



# MID-AMERICA TRANSPORTATION CENTER

Report # MATC-KU: 467

Final Report  
25-1121-0001-467

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## Developing a Multi-Modal Freight Movement Plan for the Sustainable Growth of Wind Energy Related Industries

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THE UNIVERSITY OF  
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2012

A Cooperative Research Project sponsored by the  
U.S. Department of Transportation Research and  
Innovative Technology Administration

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MATC

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A Report on Research Sponsored By

Mid-America Transportation Center

University of Nebraska-Lincoln

June 2012

## Technical Report Documentation Page

1. Report No. 25-1121-0001-467	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Developing a Multi-Modal Freight Movement Plan for the Sustainable Growth of Wind Energy Related Industries		5. Report Date June 2012	
		6. Performing Organization Code	
7. Author(s) Rita Neff and Yong Bai		8. Performing Organization Report No. 25-1121-0001-467	
9. Performing Organization Name and Address Mid-America Transportation Center 2200 Vine St. PO Box 830851 Lincoln, NE 68583-0851		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Research and Innovative Technology Administration 1200 New Jersey Ave., SE Washington, D.C. 20590		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract As the demand for wind power increases so too has the popularity of larger and larger turbines. Larger turbines are able to produce more power for the input they receive but they are also much more difficult to transport. This project examines these difficulties with a focus on effective strategies to overcome them. Particular attention was paid to transportation of turbine components through the state of Kansas.			
17. Key Words Freight, Transportation, Turbine, Wind		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 34	22. Price

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## List of Abbreviations

ATS International (ATSI)  
Energy Return on Investment (EROI)  
Heavy Vehicle Use Tax (HVUT)  
Kansas Department of Transportation (KDOT)  
Megawatts (MW)  
Mid-America Transportation Center (MATC)  
National Pavement Cost Model (NAPCOM)  
Noble Environmental Power (NEP)  
United States Department of Transportation (US DOT)

## Acknowledgements

This research project was funded by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the Mid-America Transportation Center at the University of Nebraska-Lincoln.

## Disclaimer

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## Abstract

As the demand for wind power increases, so too has the popularity of larger and larger turbines. Larger turbines are able to produce more power for the input they receive, but they are also much more difficult to transport. This project examined these transport-related difficulties, with a focus on effective strategies to overcome them. Particular attention was paid to the transportation of turbine components through the state of Kansas.

## Chapter 1 Introduction

### 1.1 Background

Renewable energy is the watchword of the early 21<sup>st</sup> century. Concern over the effects of greenhouse gasses is becoming more and more widespread worldwide. Combine that with rapid development in heavily populated countries such as China and India plus the unquenchably increasing demand for power worldwide, and it is easy to see why so much time is being devoted to the study and development of green energy.

There are other factors fueling this drive as well. Rising and rapidly fluctuating oil prices have convinced some that renewable energy may well become a more economical alternative in the years to come. There are also political pressures at work. Much of the oil used in the United States is produced overseas, making the country heavily dependent on other nations. On the other hand, many forms of alternative energy can be produced domestically, increasing U.S. energy independence and bringing jobs back from overseas.

Approximately 121,188 megawatts (MW) of electricity were produced from wind power worldwide in early 2008—enough to power 37 million households (CN 2009). By the end of 2010, worldwide wind capacity had expanded to 196,630 MW (WWEA 2010). The overall growth rate of the wind industry at that time was 23.6%, the lowest rate of growth since 2004 and second lowest since 2000. In 2010, China comprised 50% of the world market for new wind turbines, adding 18,928 MW that year and replacing the U.S. as the world's number one producer of wind energy (WWEA 2010).

#### *1.1.1 Offshore Wind Farms*

The majority of wind farms are located on land; however, some farms are located offshore, in oceans or lakes. So far, being more expensive to install and maintain, as well as

more difficult to situate than onshore farms, offshore wind farms have seen limited development. Offshore wind farms currently account for only about 1% of the total wind energy production capacity of wind farms in the world, with the majority of these being located in Europe (Morthorst 2009).

## 1.2 Environmental Benefits

The estimated energy return on investment (EROI) for a large wind turbine is approximately 33; that is to say that a large wind turbine produces approximately 33 times the energy that is needed to build and operate the turbine; this is about a third of the energy a new thermal coal plant would need to produce the same output (Ozment and Tremwel 2007).

The energy used to transport wind turbines from the manufacturer to their final destination figures into their lifecycle emissions. The efficiency of the transportation mode selected impacts a turbine's EROI. Table 1.1 shows the energy consumption (in trillions of BTUs) for the most common modes of transporting turbine components.

