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# **MINNESOTA'S WINDS OF PROGRESS**

***HOW OUR WIND ENERGY INDUSTRY  
CAN CONTINUE GROWING***

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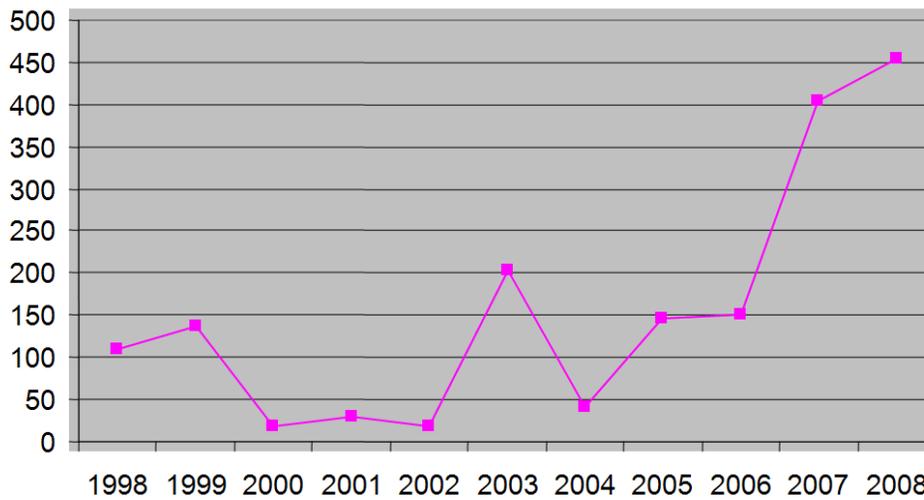
# Executive Summary

When placed in the most optimal location, with the proper investment, research and development, wind farms can create thousands of jobs, revive the economic base of many Minnesota communities hit hard by the recession and help the United States become more energy independent. Already, Minnesota is among the leading states for wind energy, with about 1800 Mega Watts of installed capacity, enough to power up to 450,000 homes, according to Alliant Energy.<sup>1</sup> Only Texas, Iowa and California rank ahead of Minnesota when it comes to installed capacity so far.

Since 2005, Minnesota has been dramatically increasing its wind capacity, growing by about 31 percent every year. This is due in large part to federal subsidies known as production tax credits (PTC).

**Figure 1: Minnesota's Annual Installed Wind Capacity**

Installed Capacity (MW)



Minnesota is in a good position to capitalize on this advantage for several reasons, including the state legislature's mandate that utilities purchase or generate 25 percent of their power from renewable resources by 2025 (30 percent by 2020 for Xcel Energy).

This Renewable Energy Standard (RES) has the potential to increase the state's wind power capacity

Source: American Wind Energy Association (AWEA) project database (updated April 31, 2009) by about 4,000 MW (1 million homes), which would create up to 2,200 new jobs during the 17-year construction phase and more than 900 sustained jobs during the wind farms lifetime operations. These numbers would only grow as the state reached beyond the 25 percent minimum RES.

Construction of 4,058 MW of wind power would pump nearly \$9 billion into Minnesota's economy over a 17 year period. Operation costs would propel another \$1.5 billion annually into Minnesota's towns.

A good portion of the jobs created would be in the manufacturing sector, an industry hit especially hard during this economic slowdown. Employment in fabricated metal production—a key component of wind turbines—fell by 10 percent since the start of the recession. These lower skilled jobs are also less venerable to outsourcing in wind production because of the high cost associated with transporting wind blades and other heavy components.

Minnesota is also positioned well when it comes to the number of industries already producing components necessary for wind production. The state ranks 13th in the number of workers already in related industries and 14th in the number of actual companies engaged in related manufacturing processes. Duluth-based Northstar Aerospace, an airplane parts manufacturer, had to lay off most of its 115 workers when its main customer,

<sup>1</sup> (<http://www.alliantenergy.com/Newsroom/MediaKitsPhotoGalleries/015077>)

Cirrus Design, cut production. In last few weeks, Northstar hired back about 20 workers after branching out to make parts for wind generation manufacturers.<sup>2</sup>

## Impacts of the Financial Crisis on the Wind Industry

The development of the wind industry in Minnesota has the potential to revive the state's manufacturing sector. However, the economic downturn is also causing problems for wind production because it has made it difficult for the wind industry to access capital.

Most wind projects are financed by strategic and institutional investors with the capability to efficiently use the production tax credit (PTC) to offset earnings. However, the economic recession has reduced the pool of investors with sufficient earnings to efficiently utilize the PTC. The credit crisis has also reduced the debt financing available for wind projects. This all means that there will be an imbalance between the supply of wind projects seeking financing and the demand from financial institutions. Essentially, the credit crisis has put the brakes on the development of many wind projects.

## Outlook for 2009 and Beyond Still Positive

Minnesota's wind industry will experience slower growth because the economic recession has reduced the financing available for wind projects. However, in February 2009, Congress passed the American Recovery and Reinvestment Act (ARRA), which includes several provisions to aid development of wind energy, such as:

- a 3-year extension of the Production Tax Credit (PTC) beyond 2009;
- an option to elect a 30 percent Investment Tax Credit (ITC) in place of the PTC. This credit can then be converted into a grant for projects beginning construction or starting operation in 2009 or 2010;
- a new \$6 billion Department of Energy (DOE) renewable energy loan guarantee program.

It is expected that the wind industry will experience strong growth in 2010 and 2011, because the ARRA requires companies to begin construction prior to 2011 to take advantage of these energy subsidies. It is also expected that the loosening of the credit markets will improve access to project financing by 2010. The cash grant in lieu of the tax credit will be an important source of financing for wind projects unable to secure tax equity.

## Key Findings

- 4058 megawatts of additional wind capacity has the potential to energize Minnesota's economy.
  - o 100 percent local ownership of wind projects is estimated to have an annual impact that is almost three times greater than corporate-owned projects.
  - o Under the baseline scenario, the construction of wind projects to meet the RES requirement is estimated to create 2,222 new jobs over the next 17 years. 1,422 are estimated to be created in the turbine supply chain, and 190 new jobs are expected to be created in the construction sector and project development related services.

<sup>2</sup> [http://minnesota.publicradio.org/display/web/2009/07/07/northstar\\_aerospace/](http://minnesota.publicradio.org/display/web/2009/07/07/northstar_aerospace/)

o Most of these jobs can't be outsourced because of the on-site work that is needed and high transportation costs associated with shipping components.

o Under the baseline scenario, RES requirement is estimated to add 922 jobs during the operations period of wind farm. These jobs include field technicians, administration, and management.

**Table 1: Construction Period Impacts from the installation of 4,058 MW of wind energy in Minnesota**

Scenarios	Jobs <sup>3</sup>	Earnings (millions of \$)	Output (millions of \$)
Status quo economy	2222	\$1718.5	\$5,090.4
17.4% increase in turbine component (excluding blades) manufacturing	2298	\$1,763.08	\$5,225.89
34.7% increase in turbine component (excluding blades) manufacturing	2343	\$1,807.68	\$5,361.33
25% of blades manufactured in-state	2313	\$1,769.64	\$5,313.03
50% of blades manufactured in state	2404	\$1,846.88	\$5,653.33
50% of Towers manufactured in-state	2402	\$1844.6	\$5650.0
100% of Towers manufactured in-state	2585	\$1999.1	\$6330.6
50% of blades manufactured in state	2404	\$1,520.95	\$4,710.61
75% in-state construction labor	2080	\$1,579.96	\$4,833.69
75% in-state construction materials	2144	\$1,645.39	\$4,865.63

<sup>3</sup> Jobs are the number of full-time jobs during each of the 17 years from 2009 – 2025.

**Table 2: Operations Period Impacts from the installation of 4,058 MW of wind energy in Minnesota**

<b>Scenarios</b>	<b>Jobs<sup>4</sup></b>	<b>Earnings (millions of \$)</b>	<b>Output (millions of \$)</b>
Status quo economy	922	\$43.3	\$127.2
100% community owned wind projects	2,962	\$118.80	\$364.62
Minnesota Flip finance structure (60% debt, 40% equity)	1516	\$65.3	\$196.4
50% in-state operations period labor	758	\$33.51	\$110.51
75% in-state operations period labor	840	\$38.40	\$118.83

- Promoting the wind industry will increase demand for displaced workers in the hard-hit manufacturing sector. This report finds that about 60 percent of the direct employment and 70 percent of the direct and indirect employment in the wind industry is in manufacturing.
  - o Of the direct jobs created in the manufacturing sector, 20 percent are benchwork occupations. This category includes occupations in assembly and inspection.
  - o 31 percent of the direct jobs created in the manufacturing sector are machine trades occupation. These include metalworking (sheet and bar rolling occupations and fabricating machine occupations) and metal machining occupations.
  - o 45 percent of the direct jobs created in the manufacturing sector are structural work occupations. Structural work occupations include welders and cutters.
- 1000 megawatts of additional wind capacity has the potential to energize Minnesota’s economy.
  - o 100 percent local ownership of wind projects is estimated to have an annual impact that is almost two times greater than corporate-owned projects.

**Recommendations**

- Minnesota’s short-term goal should be to localize wind turbine manufacturing and attract foreign wind

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<sup>4</sup> Jobs are the number of full-time jobs during each of the 17 years from 2009 – 2025.

energy companies. Developing new, in-state, wind energy companies is a longer-term goal.

- Provide assistance to Minnesota companies in meeting the aggressive certification and standardization requirements of wind turbine manufacturers.
- Promote partnerships and joint venture enterprises between Minnesota companies and more advanced foreign wind energy companies. These partnerships would allow for technology transfer and give Minnesota companies opportunities to gain experience in the wind turbine manufacturing sector.
- Increase workforce training to increase use of local labor during the construction and operating periods of the wind project. Establish workforce training centers to train wind technicians.
- Promoting the wind industry will increase labor market demand for displaced workers in the hard-hit manufacturing sector. This report finds that about 88 percent of the direct and indirect employment in the wind industry is in turbine supply chain.

#### *Recommendations for the short term*

- Minnesota's short-term goal should be to localize existing wind turbine manufacturing and attract foreign wind energy companies.
- Provide assistance to Minnesota companies in meeting the aggressive certification and standardization requirements of wind turbine manufacturers.
- Increase workforce training to increase use of local labor during the construction and operating periods of the wind project.
  - o Establish more workforce training centers to train wind technicians. Riverland Community College in Albert Lea and Minnesota West Community & Technical College in Canby are currently the only two wind technician training centers in Minnesota.

