, which are supplied in a global value chain that spans Europe, North America and the Asia-Pacific region. Some of these manufacturers also make major components such as blades, towers, nacelles, gear boxes and controls. Others rely on outside suppliers, or use a mix of internal and external production.

Components can be sourced from domestic or foreign companies, but there might be a tendency to favor local suppliers who have the advantage of proximity to reduce transaction costs and are more likely to have local manufacturing capabilities. This might be changing as more manufacturers and suppliers set up manufacturing and even R&D to be near the final market. In some cases, industry clusters from the home country are replicated in another major market. For instance, Vestas has established production in the Midwestern states of the U.S., and many of its European suppliers have set up manufacturing in the same region. According to the Global Wind Energy Council (GWEC, 2011) domestic content in U.S.-deployed turbines is about 50%.

The most costly components of a large scale wind turbine are the tower, blades, and gear box (Table 2). It is important to keep in mind the size of a utility-scale wind turbine. Towers run from 40-100 meters, while blades can be over 60 meters in length. This makes transportation very expensive and favors manufacturing close to the site of the wind farm. Other parts are smaller and can be shipped more economically, but as turbines continue to get larger, transportation cost will be a major factor in manufacturing location decisions.

Table 2. Main parts and contribution to cost of large wind turbine (REpower MM92)

Tower	26.3%
Rotor blades	22.2
Gear box	12.9
Power converter	5.0
Transformer	3.6
Generator	3.4
Main frame	2.8
Pitch system	2.7

Source: *Wind Directions*, 2007

Methodology

We applied a methodology developed in our previous studies of the iPod, notebook PCs and smart phones to determine the distribution of financial value among firms and countries in the global value chain of the electronics industry (Linden, Kraemer and Dedrick, 2008; Dedrick, Kraemer and Linden, 2009, 2010). While the wind industry is much different from electronics in many ways, both are very global, and the methodology is conceptually the same. A detailed explanation of the methodology is provided in Linden et al. (2007): http://crito.uci.edu/papers/2007/MappingTheValue.pdf. We briefly explain its application here.

First, we identify the suppliers of major parts and components for a wind turbine. This is done by obtaining a list of suppliers for each lead firm and then constructing an industry supply chain such as that illustrated in Appendix. At this point we also identify the cost of components and the proportion each supplier represents of the bill of materials (BOM) for the product . We further identify the geographic location of the headquarters for each firm.

Second, we estimate the value captured by firm for the suppliers and the lead firm. We use firm-level gross profit in dollars. Gross profit is the difference between "net sales" and "cost of goods sold." Gross profit does not equal the full value added, since it excludes direct labor. Instead, it measures the value the company (excluding its direct workers) captures from its role in the value chain, which it then can use to reward shareholders (dividends), invest in future growth (R&D), cover the cost of capital depreciation, and pay its overhead expenses (selling, general, and administration).

Third, we aggregate value capture by geographic location (country) of the headquarters for each firm to estimate value capture by country.

Data

In our study of electronics products, we were able to use "teardown" reports by industry analysts who would literally tear apart a new product and identify the source and cost of many key components. Tearing apart a multi-million dollar wind turbine is not feasible, so we used other sources, including interviews with turbine makers, published reports and reports by industry analysts with deep knowledge of the supply chain. Based on these reports, we were able to identify sources (sometimes multiple) for key components. Gross margins were obtained from company financial reports. When this data was not available (e.g., for privately held companies), we used industry averages or data on comparable firms to estimate margins.

Analysis

We carried out financial value capture analyses of two wind turbines, a 2.5 MW Clipper Liberty turbine, and a 2.0 MW Gamesa G8 turbine. Each has an estimated cost of $3.5 million. The idea was to compare the distribution of value capture in U.S. (Clipper) and non-U.S. (Gamesa) turbines.

The gross margin for Gamesa (23%) was taken from the company's annual reports. Since this is a relatively large company that only makes wind turbines, we applied the company's margins to the individual turbine. We also applied that margin to the many components that Gamesa produces in-house.

Clipper is a much smaller company that was losing money overall in 2008 due to its lack of economies of scale in production. We assumed, however, that its pricing and cost structure for an individual turbine would be closer to industry averages, so we used an industry average gross margin of 20% for the Liberty turbine that we analyzed.

Table 3. Value capture for 2.5MW Clipper Windpower Liberty turbine, 2008

Component	Supplier	Supplier HQ country	Estimated cost as % of total inputs	Cost of component	Gross margin	Estimated value capture
Tower	Aerisyn (Schaff Industrie AG	Germany	26.3	$736,400	18%	$132,552
Rotor blades/hub/bearings	Tecsis	Brazil	24.8	$694,120	20%	$138,824
Gearbox	Brad Foote/Indiana Gear	US	12.91	$361,480	19%	$139,916
Power converter	Xantrex	US	5.01	$140,280	31.5%	$44,188
Power transformer	Wesco	US	3.59	$100,520	20.4%	$20,506
Generator	Potencia	Mexico	3.44	$96,320	30%	$28,896
Main frame	ThyssenKrupp	Germany	2.8	$78,400	17%	$13,328
Pitch bearings	Rotek	US	1.33	$37,240	23.1%	$8,614
Pitch drives	Sipco	US	1.33	$37,240	20%	$7,448
Cables, screws, etc.	Various	n.a.	2	$56,000	20%	$11,200
Main shaft	Skoda	Czech Rep	1.91	$53,480	20%	$10,696
Nacelle housing	Tecsis	Brazil	1.35	$37,800	20%	$7,560
Brake system	Svendborg	Denmark	1.32	$36,960	20%	$7,392
Yaw bearings	Rotek (ThyssenKrupp)	US	1.25	$35,000	23.1%	$8,614
All other	Various	n .a.	10.67	$298,760	20%	$11,200
Totals			**100**	**$2,800,000**		