**Table 1.1** Energy consumption by transportation mode in trillions of BTUs (US DOT 2012)

Mode	2007	2008	2009
Truck	6,326	6,382	5,944
Class I Rail	563	549	433
Water	1,367	1,065	997
Pipeline (natural gas only)	642	668	617

The carbon footprint of a wind turbine can also be seen in other ways. The large and awkward components of a turbine are difficult to transport; they may require investments in the infrastructure in the form of widened roads, straightened curves, or even new roads. What's

more, many wind farms are in semi-remote locations, meaning that the roads that need to be modified can sometimes be well off the beaten track (Ozment and Tremwel 2007).

### 1.3 Turbine Components

A windmill is made up of a tower and its in-ground base. It also requires a nacelle—the housing for the generator attached at the top of the tower to the blades—as well as the blades, themselves. These components are usually shipped separately and assembled on site. An entire turbine typically weighs about 65 tons (Korpella 2008).

Blades are relatively lightweight but unusually long; a few are longer than 120 yds (Korpella 2008). Trucks carrying long blades may be unable to make certain corners, and must re-plan their routes. Furthermore, blades over 50 yds long are approaching the limits of what can be shipped on the interstate or by rail. The possibility of breaking a blade into multiple pieces for transportation is being investigated, but so far no way has been found which allows the blades to retain their required structural integrity when pieced back together (Galbraith 2009). Towers and bases are exceptionally heavy, but unlike blades, they can be split up into multiple sections and transported separately.

A complete 2.0 MW wind turbine requires approximately 1,500 cubic meters to transport, which is about 13 times the volume of an ordinary trailer, and more than 20 times the space required to transport a 100 kW turbine (Ozment and Tremwel 2007). A single turbine may need to be split into up to eight loads in order to be transported (one nacelle, one hub, three blades, and three tower sections). To ship an entire 150 MW turbine to the U.S from overseas. might require as many as 689 truckloads, 140 rail cars, and eight vessels. Furthermore, many projects today are much larger in scope than 150 MW energy production capacity. The largest operating

project in the U.S. is currently 736 MW, and projects generating more than 4,000 MWs are in the early stages of development (CN 2009).

## 1.4 Modes of Transportation

### *1.4.1 Truck*

The extensive network of highways and roads throughout the U.S. allows trucks much greater flexibility than with other modes of transportation. Barring large bodies of water, trucks are usually capable of delivering cargo all the way from its point of origin to its final destination. Even when other modes of transportation are employed for some or most of the journey, trucks are usually required for the last leg in order to carry cargo to and from ports and multi-modal facilities, where it is delivered by ship or rail. Trucks also have greater options for re-routing around bridges and underpasses that oversize shipments cannot clear.

The odd dimensions of turbine components present a challenge to trucking that is becoming increasingly difficult to overcome as components grow in size. Some turbine components, such as blades, cannot be placed in standard cargo containers, and require specially designed trailers to transport their odd shapes. This incurs extra cost to the shipping company, as the trailers cannot be used for anything else. It is also much more difficult to optimize shipping routes. The majority of trucks made for wind components are empty 20% of the time (Ozment and Tremwel 2007), making it even harder for shipping companies to make a profit.

Wind turbine trucks are almost always oversized. Their routes must be planned to avoid bridges that will not support them and overpasses through which they cannot fit. Different states also have different regulations and permit requirements for oversize vehicles, and all interstate trucks must have the necessary permits for every state through which it will travel. Some states even require trucks carrying large turbine components to have a police escort, which takes time

to arrange. Drivers of oversize trucks are also required to have more training, which can make drivers difficult to find.

In addition to these transport-related issues, heavy shipments encounter the usual problems involved when shipping goods by truck: driver shortages, rising fuel prices, and congestion, among others.

#### *1.4.2 Rail*

The railway system is better able to handle shipments of great size and weight. Again, the odd shapes of turbine components mean that trains must have special cars dedicated only to carrying those components; for example, BNSF's special rail cars can carry up to 460,000 lbs on eight axles, while their regular cars can only hold up to 250,000 lbs on four axles.. These longer rail cars cannot always make the turns the railway was designed for. Loads can also be too tall, forcing routes to be changed in order to miss tunnels and bridges that are too low. These difficulties are only enhanced when shipping goods over mountain ranges. The limited number and locations of rail lines can make it much more difficult to plan routes around these multiple difficulties than it is for trucks to adjust their shipping routes.

#### *1.4.3 Water*

Most nacelles are produced in Asia and Europe, then shipped to the U.S. by boat. Water travel is time consuming—it can take months for the oversize components to complete their journey—but it is also much less expensive than air travel, the other option for overseas shipping.