#### *Recommendations for the long term*

- Use Minnesota's existing knowledge base and localization advantages to develop new, in-state, wind energy companies (e.g. Northstar Aerospace)
- Promote partnerships and joint venture enterprises between Minnesota companies and more advanced foreign wind energy companies. These partnerships would allow for technology transfer and give Minnesota companies opportunities to gain experience in the wind turbine manufacturing sector.

# Introduction

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Wind energy is a major investment and spending on wind projects has the potential to generate a significant number of jobs and economic development in Minnesota. The purpose of this paper is to investigate the economic development impacts from wind power, and, in particular, wind development to comply with Minnesota's Renewable Energy Standard (RES). The RES requires utilities to purchase or generate 25 percent of their retail sales in 2025<sup>1</sup> (30 percent in 2020 for Xcel Energy) from eligible renewable energy sources. Accordingly, this paper seeks to investigate the economic development impacts from the installation of 4,058 MW of wind capacity in Minnesota beyond 2010 to meet the RES requirement in 2025. Understanding the economic development impacts of wind energy projects allows policymakers to make more informed decisions about energy policy and whether and how to promote the wind industry in Minnesota. This paper also conducts a sensitivity analysis to determine the main drivers of local economic benefits from wind projects. The sensitivity analysis will aid policymakers in adopting policies that maximize the local economic benefits from wind projects. This study finds that the greatest returns come from policies designed to promote local ownership of wind projects and from policies to promote in-state manufacturing of wind turbine components.

Technological change, international competition, and the current economic recession have led to large-scale displacement of low-skilled workers and increasing wage differentials by educational attainment. Displaced workers suffer large and persistent income losses (Kletzer 1998). The pattern of job loss in Minnesota suggests that workers in routinized jobs are particularly vulnerable to displacement. These workers in Minnesota have also experienced a steady decline in employment opportunities and earnings relative to higher skilled workers. This long-term trend has been exacerbated by the recent economic recession. Employment is down sharply in manufacturing sub-sectors with employment falling by more than 10 percent in the fabricated metal products sub-sector since January 2008.

Policymakers are concerned about job displacement and the recent dramatic rise in unemployment in the manufacturing sector. The consequences for workers are severe. With this in mind, policymakers design public policy with the goal to increase employment and earnings for low-skilled workers. There are two broad categories of public policies: labor supply policies and labor demand policies. Labor supply policies aim to increase the quality or quantity of the labor supplied by low skilled workers. Relocation assistance and job training programs are labor supply policies. Labor demand policies induce employers to hire more low-skilled workers. Wage subsidy programs are examples of labor demand policies. Other labor demand policies include policies designed to stimulate production and investment, such as increased government spending. This paper supports the need for both labor supply and labor demand policies and investigates the potential job creation and economic development impacts from the installation of wind energy in Minnesota. The promotion of wind development is a labor demand policy and would be particularly effective in increasing employment opportunities and earnings during this time of high unemployment and job shortages.

Wind development in Minnesota is a particularly effective way to create new manufacturing jobs for displaced workers in Minnesota. There are several recent studies showing that a significant portion of the new jobs are

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<sup>1</sup> The utility companies in their application for a certificate of need for three 345-KV transmission lines estimate that 4,058 MW of wind energy will need to be installed beyond 2010 to comply with the RES in 2025. This estimate assumes a 1 percent demand side management (DSM) and a 40 percent capacity factor. The Office of Energy Security (OES) of the Minnesota Department of Commerce estimated that 3,409 MW of wind power over eligible renewable energy installed as of 2010 will be required to comply with the RES in 2020 if all new renewable energy generation in Minnesota comes from wind power. This estimate is also assumes 1 percent DSM and a 40 percent capacity factor (PUC Docket No. ET2, E002 et al./CN-06-1115). The OES estimate is very close to the utility companies' estimate of 3,555 MW (assuming a 1 percent DSM and a 40 percent capacity factor) over the 2010 level by 2020 in their application for a certificate of need for the three 345-KV CapX2020 transmission lines.

created in the manufacturing sector. The EWEA, in its 2008 edition of *Wind at Work*, concludes that 59 percent of the direct jobs created in the wind energy sector are in the manufacturing sector. The same EWEA report also concludes that 83 percent of the direct and indirect jobs created are in the manufacturing sector. This study finds that 88 percent of the newly created direct and indirect jobs during the construction period are in the manufacturing sector. Singh and Fehrs (2001) estimate that 62.5 percent of the direct jobs created in the wind sector are in the manufacturing sector. Many of these jobs are created in the metal fabrication industry where workers cast, weld, shape, and cut metal to make wind turbine components. As such, the wind industry is well situated to provide employment and earnings opportunities for these workers in the manufacturing sector who face employment difficulties from structural unemployment and the current economic recession. Many of these jobs in the wind industry are also less vulnerable to outsourcing and international competition relative to other jobs in the manufacturing sector because it is very costly to transport heavy wind turbine components such as towers and nacelles.

The development of wind projects will not necessarily lead to the localization of wind energy manufacturing in Minnesota. It is also important to note that in-state manufacturing of key wind energy components can take multiple appearances. A foreign manufacturer may establish a local manufacturing presence. Minnesota companies may manufacture components through their own innovation. A third possibility is the transfer of technology from existing wind energy manufacturers to Minnesota companies through licensing agreements. Finally, local manufacturing bases may span the whole turbine supply chain, part of the supply chain, or just serve as an assembly base for imported components. This study does not distinguish between forms of the manufacturing base in its estimation of the in-state economic benefits from expanding Minnesota's wind energy manufacturing base. However, the appearance of Minnesota's manufacturing base enters the discussion in the assessment of Minnesota's potential to expand its manufacturing base and in a subsequent section about the policy measures that should be taken to promote localized manufacturing. This study finds that the best opportunities for entering the wind sector in the short term are in the manufacturing of low-tech components and the assembly of components. Different policy measures will be needed to grow a manufacturing base from scratch, especially in the manufacturing of high-tech components.

A key finding is that policymakers should expect to find the greatest return from their effort in designing policies to promote local ownership. The Minnesota Flip structure is estimated to create 64 percent more new jobs than the corporate owned structure. Local ownership allows Minnesotans to capture and spend the profits in-state. This, in turn, boosts aggregate demand and equilibrium output, creating new jobs.

# Estimating Wind Projects' Economic Impact

The process for estimating the economic effects from the construction of 4,058 MW of wind capacity in Minnesota involves three steps. First, a default case is constructed to estimate the economic benefits flowing to Minnesota under the current economic conditions. Then alternate economic forecasts are constructed based on Minnesota's potential to capture a greater share of wind development and construction activities. Lastly, the differences between the default and alternate scenarios are tabulated and results are discussed for their implications for policymaking.

The direct effects from the development and construction of a wind project include land lease payments, tax revenue flowing to local governments and schools, and the creation of new jobs in construction, manufacturing, wind-related services, and operations and maintenance. The direct effects also include expenditures flowing to companies that manufacture wind turbine towers, gearboxes, blades, and other key wind energy-related components. Other direct effects include the purchase of construction and maintenance materials and equipment, and the purchase of accounting, legal, and banking services. The indirect effects include subsequent rounds of spending further up the supply chain. Finally, there are induced effects that ripple through the economy. The flow of tax revenue to local governments results in additional government spending on goods and services. Household wage and salary earnings from employment growth increase household expenditures on goods and services.

I specify several scenarios depicting the economic benefits flowing to the Minnesota economy from the installation of 4,058 MW of wind power in Minnesota. The scenarios are "what if" statements that represent assumptions about the in-state supply of key wind energy components, construction and operations materials and labor, and the financial structure used to finance the development and construction of wind project. The scenarios are used to isolate the economic benefits to Minnesota from in-state manufacturing of key wind energy components, the particular financial structure used, and the local supply of labor and materials during the operations and maintenance periods. In a subsequent section, there is a discussion of the findings and implications for policymakers. In all of the scenarios, the year chosen for analysis is 2009, the project size is 4,058 MW, and the turbine size is 2.1 MW because it is a representative size for many of today's wind turbine projects.

## **Scenario 1: The Default Scenario**

The Jobs and Economic Development Impact (JEDI) model uses default values based on data collected from analysis of actual wind projects. The JEDI model provides detailed data on expenditures during the construction and operations periods, as well as detailed data on the financial structure and tax burden. The default data also includes the portion of in-state spending for each cost input and Minnesota specific multipliers. The default scenario assumes a corporate owned financial structure with an 80:20 debt-to-equity ratio. I modified the JEDI default assumptions about the Minnesota share of manufacturing of key wind energy components for utility scale turbines to more accurately reflect the current conditions in the Minnesota economy (see Table 1).

**Table 1: Modified Default Assumptions about the Minnesota Share of Wind Turbine Manufacturing**

<b>Wind Turbine Equipment</b>	<b>Minnesota Share of manufacturing as modified</b>
Turbine Components (excluding blades and towers)	12.1%
Blades	9.10%
Towers	7.50%
Transportation	100.0%

First, I calculated the cost of each key wind energy component as a percentage of the total equipment cost. Then I estimated the current in-state production of each key wind energy component for utility-scale wind turbines as a percentage of total production of each component needed to meet the RES requirement. Lastly, I multiplied the two values to get the Minnesota portion of in-state spending. The “turbine components” category aggregates key components excluding blades and towers.

**Scenario 2: Minnesota Manufactures 50 Percent of Wind Turbine Towers Installed in Minnesota**

Local manufacturing of key wind turbine components has the potential to reduce costs in at least three ways: (1) reduction in materials costs, (2) reduction in transportation costs, and (3) reduction in labor costs (Lewis and Wiser 2007). Significant cost savings would be achieved through a reduction in transportation costs by locating wind energy manufacturing in Minnesota within close proximity to wind project sites. As large modern wind turbines increase in size, the transportation and general handling of the different wind turbine components becomes an increasing problem due to the size and weight of the components. The trend in the wind industry has been to move production of low-technology components to low cost centers and increasing the number of suppliers because these components require only minimum quality specifications relative to high-technology components (Merrill Lynch 2007). Low-technology components are: (1) towers; (2) cast/forged parts; and (3) the Nacelle cover/spinner. The towers are a heavy part of the wind turbine and so transportation costs are significant. Wind towers represent approximately 60 percent of the total weight of the wind turbine (Ancona and McVeigh 2001). Unlike the nacelle, it is cost advantageous to assemble the tower at the project site, and so wind manufacturers prefer to use local suppliers to decrease transportation and logistics costs. In fact, the wind turbine tower is usually the first component to be manufactured locally (Lewis and Wiser 2007).