Source: Rackstraw, 2007; authors' calculations

Table 4. Value capture for G8x 2.0 MW Gamesa (Spain) turbine, 2008

Component	Supplier	Supplier HQ	Cost as % of total	Cost of component	Gross profit margin	Value capture
Tower	Gamesa	Spain	26.3	$708,785	23%	$163,021
Rotor blades/hub/bearings	Gamesa	Spain	24.79	$668,091	23%	$153,661
Gearbox	Gamesa	Spain	12.91	$347,925	23%	$80,023
Power converter	Gamesa	Spain	5.01	$135,020	23%	$31,054
Power transformer	ABB	Switzerland	3.59	$96,751	20%	$19,737
Generator	Gamesa	Spain	3.44	$92,708	23%	$21,323
Main frame	Gamesa	Spain	2.8	$75,460	23%	$17,356
Pitch bearings	Fundicion Nodular del Norte	Spain	1.33	$35,844	23%	$8,244
Pitch drives		n.a.	1.33	$35,844		n.a.
Cables, screws, etc.	Various	n.a.	2	$53,900		n.a.
Main shaft		n.a.	1.91	$51,475		n.a.
Nacellle housing		n.a.	1.35	$36,383		n.a.
Brake system		n.a.	1.32	$35,574		n.a.
Yaw bearings		Spain	1.25	$33,688	23%	$7,792
All other	Various	n .a.	10.67	$287,557		n.a.
Totals			100	$2,695,000		

Source: *Wind Directions*, 2007; authors calculations.

For the Clipper turbine, we estimated that Clipper captured 20% of the value of the turbine, with a mix of U.S., German, Brazilian, Mexican and other suppliers sharing another 17%. The rest was accounted for by upstream components and inputs (Figure 1). The total U.S. value capture is 27%.

For the Gamesa turbine, Gamesa captured 36% of the value as gross margin. The difference is that Gamesa is much more vertically integrated, making its own blades, gearboxes and other key components. Outside suppliers' margins accounted for only 7.3% of the value, with no country other than Spain accounting for even 1% (Figure 2). The total value capture for Spain (37.6%) is only slightly larger than that of Gamesa (37%).