The ability of Minnesota to expand its wind energy manufacturing base is also dependent on the technical capacity of Minnesota companies. Companies in industries with similar knowledge bases could potentially enter the wind sector. I follow the methodology of Sterzinger and Svrcek (2004) to estimate the number of Minnesota companies with the technological capacity and knowledge base to enter the wind sector. Table 2 shows the number of Minnesota companies with knowledge bases and technological capabilities that overlap

with the knowledge bases and technological capabilities of companies already engaged in the manufacturing of wind turbine towers. Based on the benefits of localizing wind turbine tower manufacturing in Minnesota and the number of Minnesota companies with the potential to engage in the manufacturing of wind turbine towers, Scenario 2 estimates the economic benefits flowing to the Minnesota economy if 50 percent of the towers installed in Minnesota were manufactured in-state.

**Table 2: Number of Minnesota Companies Operating in Manufacturing Sub-Sectors Related to the Manufacturing of Wind Turbine Towers**

Component	Sub-component	NAICS 6-digit code*	Code description	Number of Minnesota companies in each sub-sector
Tower	Tower	332312	Fabricated Structural Metal	40
	Tower Flange	331511	Iron Foundries	13

\* The North American Industry Classification System (NAICS) codes is the standard for classifying businesses for the purpose of collecting statistical data related to the economy.

### Scenario 3: Minnesota Manufactures 100 Percent of Wind Turbine Towers Installed in Minnesota

Wind turbine tower manufacturing represents a very promising opportunity for Minnesota companies to pursue because the barriers to entry are low. The manufacturing process is low-technology and the biggest constraint is the ability to roll and bend large steel plates. Minnesota companies already operating in the fabricated structural metal sub-sector should have a steep learning curve and with the right equipment should be able to ramp up production fairly quickly. Because of the tremendous shipping costs, it was already said that there is a significant advantage to localizing the manufacturing of wind turbine towers. Given the low technological barriers to entry and the advantages of localizing wind turbine tower manufacturing in Minnesota, Scenario 3 assumes 100 percent of the towers installed in Minnesota were manufactured in-state and estimates the economic benefits flowing to the Minnesota economy.

### Scenario 4: Minnesota Manufactures 25 Percent of Wind Turbine Blades Installed in Minnesota

Most rotor blades are produced in-house, although LM Glasfiber is a large independent producer of blades (LM Glasfiber has a market share of about 27 percent (Merrill Lynch 2007)) and has a production facility located in North Dakota. Vestas, Siemens, and Enercon design and manufacture their rotor blades in-house. GE subcontracts to build-to-design companies and buys blades produced by LM Glasfiber (Merrill Lynch 2007). The in-house capabilities of most of the major wind turbine manufacturers, with the exception of GE and Clipper, in addition to the relatively close proximity of existing competitors like LM Glasfiber, will make it difficult for Minnesota companies to gain entry into utility-scale blade manufacturing.

The technical and financial barriers to entry are also very high. A large facility with overhead cranes to move the blades is required. As the blades continue to grow in size, there are greater technical demands placed

on the manufacturing process. Automation becomes important when manufacturing larger blades in order to achieve shorter production lead times. The initial capital investment is very high because, in addition to physical plant investments, there are licensing fees for a blade designs. The technical and financial barriers coupled with the existence of experienced competitors will make it very difficult for Minnesota companies successfully enter this market.

The blade is a heavy component and the blade's weight coupled with the increase in the blade length make shipping blades very expensive. It is expected that vertically integrated companies will continue to locate blade manufacturing facilities in the United States to reduce shipping costs. In addition, existing companies, like LM Glasfiber in North Dakota and MFG in Texas will continue to expand. Because the barrier to entry is high, Minnesota should concentrate on luring existing blade manufacturers as it was able to do with Suzlon. Efforts to attract blade manufacturers will benefit from the fact that blade manufacturers depend very little on subcontracting and rely mostly on a low-skilled workforce that can be trained in a relatively short period of time. Therefore, blade manufacturers are well-suited to locate in rural areas near wind project sites. Scenario 4 assumes that Suzlon based in Pipestone, MN will expand production of blades for installation in Minnesota.

### **Scenario 5: Minnesota Manufactures 50 Percent of Wind Turbine Blades Installed in Minnesota**

Scenario 5 assumes the location of an additional blade manufacturer in Minnesota. To reflect this, Scenario 5 increases the portion of in-state supply of blades for installation in Minnesota from 14.2 percent, as specified in Scenario 4, to 16.4 percent.

### **Scenario 6: Minnesota Manufactures 14.2 Percent of Turbine Components Installed in Minnesota**

The major wind turbine components (excluding the blade and the tower) are the nacelle components and the hub. The major nacelle components include the gearbox, generator, high and low speed shafts, the nacelle cover, an internal frame. Each component has different prospects for in-state development. This scenario makes assumptions about the likelihood of the localization of each component in Minnesota and then estimates the economic benefits to the Minnesota economy from in-state production.

#### *Gears*

Gearbox manufacturers assemble the castings, bearings, and gears to produce an "off the shelf" gearbox. Most gearbox manufacturers are vertically integrated, but sub-contract work to smaller companies (BTM Consult ApS 2008). The barriers to entry into the manufacturing of gears for the utility-scale wind industry are high. Large initial capital investments need to be made to purchase equipment to have the technological capability to manufacture large gears. Limited technical capacity and experience manufacturing large gears for the wind industry are barriers to entry. Quality control is still a problem and gearbox manufacturers will not subcontract with companies that cannot offer quality assurance through their reputation and established track record with clients (Musial, Butterfield, and McNiff 2007). The benefits of localizing gear manufacturing are not substantial. Transportation costs and shipping distance are not significant factors.

Columbia Gear Corporation, in Avon, MN, has the capability to manufacture large gears for the utility-scale wind industry custom manufacturers, but does not sell "off the shelf" gearboxes. Scenario 6 assumes Columbia Gear Corporation expands production of gears for installation in Minnesota.

## Generators

Wind turbine generators are produced in-house and by several large manufacturers, including ABB and Siemens (Merrill Lynch 2007). The technical barriers to entry into the manufacturing of generators for the wind industry are not high (Merrill Lynch 2007). Table 3 shows the number of existing manufacturers of turbine generators located in Minnesota. There are two companies in Minnesota that potentially have the technical capacity and knowledge base to enter the utility wind sector. However, an existing manufacturer of small turbine generators would have to make significant investments to scale-up manufacturing facilities to handle the large size of utility-scale wind generators (Merrill Lynch 2007). There are also cost moderate advantages to locating the production of utility-scale wind generators in close proximity to wind project sites. Scenario 6 assumes that the capital costs to scale-up operations are too great of barrier for these companies to enter the utility-scale wind sector.

**Table 3: Number of Minnesota Companies Operating in Manufacturing Sub-Sectors Related to the Manufacturing of Generators for the Utility-Scale Wind Industry**

Component	Sub-component	NAICS 6-digit code*	Code description	Number of Minnesota companies in each sub-sector
Generator	Generator	333611	Turbines, Turbine Generators, and Turbine Generator Sets	2

## Gearboxes

The wind industry has experienced severe shortages in the supply of gearboxes. Gearboxes are also responsible for most of turbine equipment failures. Both the severe shortage and high failure rate have resulted in a shift to in-house manufacturing of gearboxes (Merrill Lynch 2007). A significant barrier to entry into the manufacturing of utility-scale gearboxes is the preference of OEMs to contract with companies that already have a positive track record in the industry (Musial, Butterfield, and McNiff 2007). Potential entrants will need to compete with these large companies that have already established credibility in the industry. The learning curve is long because new entrants will need to gain knowledge of design specifications and manufacturing processes and develop a proven track record before they are able to effectively compete in the industry (Chicago Renewable Energy Taskforce Survey and Supply Chain Assessment 2007). The initial start-up costs are high because significant investments are required to obtain the knowledge base to develop advanced technology, construct the manufacturing facilities, and purchase equipment to engage in large-scale production and assembly of gearboxes. There are no substantial benefits to localizing gearbox production in close proximity to wind projects.

The best approach to localizing gearbox manufacturers is likely to be attracting existing gearbox manufacturers to locate in Minnesota. Moventas is a leading independent gear supplier and is constructing an assembly plant in Faribault, MN. Moventas supplies gears to GE, Vestas, WinWinD, and Acciona. Hansen, Bosch Rexroth, and Winergy have supply relationships with Vestas. Bosch Rexroth, Winergy, and Eickhoff have supply relationships with GE. GE also supplies some gearboxes in-house. Suzlon acquired Hansen Transmission to integrate its

supply of gearboxes. Siemens acquired Winergy to supply its gears in-house.<sup>2</sup> The default scenario assumes that the Faribault plant will supply 41 percent of the gearboxes for wind turbines installed in Minnesota. The assumption is that Winergy (centrally located in Illinois) and other gearbox suppliers will supply 50 percent of the gearboxes installed in Vestas and GE turbines in Minnesota. Scenario 6 assumes 45 percent of gearboxes installed in Minnesota are produced in-state.

### *Large Bearings*

There are only a handful of manufacturers capable of producing large bearings for wind turbines. There are not significant cost advantages to localizing production of large bearings in Minnesota. The biggest barriers to entry are the technical capability and a proven track record and bearing failure is a frequent reason for gearboxes to fail (Chicago Renewable Energy Taskforce Survey and Supply Chain Assessment 2007). Therefore, a positive track record and reputation are important. Minnesota companies have limited knowledge of the design and manufacturing processes used to produce large bearings. It is not likely that Minnesota companies would be able to develop the best available technology from scratch. This coupled with the reputational requirements make for a very long learning curve. In addition, the initial capital investments are high and significant investments are required to achieve the desired quality and acquire the best available technology (process procedures and design specifications) (BTM Consult ApS 2008). Scenario 6 assumes that no Minnesota companies supply large bearings to the wind industry.

### *Nacelle Assembly*

There are low barriers to entry. The technical requirements are minimal. The assembly facility needs to have adequate square footage and cranes. The initial capital investment is low. No advanced technologies are needed (Merrill Lynch 2007). There are significant cost advantages to locating assembly facilities in close proximity to wind projects. The nacelle is a very large component and the transportation costs are substantial. Scenario 6 assumes the location of a nacelle assembly plant in Minnesota.

### *Forgings and Castings*

There are low barriers to entry into the casting and forging of wind components as there is no special manufacturing process (Merrill Lynch 2007). Experienced companies should be familiar with the process. The biggest barrier is required size of the iron foundry (Chicago Renewable Energy Taskforce Survey and Supply Chain Assessment 2007). The initial capital investment is low if starting with an iron foundry that is of adequate size. The required capital investment is high if the iron foundry needs to be scaled up to make large scale casting components. Scenario 6 assumes iron foundries in Minnesota are able to gain entry into the wind sector.

### *Nacelle Covers*

There are significant cost advantages to locating the manufacturing of nacelle covers in close proximity to a nacelle assembly plant. There are low barriers to entry into the manufacturing of nacelle covers. The process technologies do not represent a significant barrier to entry. The key process is the laying of fiberglass by hand. This process is labor intensive and workforce training is required to production efficiency. The technical requirements are low (Merrill Lynch 2007). Overhead cranes are needed to move the nacelle cover and the manufacturing facility needs to have enough space to accommodate the size of these components. The initial capital investment is low if the existing facility has adequate space. Scenario 6 assumes the location of a

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<sup>2</sup> Supply chain information is based on Merrill Lynch 2007, Wind turbine manufacturers; here comes *pricing power*.

nacelle cover manufacturing plant in Minnesota.

### **Scenario 7: Minnesota Manufactures 16.4 Percent of Turbine Components Installed in Minnesota**

This scenario models the upper bound on Minnesota's potential to manufacture major wind turbine components (excluding blades and towers).

### **Scenario 8: Minnesota supplies 75 Percent of Construction Materials**

Construction materials should be procured from local sources in close proximity to the wind project. Because of the time and cost required to move construction materials, maximum use is made of locally available construction materials such as gravel and concrete. The default analysis assumes that 90 percent of construction materials are obtained in Minnesota. Scenario 8 assumes that only 75 percent of construction materials are obtained from sources in Minnesota.

### **Scenario 9: Minnesota Labor Supplies 60 Percent of Construction Jobs**

Construction labor represents an important source of economic benefits to Minnesota economy. The default scenario assumes that either M.A. Mortenson Co. or D.H. Blattner & Sons serves as the general contractor. The general contractor will construct the project and/or utilize local construction subcontractors to perform 100 percent of the work. Scenario 9 assumes that an out-of-state company serves as the general contractor. The general contractor will hire out-of-state subcontractors to help construct a large portion of the wind project.

### **Scenario 10: Minnesota Labor Supplies 75 Percent of Construction Jobs**

Scenario 10 assumes that the general contractor from outside Minnesota. Scenario 10 assumes that out-of-state construction labor will be brought in for specialized work that cannot be completed by in-state construction labor. The bulk of the construction work is performed by in-state contractors.

### **Scenario 11: Minnesota Labor Supplies 50 Percent of Operations Period Jobs**

The default scenario assumes that all operations and maintenance staff reside permanently in Minnesota once the wind project is operational. Wind technicians usually live near the field site. Note that the operations labor does not include repair and maintenance services carried out by wind manufacturers – it only includes field technicians, administration, and management. Moventas, and other wind turbine component manufacturers, will send technicians to do on-site repair and maintenance or will do the repairs at one of their service centers. This labor is not part of the model and as such is assumed to be derived from outside Minnesota. Research indicates that this is a correct assumption in the case of Minnesota.

Scenario 11 assumes that wind project operations and maintenance may be contracted out to out-of-state companies.

### **Scenario 12: Minnesota Labor Supplies 75 Percent of Operations Periods Jobs**

Scenario 12 assumes that there are wind technician training programs to ensure that local labor is competitive with the out-of-state local. Therefore, the local labor supplies a larger percentage of the operations and

maintenance jobs than in scenario 11.

### **Scenario 13: 100 Percent Community-Owned Wind Projects**

This scenario models the economic benefits flowing to the Minnesota economy from a community-wind financing structure with 100 percent local equity. The typical 100 percent local equity model involves numerous local residents with each resident investing small amounts of capital in the project. This ownership structure is based on the Minwind projects, developed in Southwestern Minnesota. The Minwind projects involve a large number of local investors. It is assumed that all of the distributable cash (profits) is spent or reinvested in Minnesota.

### **Scenario 14: The Minnesota Flip Structure**

Scenario 12 estimates the economic benefits flowing to the Minnesota economy from the Minnesota Flip financial structure. The Minnesota Flip is typically structured as follows: the local equity investors take a 1 percent stake in the project over the first 10 years of the operations period and receive 1 percent of the sum of the distributed cash over this time. The tax investor contributes 99 percent of the project's equity and, in return, receives 99 percent of the tax benefits and distributable cash. The flip point is when the tax investor reaches a pre-negotiated internal rate of return. This model assumes that the flip point is reached after 10 years. This model also assumes that the local investors buy out the strategic tax investor after the flip point (the expiration of the tax benefits after ten years, reduction of cash flow, and increased risk mechanical failure reduces the fair market value of the tax investor's ownership interests). At this point, the local investors take full ownership and a 100 percent equity stake, thereby providing them with 100 percent of the profits during years 11 to 20 of operations. This equity structure results in an average annual ownership value of 51% and qualifies these projects for Community Based Energy Development (CBED) status.<sup>3</sup> I assume that the strategic investor's pre-negotiated internal rate of return is 7 percent (Harper, Karcher, and Bolinger 2007) and that all the profits going to the local investor are spent or reinvested in Minnesota. I also assume a 60-40 debt-to-equity ratio (Harper, Karcher, and Bolinger 2007).

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<sup>3</sup> Minnesota Statutes §216B.1612

# Results

**Table 4: Construction Period Impacts from the installation of 4,058 MW of wind energy in Minnesota**

Scenarios	Jobs <sup>4</sup>	Net Job Gain (Loss)	% Job Gain (Loss)	Earnings (millions of \$)	Output (millions of \$)	Net Output Gain (Loss)	% Output Gain (Loss)
Status quo economy	2222			\$1718.5	\$5,090.4		
17.4% increase in turbine component (excluding blades and towers) manufacturing	2298	76	3.4%	\$1,763.08	\$5,225.89	135.49	2.7%
34.7% increase in turbine component (excluding blades and towers) manufacturing	2343	121	5.4%	\$1,807.68	\$5,361.33	270.93	5.3%
25% of blades manufactured in-state	2313	91	4.1%	\$1,769.64	\$5,313.03	222.63	4.4%
50% of Towers manufactured in-state	2402	180	8.1%	\$1844.6	\$5650.0	\$559.6	11.0%
100% of Towers manufactured in-state	2585	363	16.3%	\$1999.1	\$6330.6	\$1240.2	24.4%
50% of blades manufactured in state	2404	182	8.2%	\$1,846.88	\$5,653.33	562.93	11.1%
60% in-state construction labor	1994	(228)	-10.3%	\$1,520.95	\$4,710.61	(379.79)	-7.5%
75% in-state construction labor	2080	(142)	-6.4%	\$1,579.96	\$4,833.69	(256.71)	-5.0%
75% in-state construction materials	2144	(78)	-3.5%	\$1,645.39	\$4,865.63	(224.77)	-4.4%

<sup>4</sup> Jobs are the number of full-time equivalent jobs during each of the 17 years from 2009 – 2025.

**Table 5: Operations Period Impacts from the installation of 4,058 MW of wind energy in Minnesota**

Scenarios	Jobs <sup>5</sup>	Net Job Gain (Loss)	% Job Gain (Loss)	Earnings (millions of \$)	Annual Output (millions of \$)	Net Output Gain (Loss)	% Output Gain (Loss)
Status quo economy	922			\$43.3	\$127.2		
100% community owned wind projects	2,962	2040	221.3%	\$118.80	\$364.62	\$237.42	186.7%
Minnesota Flip finance structure (60% debt, 40% equity)	1516	594	64.4%	\$65.3	\$196.4	\$69.2	54.4%
50% in-state operations period labor	758	(164)	-17.8%	\$33.51	\$110.51	(\$16.69)	-13.1%
75% in-state operations period labor	840	(82)	-8.9%	\$38.40	\$118.83	(\$8.37)	-6.6%

<sup>5</sup> Jobs are the annual number of full-time equivalent jobs created during the operational period.

# Discussion & Policy Implications

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My results suggest that policymakers would receive the greatest return from their effort by crafting policies to promote local ownership of wind projects. The Minwind financial structure (100 percent local ownership) provides 3.21 jobs during the operations and maintenance period for every job created under the corporate structure. Local ownership results in profits being spent in the local economy (in this case, profits stay in the Minnesota economy). Aggregate demand receives a boost and the multiplier creates induced impacts. The Minwind financial structure also results in the addition of \$237 million of annual income to the Minnesota economy. The Minnesota Flip structure also has substantial job-creating effects. For every operations period job created under a corporate financial structure, the Minnesota Flip structure creates 1.64 jobs. This is the result of induced effects from the spending of profits in Minnesota economy. The corporate financial structure assumes that any profits leak out Minnesota economy.

Increasing the in-state supply of wind components also generates significant economic benefits for the Minnesota economy. If 100 percent of the wind turbine towers installed in Minnesota are manufactured in-state, an additional \$1.24 billion will flow into the Minnesota economy and 363 new jobs will be created in wind manufacturing. Significant economic benefits also flow to Minnesota in the intermediate wind turbine tower manufacturing scenario. If 50 percent of the wind towers installed in Minnesota are manufactured in-state, \$559 million will flow into the Minnesota economy. The job-creating effects from this scenario are also significant. Another 180 new jobs will be created over the baseline job-creation number.

The local supply of operations and maintenance labor has a sizeable impact on the annual economic benefits. The default scenario assumes that operations and maintenance labor is fully derived from within Minnesota. If operations and maintenance work is contracted and out-of-state crews are used, the operations period economic benefits captured by the Minnesota economy are substantially diminished. If only 50 percent of the operations and maintenance labor is sourced from within Minnesota, 164 potential new jobs will be lost. Minnesota will also miss out on \$16.7 million of income on an annual basis. The intermediate scenario seems more likely as Minnesota ramps up workforce training to make its workforce competitive with out-of-state crews. If 75 percent of the operations and maintenance labor resides permanently in Minnesota, then 82 potential new jobs will be lost. In order to reduce lost economic benefits, Minnesota should invest more in work technician training programs.

## Policy Implications

### *1. Stable Public Policy is Important*

The quantity demanded and the stability of the quantity demanded from year-to-year are two important factors in the decision to localize wind component manufacturing.