Figure 1. Value capture in 2.5MW Clipper Liberty turbine

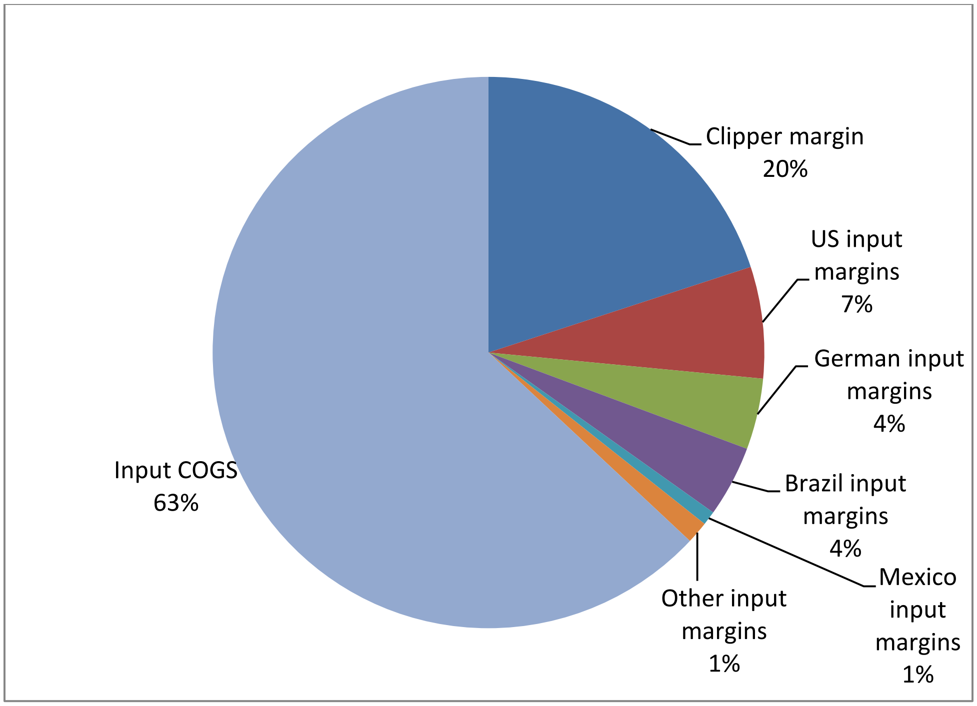
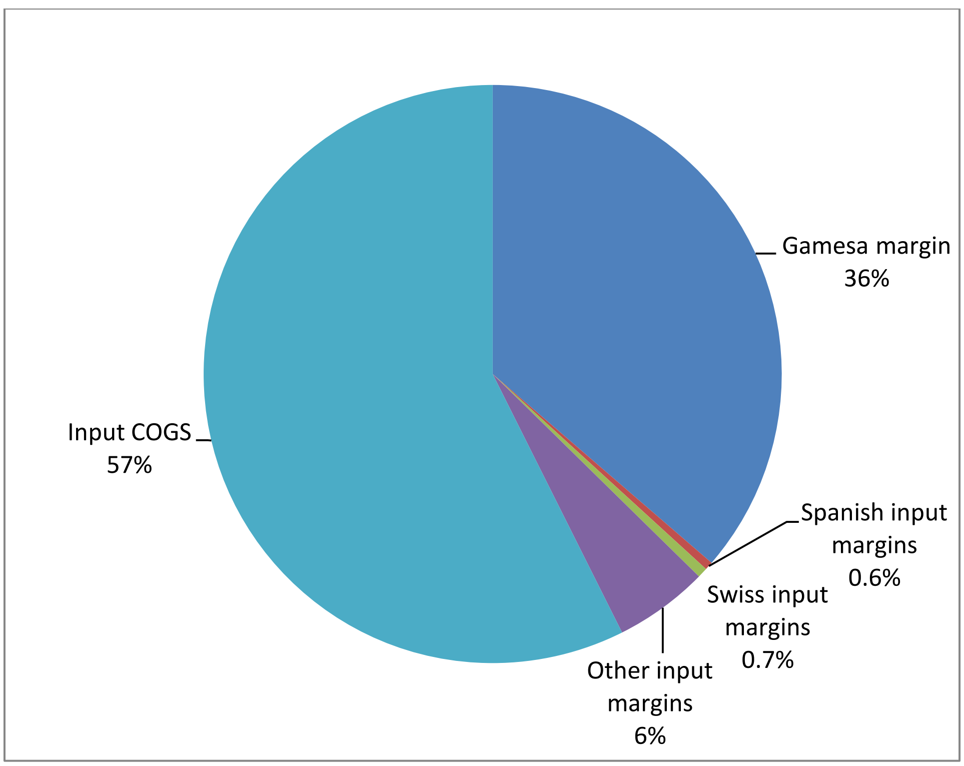


Figure 2. Value capture in a 2.0 MW Gamesa G8 turbine



Findings

The headquarters location of the turbine manufacturer makes a key difference in value capture. Not only does the manufacturer earn a margin on its product, it also pays salaries for R&D, management and other functions in its home country. And in the case of Clipper, the lead firm was more likely to use U.S. suppliers. This is consistent with the findings in our study of electronics products.

Whether the turbine manufacturer is vertically integrated or relies heavily on outsourcing makes a difference in terms of value capture. European manufacturers are generally more vertically integrated than U.S. manufacturers and have higher value capture. The largest U.S. manufacturer, GE, relies heavily on outside suppliers, as does Clipper. We obtained data on the Danish company Vestas, the world's largest turbine manufacturer, and found a pattern of vertical integration similar to Gamesa. The U.S. model is to the U.S. electronics industry, while the European model is more like Japanese or Korean electronics companies.

The trend is likely to be towards the U.S. model, as China emerges as the leading market for wind power and requires the use of local suppliers to participate in its market. Also, the cost of R&D to keep up in multiple component technologies will likely lead to greater use of outside suppliers as the industry matures.

Discussion

Beyond the immediate findings from the study, we have several broader conclusions based on this and broader research.

Wind turbines are very large and expensive to transport, so it is likely that some manufacturing will gravitate towards large markets to be cost effective. European manufacturers are already producing in the U.S., and their component suppliers have begun to set up manufacturing as well. While there is concern that U.S. investment in wind energy will just create jobs offshore, it appears likely that a growing U.S. market will create some manufacturing jobs in the U.S., even if a large share of the turbines are supplied by foreign manufacturers.

The wind industry is quite volatile, relying on government subsidies that rise and fall with political shifts in the U.S. and other countries, and greatly affected by the price of other energy sources. China's promotion of renewable energy is the latest example of government policy driving investment and creating a market for domestic suppliers. For a viable U.S. industry to develop, a stable set of incentives is needed, but eventually the cost of wind power must be competitive with other energy sources (taking into account social costs such as local pollution and greenhouse gas emissions).

Policies to promote wind energy can directly or indirectly favor domestically-owned manufacturers. For instance, it is claimed that foreign manufacturers have been excluded from China's major wind farm projects (Kirkegaard et al., 2010). The U.S. should work for market access in other countries and create a favorable investment environment in the U.S. so that foreign suppliers are more likely to conduct manufacturing, R&D and other activities in the U.S.

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Appendix. Illustrative wind supply chain