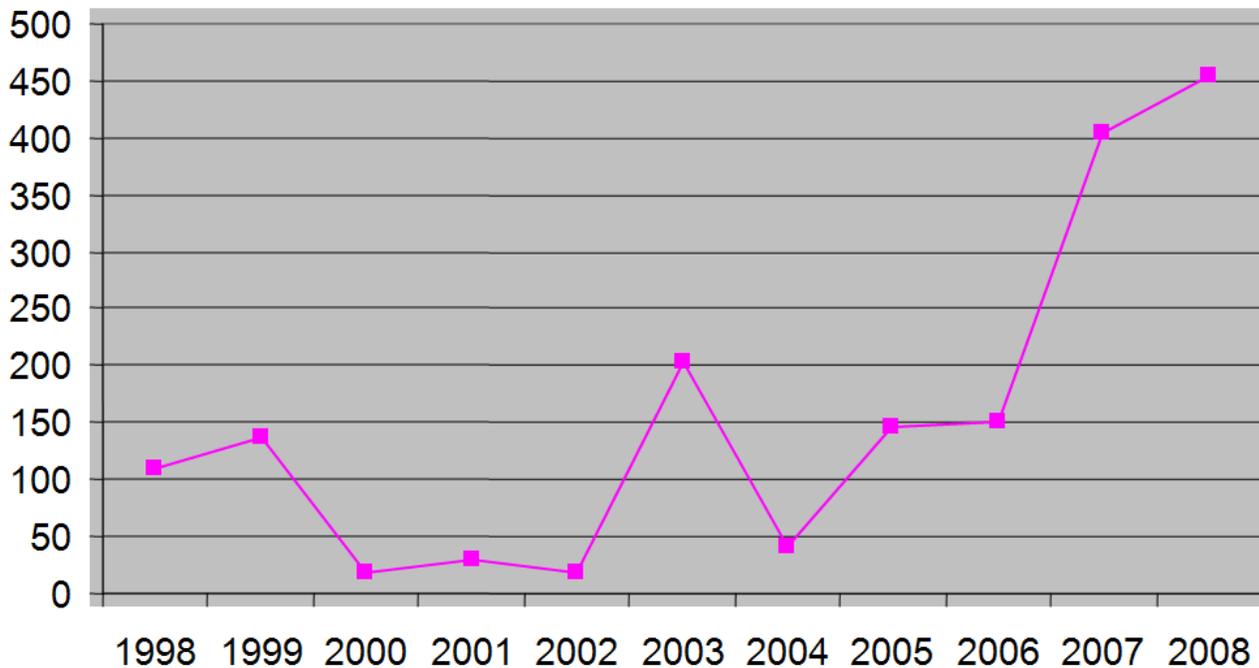
Figure 1 shows Minnesota's wind power development over the last 12 years. Wind power development has been characterized by strong growth during the years leading up to the expiration of the federal renewable energy tax credit (PTC). Expiration of the PTC results in dramatic slow down in the installation of planned wind projects. Growth in annual added wind capacity lags behind restoration of the PTC. Once the wind industry recovers, it experiences strong growth until the tax credits expire again. The PTC was allowed to expire three times (June 1999, December 2001, and December 2003). With no PTC in place for most of 2004, Minnesota's wind development declined dramatically after experiencing strong growth in 2003. The pattern of expiration of the PTC followed by short term renewal destabilized the quantity demanded from year-to-year and worked

against the localization of wind component manufacturing in Minnesota.

However, beginning in 2005, Minnesota's wind industry has experienced a secular increase in annual installed wind capacity. In 2008, Minnesota added 454 MW of wind capacity. This represents a 35 percent increase in wind installations. The four year average annual growth rate (2005 – 2008) is 31 percent. The sizable quantity demanded a rapid increase in annual installed capacity will promote the localizing of wind component manufacturers in Minnesota. The takeaway here is that stable public policy is important to stabilize the quantity demanded and promote the growth of annual installed capacity.

**Figure 1: Minnesota's Annual Installed Wind Capacity**

**Installed Capacity (MW)**



Source: American Wind Energy Association (AWEA) project database (updated April 31, 2009)

Currently, a major challenge facing the wind industry is getting access to capital. The economic recession has made it difficult for wind developers to access capital. Wind projects are frequently financed by strategic and institutional investors capable of making efficient use of the PTC to offset earnings. However, the economic recession has reduced the pool of investors with sufficient earnings to efficiently utilize the PTC. The credit crisis has also reduced the debt financing available for wind projects (debt financing has become more expensive). This all means that there will be a severe imbalance between the supply of wind projects seeking financing and the demand from financial institutions. Essentially the credit crisis has put the brakes on the development of many wind projects. The destabilized quantity demanded and negative growth rate in the annual installation of wind energy has deterred companies from making the investments necessary to enter the wind manufacturing sector.

Minnesota's wind industry will experience slower growth because the economic recession has made it more difficult to obtain for wind projects. However, in February 2009, the American Recovery and Reinvestment Act (ARRA) was passed, which includes several provisions to aid development of wind energy, such as:

- a 3-year extension of the Production Tax Credit (PTC) beyond 2009;
- an option to elect a 30 percent Investment Tax Credit (ITC) in place of the PTC. This credit can then be converted into a grant for projects beginning construction or starting operation in 2009 or 2010;
- a new \$6 billion Department of Energy (DOE) renewable energy loan guarantee program;

It is expected that the wind industry will experience strong growth in 2010 and 2011, because the ARRA requires wind projects to begin construction prior to 2011 in order to take advantage of these energy subsidies. It is also expected that the loosening of the credit markets will improve access to project financing by 2010. The cash grant in lieu of the tax credit will be an important source of financing for wind projects unable to secure tax equity partner.

## *2. Financial Incentives to Promote In-State Manufacturing Activity*

There are a variety of tax incentives that can be used to promote in-state manufacturing activity. Minnesota currently exempts wind projects from Minnesota's sales tax. Materials used to manufacture wind components are also exempt from Minnesota's sales tax. Other tax incentives could be used to encourage Minnesota companies to enter the wind sector. Minnesota should consider providing tax credits or deductions to companies for investments in enhance their technical capacity and knowledge base to manufacture major wind components. In-state manufacturing of wind components could be promoted through the use of generation subsidies or below-market loans for projects that use components manufactured in Minnesota.

## *3. Feed-in tariffs*

A feed-in tariff requires local utilities to pay premium rates for wind-generated electricity. If the feed-in tariff is structured properly, it will lend stability to the wind industry thereby promoting the localization of wind component manufacturing. The feed-in tariff also promotes the development of community-wind projects because all the returns derive from cash flow revenue. This removes the need to find tax motivated investors and opens the doors to new sources of capital. Because the payments are guaranteed and stable and allow for a reasonable rate of return, the cost of capital is cheaper (i.e. larger cash flows reduce the amount of equity an investor needs to put into the project and enables to the investor to take on additional debt and still meet the required debt-service coverage ratio). The feed-in tariff should be explored as an option to mitigate the negative effects of the credit crunch and economic recession on access to capital.

## *4. Partnerships with Existing Wind Component Manufacturers*

Minnesota should promote partnerships and joint venture enterprises between Minnesota companies and more advanced out-of-state wind energy companies. These partnerships would allow for technology transfer and give Minnesota companies opportunities to gain experience in the wind turbine manufacturing sector. This would shorten the learning curve by providing access to new technologies.

# Assessing Competing Views on Wind Subsidies

A few words need to be said about the objections to government subsidies and, in particular, government subsidies of wind energy because these incentives are critical right now to the development of the wind industry. There are currently two principal federal incentives to promote the development of the wind industry. These include the PTC and the Modified Accelerated Cost Recovery System (MACRS). The PTC provides an inflation-adjusted 1.5 cents/KWh during the first ten years of a wind project. For 2008, the inflation-adjusted PTC provided a 2.1 cent/KWh tax credit. The MACRS allows depreciation deductions over an accelerated five year schedule. The federal incentives contribute a significant portion of the value of a wind project and are important tools for making wind power competitive. Harper, Karcher, and Bolinger (2007) estimate that without the PTC wind power prices would rise by as much as \$20/MWh so that investors could meet their required rate of return.<sup>6</sup> The importance of the PTC to the development of the wind industry is illustrated by the year-to-year ramping up and ramping down of investments in wind projects following the pattern of expiration and short term renewal of the PTC. Given that the PTC is critical to the competitiveness of wind energy and its development, it is necessary to respond to its opponents before investigating the economic development impacts of wind energy.

One objection to government subsidies is that they result in inefficient allocations of resources. It is well known in economics that a deadweight loss occurs as a result of a subsidy, and this deadweight loss represents the loss of economic efficiency from an equilibrium that is not Pareto optimal. However, the ecological benefits of wind energy, including a reduction in greenhouse gas emissions and improved air quality, are marginal social benefits of wind energy that exceed the marginal private benefits and go undervalued by the market. The substantial positive externalities that exist mean that wind energy is being under consumed. A government subsidy is the proper corrective measure to ensure that the socially optimal quantity of wind energy will be developed. From this perspective, the total social value of production can be increased by producing less of the pollution-generating product (e.g. coal power) and more wind energy.

A second objection to government subsidies is based on the idea that costs and benefits are subjective and therefore social costs and benefits do not exist. But this objection is incompatible with government enforcement of property rights and contract laws and provision of national defense. No reputable economist would object to government provision of national defense on the basis that government does not know the subjective valuations of national defense, and therefore cannot know the optimal amount of national defense. Almost all economists agree that the private sector would either undersupply the good or not supply it at all. In the latter case, no single individual is able or willing (because of the free rider problem) to pay for some amount of national defense. In the former case, individuals take advantage of the private provision of some of the public good without paying since they cannot be excluded. It is inconsistent to object to subsidies on the basis that government does not know the optimal level and social costs and benefits do not exist and then support government expenditures on national defense when the optimal level of national defense is unknowable to the government.

A third objection to government subsidization of wind energy can be stated as an objection to deficit spending because it results in the crowding out of investment. The government must borrow to finance deficit spending. It does so by selling bonds which compete with corporate financial instruments for the supply of loanable funds. The budget deficit will increase interest rates. A higher interest rate will lead to

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<sup>6</sup> The \$20/MWh is calculated based on 2007 numbers. The PTC was \$20/MWh in 2007. Harper, Karcher, and Bolinger (2007) assume that most wind project owners are in the 35 percent tax bracket and so \$20 equals about \$30.8 in pre-tax dollars. The ten year incentive of \$30.8/MWh equals approximately \$20/MWh (in constant 2007 dollars) when it is spread out over the 20 year lifetime of a typical wind project.

less investment. In other words, government will claim an increasing share of the economy's total saving and crowd out private borrowers. Less investment means that the capital stock and potential GDP grow more slowly. However, it is important to point out that crowding out only takes place when the economy is operating at full employment where actual output equals potential employment.

To see why let us first consider an economy where there are flexible prices. When prices are fully flexible the economy will operate at full employment with actual output equal to potential output.<sup>7</sup> The interest rate plays a key role in making sure that aggregate demand equals potential output. The equilibrium condition, aggregate demand equals potential output, is equivalent to savings equals investment.<sup>8</sup> The interest rate adjusts to equilibrate savings and investment. Now let us see what happens when government spending is increased in a flexible price economy. Government spending will not change potential output. Therefore, the consumption function is not affected and total saving is fixed. Government spending will have an indirect effect on investment because the interest rate will change. The supply of loanable funds to private industry will be reduced and this will result in a higher interest rate to equilibrate savings and investment. It is important to realize that while the increase in government spending has no effect on the level of real GDP (potential output) and consumption it does have ramifications for economic growth. In the long run, changes in technology, capital, and labor increase the potential output level of the economy at full employment. Therefore, in the long run, positive changes in the savings rate will add to the capital stock and increase the steady state capital-output ratio and increase the output-worker and capital-worker ratios along the steady state growth path. An increase in government spending in an economy with full employment will draw capital from private industry and crowd out private sector investment. Therefore, economic productivity and output will fall if the government spending is more wasteful than the private sector investment and slower economic growth will occur.<sup>9</sup>

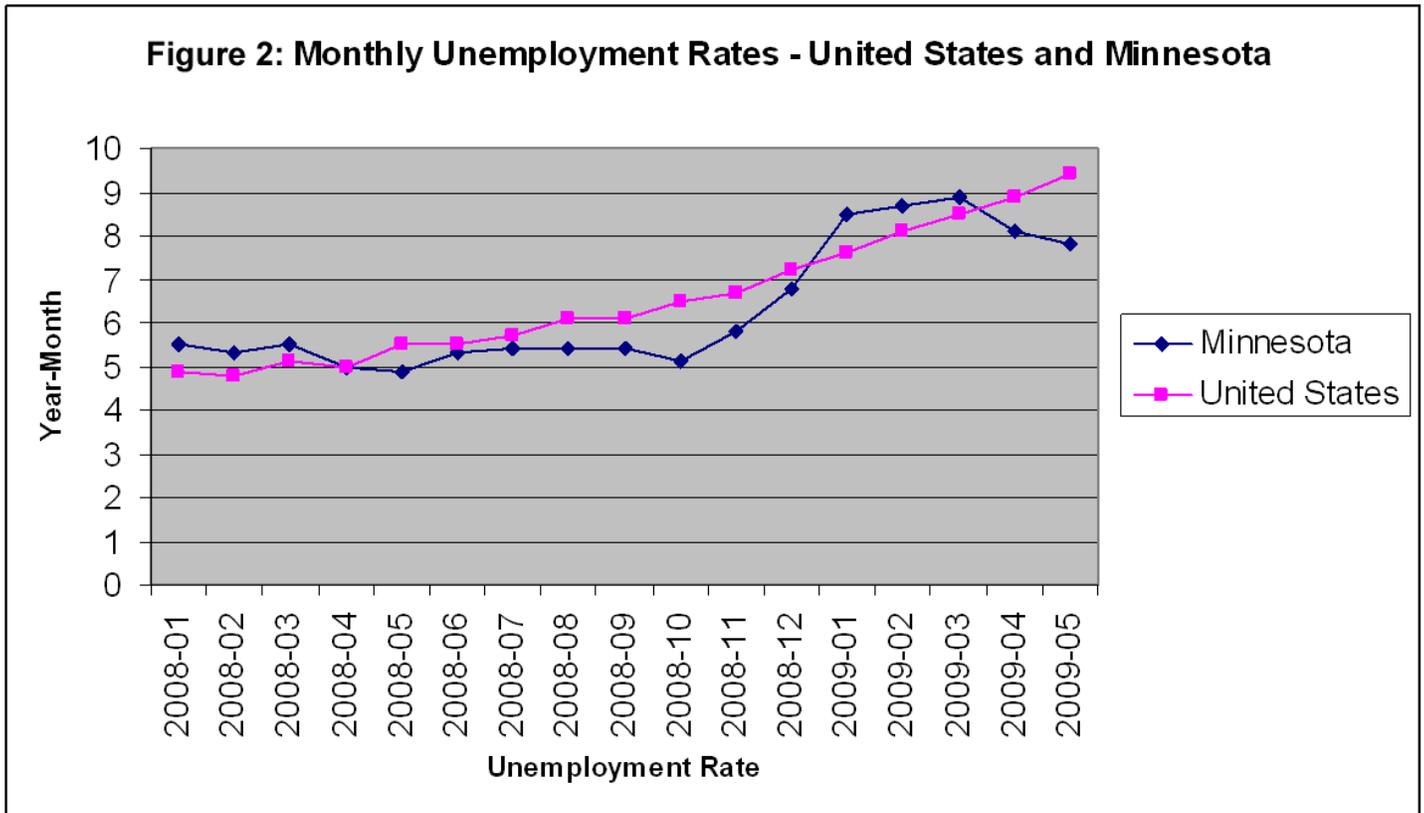
However, the present situation of the current economy is one of underemployment. Figure 2 shows us that the unemployment rate continues to climb across the United States and in Minnesota.

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<sup>7</sup> In the classical model, the levels of potential output and real wages are determined by the production function and supply and demand in the labor market. The production function is represented as: where  $Y^*$  is potential output,  $A$  is the efficiency of labor,  $K$  is the capital stock, and  $\alpha$  describes how fast returns to investment diminish. The construction of the aggregate supply curve is different from the construction of a supply curve for an individual good. The supply curve for an individual good assumes that the price of inputs remains constant. Therefore, as the price of the good increases relative to input prices, the supplier is willing to supply more of the good. The aggregate supply curve is constructed in terms of the price level. A decrease in the price level will reduce the price that producers receive and result in less output. However, a decrease in the price level also has a secondary effect. Eventually it will induce a decrease in input prices which will cause producers to increase production. The net result is that actual output will remain equal to potential output at a lower price level and there will be full employment. The flexible price assumption guarantees that the quantity demanded will equal the quantity supplied and the labor market will be in equilibrium where the total demand for labor is equal to the labor force.

<sup>8</sup>  $Y^* = AD = C + I + G \Rightarrow Y^* - C - G = I \Rightarrow (Y^* - C - t) + (t - G) = I \Rightarrow S_h - DEF = I$  where  $DEF$  is the government deficit,  $C$  is consumption,  $I$  is investment,  $G$  is government spending,  $AD$  is aggregate demand, and  $t$  is taxes.

**Figure 2: Monthly Unemployment Rates - United States and Minnesota**



Source: Minnesota’s Department of Employment and Economic Development

The high unemployment rate is the result of investors not willing to hold assets because they are either (1) risky (2) subject to default, (3) or of uncertain value.<sup>10</sup> All the investors decide to liquidate. However, the fixed assets backing the financial assets cannot be liquidated easily. As a consequence, when all investors desire to liquidate, the bond supply curve shifts to the right and financial asset prices plummet. Falling asset prices produce periods of high employment and low incomes because businesses that should be expanding cannot obtain financing on terms that make expanding profitable. Bond prices move inversely to interest rates, and so falling financial asset prices imply higher interest rates. The lack of business expansion because of higher interest rates causes unemployment in the industries that produce capital goods. Eventually the

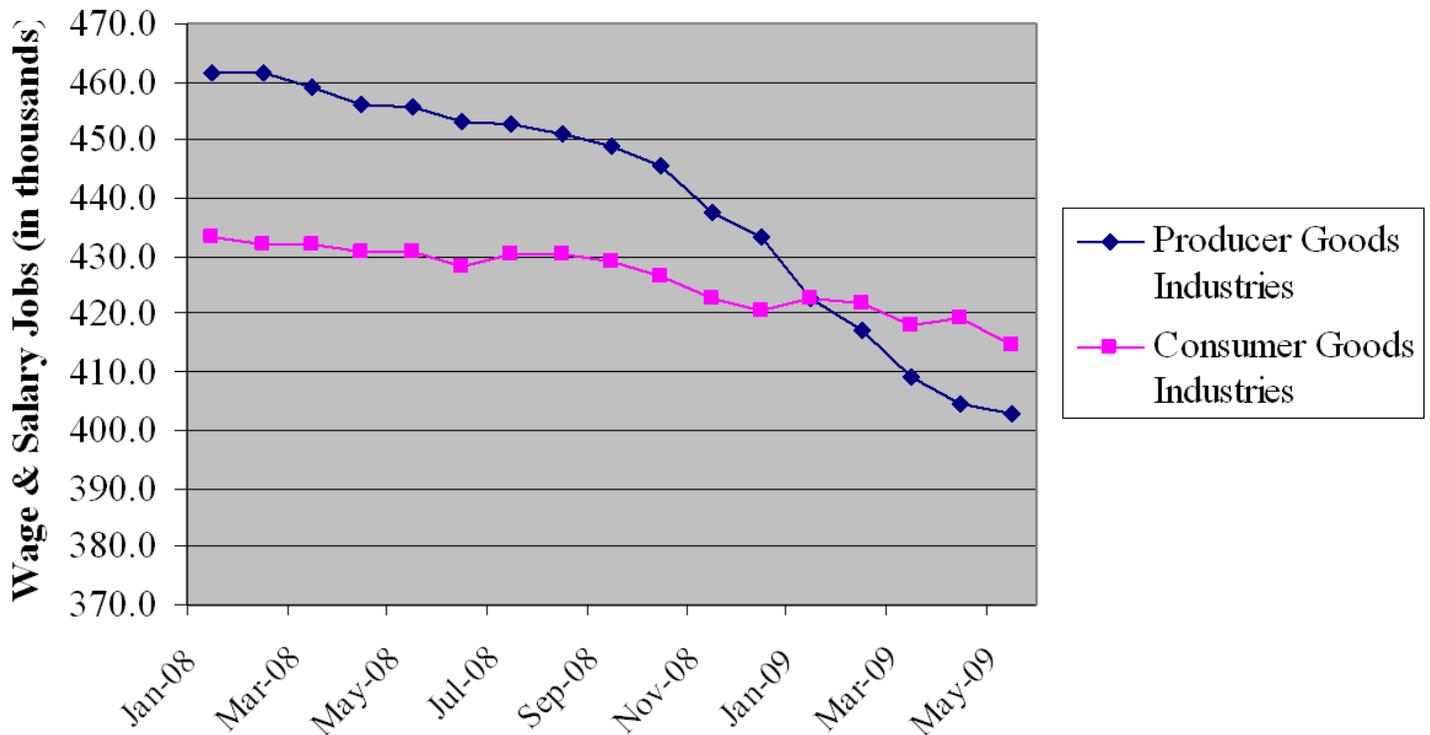
<sup>9</sup> Let us start with the production function written as:  $Y^* = K^a (E)^{1-a}$ . After a little algebraic manipulation, we get

$(Y/L) = \left(\frac{K}{L}\right)^a \times E^{1-a}$ . From this equation we can obtain the proportional growth rates of capital per worker and output per worker. The proportional growth rate of capital per worker is equal to the growth rate of capital minus the growth rate of labor:  $(K_{t+1} - K_t) / K_t - n$  where  $n$  is the growth rate of the labor force.  $K_{t+1}$  can be written alternatively as  $K_t + (s \times Y_t) - (K_t \times d)$  where  $d$  is the rate of depreciation and  $s$  is the savings rate. We substitute this alternative form back into the original equation for the proportional growth rate of capital per worker to get  $(s \times Y_t) / K_t - d - n$ . This equation tells us that a reduction in the savings rate will lower the growth rate of capital per worker. The proportional growth rate of output per worker is equal to the proportional growth rate of capital per worker plus the rate of growth of the efficiency of labor. Therefore, after rearranging some of the terms, the proportional growth rate of output per worker is  $g + ((s \times Y_t) / K_t - (d + g + n))$  where  $g$  is the growth rate of labor efficiency. We see that a reduction in the savings rate lowers the proportional growth rate of output per worker.

<sup>10</sup> DeLong: The Financial Crisis of 2007-2009: Causes, Consequences--and Possible Cures

rising unemployment and falling incomes in the capital goods industries produces unemployment and falling incomes in the consumer goods industries. Table 2 shows high unemployment in the capital goods-producing industries preceded high unemployment in the consumer goods industries in Minnesota.

### Employment by Producer and Consumer Industries in Minnesota



In equilibrium, aggregate demand is equal to output. The components that determine the level of output are consumption, realized investment, and government expenditures. The factors that determine aggregate demand are consumption, planned investment, and government expenditures. Planned investment includes business spending on plant and equipment and intended inventory. Realized investment includes planned investment plus unintended inventory. Where output is greater than aggregate demand there will be unintended inventory accumulation. The amount by which realized investment exceeds planned investment represents the unintended inventory accumulation. The accumulation of unintended inventories leads businesses to reduce output to reduce the level of inventories. There will be a tendency for output to fall until a new equilibrium is reached at lower levels of output and aggregate demand. In the present situation, investment has declined and the new level of equilibrium output is below the level of output at full employment. The appropriate fiscal response is to increase government spending to an amount sufficient to restore equilibrium at full employment.<sup>11</sup>

### The Keynesian Effect of Government Spending Programs to Promote the Wind Industry

Analysis of changes in government expenditures can be decomposed into two effects. The first considers the effect of a change in government expenditures on equilibrium income. The strength of this effect depends on the extent to which otherwise unemployed labor and capital is utilized. In the extreme, with significant

<sup>11</sup> Alternatively, a tax cut could be used. The tax cut could be used to stimulate aggregate and shift the aggregate demand curve upward. The tax cut would need to be larger than the rise in government spending because the tax multiplier is smaller.

unemployed resources, we assume that there is no crowding out of private investment and only otherwise unemployed resources are utilized by the government spending program. In this case, government spending would greatly increase output through government purchases and secondary private purchases reflecting the multiplier effect. The rise in equilibrium output would generate new savings to balance the change in government spending. The intermediate case assumes a partial crowding out of private sector spending. The positive change in government expenditures results in higher income. However, the effectiveness of the government stimulus also depends on how effectively the government spends the money. In order to maximize the effect of government spending on equilibrium output, government spending programs should target unemployed labor and capital. With over 90 percent of the labor force currently employed, it is difficult to target unemployed resources.

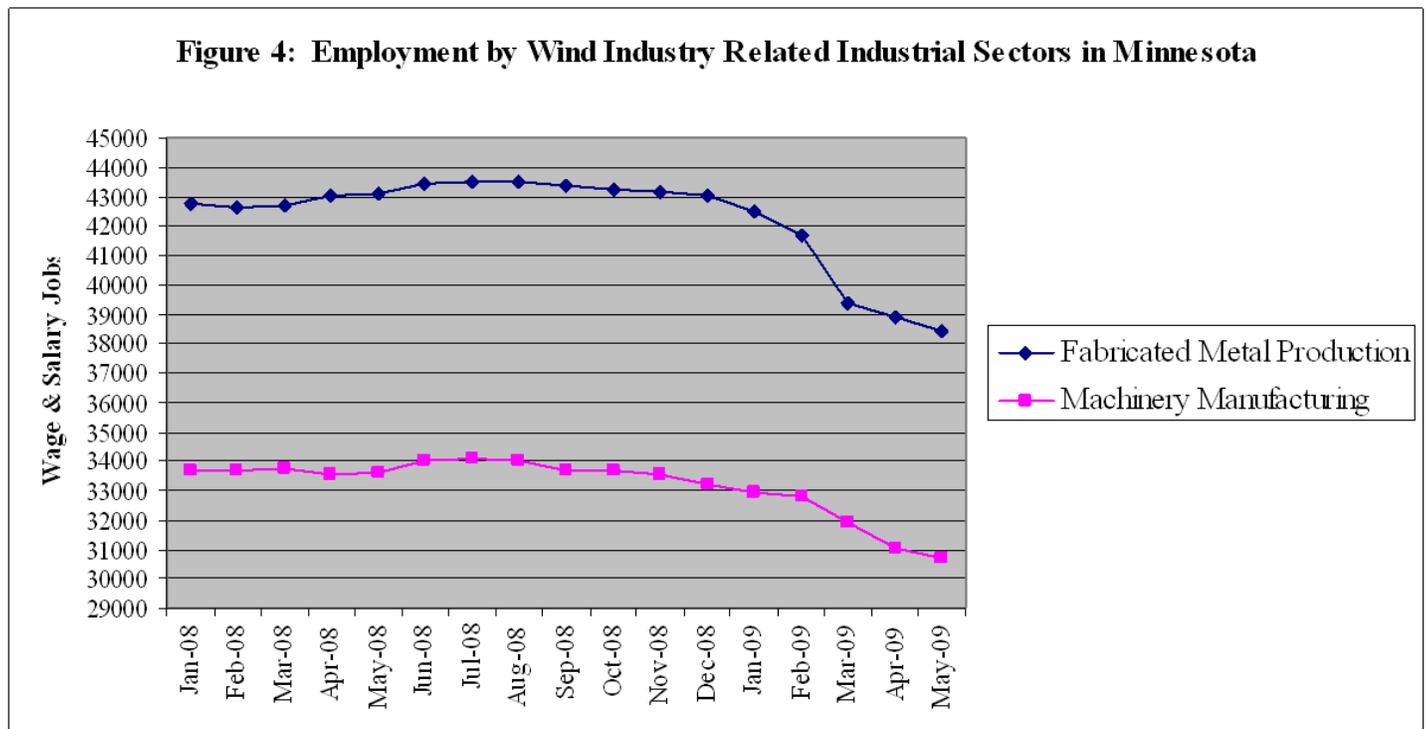
Expanding the use of wind energy in Minnesota will have a significant positive impact on employment. Moreover, government expenditures aimed at promoting the development of wind energy are unlikely to crowd out private investment by drawing on labor, raw materials, and capital from the private sector. Table 6 decomposes wind energy manufacturing into six manufacturing sectors. Primary metal manufacturing in the wind industry involves the manufacturing of ferrous forgings in steel mills. Fabricated metal product manufacturing includes forging, stamping, bending, forming, and machining, used to shape individual pieces of metal; and other processes, such as welding and assembling, used to join separate parts together. Fabricated metal processes are very important in wind energy manufacturing. Manufacturing a wind turbine tower requires cutting a steel plate and rolling it into a conical subsection for a wind turbine tower. After the conical sections are cut and rolled into the proper shape, the tower is assembled by welding these smaller subsections together. Other fabricated metal processes are used to manufacture ball and roller bearings for wind turbines.

Industries in the machinery manufacturing sector make end products that apply mechanical force. For example, in the wind energy sector, this includes the manufacturing and application of gears, couplings, high and low speed shafts, and generators. In a wind turbine, these parts are the guts - the power from the rotation of the rotor is transferred to the generator via the low speed shaft, the gearbox, and the high speed shaft. Singh and Fehrs (2001) surveyed firms in the wind industry located in the United States and used the results to estimate the jobs and skills required to construct a wind project. They concluded that 62.5 percent of the direct jobs created in the wind sector are in the manufacturing sector. Of the direct jobs created in the manufacturing sector, 20 percent are benchwork occupations. This category includes occupations using handtools, and bench machines to fit, grind, carve, mold, paint, assemble, or inspect objects. The work is usually performed at a bench, worktable, or conveyor. These jobs employ low-skilled labor are typically routinized meaning that the workers follow standard procedures. Other leading occupations in manufacturing in the wind sector are structural work and machine trades. Singh and Fehrs estimated that 31 percent and 45 percent of the direct jobs created in the manufacturing sector are machine trades and structural work occupations respectively. According to the Dictionary of Occupational Titles, the machine trades category includes metalworking and metal machining occupations. Metalworking occupations include sheet and bar rolling occupations and fabricating machine occupations. Structural work occupations include welders and cutters and other occupations that shape and assemble metal.

NAICS Code <sup>12</sup>	NAICS Industry Description
326	Plastics and Rubber Products Manufacturing
331	Primary Metal Manufacturing
332	Fabricated Metal Products
333	Machinery Manufacturing
334	Computer and Electronic Product Manufacturing
335	Electrical Equipment and Component Manufacturing

Source: Department of Employment and Economic Development (DEED)

Table 6 shows that wind energy related manufacturing sectors have experienced significant changes in employment. The fabricated metal products sector has seen the greatest losses since the January 2008, down 10.1 percent. Machinery manufacturing fell 8.7 percent during the same time period. These industries showed weakness since July 2008. Furthermore, the weakness became more prominent with the expansion of the recession beyond the construction and real estate sectors. The pace of the decline picked up in the last two quarters of 2008 and accelerated during the first half of 2009. The quickening of the pace of the decline toward the end of the 2008 coincided with credit drying up. The manufacturing conditions in Minnesota weakened dramatically during the latter half of 2008 and the first half of 2009. The Minnesota Business Conditions Index produced at Creighton University measures the conditions for manufacturing growth in Minnesota. This measure peaked in April at 55.1 but by December had declined to 32.2, almost 18 points below the break-even point of 50. Notably, the portion of the index measuring confidence had dropped to about 21, indicating that businesses were very unsure about their prospects.



Source: Current Employment Statistics.

<sup>12</sup> North American Industry Classification System (NAICS) codes is the standard for classifying businesses for the purpose of collecting statistical data related to the economy.

The severe contraction in industries related to wind energy manufacturing suggests that promoting wind energy development would effectively target unemployed labor and capital. Therefore, it would be expected that every dollar of wind energy stimulus produces more than one dollar of output.

### **The Government Waste Effect of Government Spending Programs to Promote Wind Energy**

Wind subsidies are also objected to on the basis that wind energy is a less efficient way to generate electricity compared to coal-fired plants and other fuel types. The argument is that the market could provide higher quality energy at a lower cost. In other words, the wind subsidies distort resource allocation and interfere with the competitive markets for power producers. Wind subsidies lower the cost of wind so that wind projects are competitive with coal-fired plants. But these objections fail when we recognize that society is not building wind installations solely for the purposes of stimulating the economy and providing a basis for long term economic growth and prosperity. In a democratic political process, government decided to internalize wind power's positive externalities as a clean, renewable energy. Moreover, the market distortion argument assumes that Minnesota has competitive bidding for generation.<sup>13</sup> However, Minnesota does not have competitive bidding for generation. Minnesota is a cost of service state. Cost of service rate regulation means that utilities earn a specified rate of return on the cost of supplying electricity. Cost of service regulation rewards vertically integrated utilities for high costs of service. There is little incentive to operate plants efficiently or avoid construction cost overruns. It is true that in a cost of service regime, the regulators are supposed to fulfill the role of a watchdog and have the power to disallow unnecessary costs. But the reality is that regulators are human and are not effective in this capacity. Utility construction cost overruns are passed to the ratepayers (see *The Future of Nuclear Power*<sup>14</sup>). Shifting uncertainty risks to ratepayers lowers the cost of power plant construction for vertically integrated utilities and is a de facto subsidy to nuclear and coal-fired power plants where the overnight construction costs and construction lead times are considerable. The point here is that Minnesota does not have a competitive market for bidding generation; all energy sources are subsidized, and so wind subsidies do not necessarily shift resources away from more efficient generating technologies. Therefore, even if wind subsidies result in partial crowding out of private sector spending, the private activities crowded out, such as the construction of coal-fired power plants, may not be more valuable than the development of wind energy stimulated by the wind subsidies.

The economically efficient level of pollution abatement is where the marginal damages of pollution equal the marginal costs of abatement. The problem is that we need to know both the marginal benefit and marginal cost of abatement functions. The informational requirements are too great to know these functions. A more tractable method of estimating the marginal benefits is to utilize "willingness to pay" methods. Borchers, Duke, and Parsons (2006) use a contingent value method in order to reveal preferences for "green" power and discover the average price consumers are willing to pay for a particular quantity of wind generated electricity. They estimate that the average consumer, participating in an involuntary green power program, would be willing to pay a 7.6 percent premium for a 25 percent wind standard. This premium reflects a willingness to pay for pollution abatement.

The average monthly electricity bill for the study participants was \$122. Therefore, a 7.6 percent premium is equivalent to paying \$9.27 per month. The value of the PTC can be used to calculate the opportunity cost of a kWh produced by wind energy in the United States in order to obtain a rough estimate of total annual

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<sup>13</sup> Joskow (2004) notes that Order 2000 requires all utilities that own transmission lines to have open access tariffs approved by FERC at regulated cost of service prices and to provide non-discriminatory service by making availability known to third parties. Order 2000 endeavors to promote and establish a platform for a competitive wholesale power market, but it stops short of mandating unbundling of transmission from generation.

<sup>14</sup> Massachusetts Institute of Technology (2003), *The Future of Nuclear Power: an Interdisciplinary MIT Study*. Boston, MIT.

subsidy cost that would be needed to attain a 25 percent wind energy standard. A comparison between these two measures reveals that the PTC is approximately equal to the average willingness to pay in an involuntary program. Therefore, this suggests that the PTC is socially efficient.

# Appendix

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## Appendix A: Methodology

### *The Jobs and Economic Development Impact Model*

The Jobs and Economic Development Impact (JEDI) Model is a tool for assessing the local economic development impacts of financing, construction, and operation of power plants. The JEDI Model is a basic input-output model. The Minnesota multipliers for employment, income, and output patterns were adapted from the IMPLAN Professional model. The expenditures from construction of wind projects are matched with the appropriate multipliers for each sector affected by a change in expenditures from construction of wind projects.

The JEDI Model employs multipliers generated by Minnesota IMPLAN Group, Inc. Economic multipliers are useful because they help us to understand how the effects of a business expansion or new industry ripple through the economy. There are four multipliers commonly used to assess the total impact from a business expansion or location. The four multipliers are: (1) Output; (2) Employment; (3) Income; and (4) Value added. The output multiplier estimates the total change in output from a \$1 increase in final demand. Final demand is the total expenditure on final goods and is includes consumption, investment, and exports. Consumption includes expenditures on goods and services sold to their final users. Investment is expenditure on goods for future use including fixed capital. The output multiplier is useful because for determining the interdependence of industry sectors in the economy. For example, an output multiplier of 2.1 indicates that for every \$1 of steel exported to Wisconsin, and additional \$1.10 of output is produced in Minnesota. The employment multiplier estimates the total number of jobs created in an economy as a result of the initial job-creating activity. The initial change in employment is multiplied by the employment multiplier to estimate the total number of new jobs created in the economy. The income (earnings) multiplier estimates the total increase in household income as a result of a \$1 increase in household income from the initial economic activity. The value added multiplier estimates the total change in value added for every dollar of value added as a result of initial economic activity. Value added includes employee compensation, indirect business taxes, propriety income, and property income. Total value added is a measure of the gross regional product of the regional economy.

Input-output models decompose the economic impact of an initial economic activity into three components. These are the direct, indirect, and induced effects of the initial economic activity. In the case of a wind project, the direct effects in the JEDI Model include the construction and development related expenditures. Indirect effects include payments for goods and services to suppliers. For example, indirect effects include payments to the turbine, tower, and blade manufacturers. Other indirect effects include payments from the contractor to a banker for financial services. Indirect effects also include payments from the turbine manufacturer to various turbine component manufacturers. The induced effects refer to new jobs created by the spending of people directly or indirectly employed by the wind project. This would include spending on retail items, automobiles, other household goods and services, property, etc.

The JEDI model analyzes the construction period direct, indirect, and induced effects and the operations period direct, indirect, and induced effects. It also analyzes the direct, indirect, and induced effects related to the financial structure. For example, the induced effect from the amount of cash distributions captured and retained by the community is largely dependent on the wind project's financial structure. It is important to note that the jobs created during the construction phase are one-time impacts and the jobs created during the operations phase of the wind project are annual impacts. However, this report calculates the number of new jobs created during the construction period for each of the 17 years Minnesota has to meet the RES. For

example, construction of a wind project may support over 500 jobs in Minnesota (full-time equivalent) and generate millions of dollars in state economic activity during the construction period. The same project will continue to benefit the state economy during the operations phase.

The study area included when selecting the multipliers is the state of Minnesota. Therefore, the study uses state multipliers for assessing the economic impact of wind projects in Minnesota. The state multipliers reflect the economic interrelationships between businesses and industries in Minnesota. The state level is the most appropriate geographical area of analysis for a number of reasons. First, the state is large enough to serve a functional economic unit. Second, most policies and incentives promoting the wind industry are at the state level. One objective of this report is to inform policy design at the state level by showing how the economic impacts of wind projects ripple through Minnesota's economy. Third, with the declining emphasis on incentive-based competition for industrial location and the adoption of strategies aimed at creating a supportive economic development environment, economic development efforts have become increasingly focused on the overall performance of the state economy. Fourth, Minnesota's Community Based Energy Development (CBED) statute, for purposes of designating a community based energy development project, defines a qualifying owner as a Minnesota resident, a limited liability company organized under the laws of Minnesota and made up of members who are Minnesota residents, a Minnesota nonprofit, a Minnesota cooperative, or a Minnesota political subdivision. These qualifying owners have at least one common characteristic: they are either formed under the laws of Minnesota or are a Minnesota resident. This would suggest state policymakers treat Minnesota as a single community for purposes of the CBED statute as there is no requirement that the qualifying owner live in the same county, town, or city where the wind project is located. Therefore, it follows that the appropriate geographical area for analysis of the economic impacts of wind projects would be the state of Minnesota.

The local share parameters represent the portion of project expenditures that are purchased in the state or local region. These expenditures result from purchasing turbine equipment manufactured in the state or using in-state labor to construct the wind project. The local share of project expenditures represents a direct effect of the wind project. These initial direct expenditures generate local economic activity and increase demand for goods and services. The local share of expenditures is important from the standpoint that these are the portion of direct expenditures that ripple through the economy, and this economic activity is translated into the direct, indirect, and induced effects discussed above.

## **Appendix B: Estimating the Default Local Share Values for Major Component Manufacturing**

The default scenario for turbine equipment was developed by first calculating the cost of 20 turbine components as a percentage of the total cost of turbine equipment. The next step was to identify companies in Minnesota involved in the manufacturing of components for utility scale wind turbines. Utility scale is defined as 1 MW turbines or greater. The Renewable Energy Policy Project (REPP) created a database of companies that manufacture components for utility scale wind turbines (Sterzinger and Svrcek 2004). The REPP database identified CWMF Inc. as a manufacturer of towers and SMI & Hydraulics as a manufacturer of towers and tower flange and bolts. In order to identify a larger number of utility-scale wind turbine component manufacturers than those identified in the REPP database, publications by Minnesota's Department of Employment and Economic Development (DEED), news releases, and the DEED database of potential suppliers to wind manufacturers were used to identify additional manufacturers engaged in the wind sector in Minnesota.

The DEED publications, database, and news releases resulted in the identification of Suzlon Rotor Corporation, a manufacturer of wind turbine blades and nose cones, Moventas, a manufacturer of gear boxes, Zero Max,

a manufacturer of wind turbine couplings, and Anderson Trucking Service (turbine shipments), and Columbia Gear Corporation, a supplier of gears. The DEED database organizes 96 potential wind suppliers according to the 12 NAICS 6-digit codes associated with wind turbine components. It was determined through phone interviews and by comparing company capabilities with the technical specifications for utility scale wind turbines that many of the companies listed in the DEED database, like Next Generation Power Systems, specialized only in manufacturing for small wind turbines. Lastly, phone interview, news releases, and annual reports were used to estimate the capacity of these suppliers and their market share.

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