Turbines can be transported along rivers, as well. However, the limited capacity of U.S. waterways and ports, coupled with the time consuming nature of river travel, combine to make water transportation much less able to compete against the truck and rail industries. Moreover,

water transportation cannot carry components all the way from their production point to their intended wind farm.

Notably, in the case of offshore wind farms, some amount of water travel is required to move the components on site.

#### *1.4.4 Air*

While it is possible to ship turbine components by plane, the authors did not find any examples. In theory, the expense-per-pound of air shipping makes it infeasible for such heavy components. Occasionally, components will be shipped by helicopter for short distances to very remote locations, but this is rare.

Some companies attempting to produce lighter-than-air aircraft are courting the wind market as a future possible alternative. However, no currently in-use examples could be found.

## Chapter 2 Objectives, Scope, and Methodology

### 2.1 Objectives

The primary objective of this research was to examine the difficulties encountered during the transportation of wind turbine components, and to provide an overview of the strategies and technologies used to overcome them. Data was gathered through a literature review of the available materials.

### 2.2 Scope

The scope of this project was limited specifically to the transportation of wind farm components. Particular attention was paid to currently available strategies and technologies for increasing the ease and economy of turbine transportation. Some additional information on wind farms is provided to give background.

### 2.3 Research Methodology

A comprehensive literature review was conducted to gain an understanding of the transportation industry as it relates to wind farm components, as well as aspects of the wind industry itself that are believed to influence the transportation sector. Also included is information on laws and corporate practices related to these areas. This review contains information from journals, periodicals, government documents, and other sources.

## Chapter 3 Size of Components

### 3.1 Increasing Size of Turbines

The ever-increasing demand for energy and the growing popularity of green power have spurred the development of energy that can be produced by sustainable methods such as wind. This phenomenon has resulted in the need to produce more power while simultaneously maintaining control over installation and maintenance costs. So far, the most economical solution seems to be the construction of larger turbines.

Not only do larger turbines provide better land utilization, but taller turbines can also stand clear of wind-blocking obstacles. More importantly, larger turbines enable farms to reduce the per-unit cost of their system controls, the electrical connection of turbines to the grid, and maintenance. It is therefore unsurprising that turbine size has increased by nearly a factor of 100 in the last 20 years, from 25 kW to 2500 kW and more (Gardner et al. 2009).

As turbines grow, it becomes more difficult to transport their components. Turbine blades and towers are already pushing the limits of what can be carried by trucks and rail cars. Towers can at least be segmented to break up their immense heights; however, these sections are still very heavy, and their increasing diameters can place them in the oversize class. Some companies have attempted to manufacture turbine blades that can be broken into segments during transportation and reassembled on site. So far, these efforts have met with no success. Segmented turbines are too fragile; after reassembly, they break under strong winds.

### 3.2 Infrastructure Damage

#### *3.2.1 Vehicle Weight*

The amount of wear and tear a roadway or rail line receives in any given year depends on a variety of factors. These include the weather and temperature of the region, the type of terrain

upon which the infrastructure is built, and the number and weights of vehicles that travel upon the infrastructure.

Depending on these various conditions, a heavy truck is capable of causing 70,000 times more damage to a road than is a light single-passenger car (Burchardt 2006). This damage can be reduced to a certain degree by adding axles to heavy trucks, allowing them to spread their weight over a larger area; yet this strategy can provide only limited relief. While a heavy truck will always cause more damage than a car, adding axles can make a considerable difference. The exact effect can be difficult to calculate, as the relation between weight per axle and road wear is not always linear. The National Pavement Cost Model (NAPCOM) calculates that in some cases, doubling the load per axle causes 15 to 20 times greater damage, but in other instances, doubling the load per axles results in only two times the original damage (US DOT 2007).

Railway lines are privately owned and operated. The costs of maintaining rail lines is therefore calculated by the rail companies and built into the cost of shipment. Roads and highways, however, are government funded, and are paid for by a variety of taxes and fees. These fees can be a subject of much debate, and a large quantity of work goes into determining the most fair and effective ways these costs can be shouldered by the private and commercial drivers that pay them.

According to one Highway Cost Allocation Study conducted by US DOT (2007), single-unit trucks weighing less than 25,000 lbs pay approximately 150% of the damages they cause to the infrastructure, while combination trucks over 100,000 lbs pay only 50%. This, along with the desire to control oversize traffic for safety reasons, is why many of the taxes and fees imposed on oversize vehicles exist; the taxes and fees are an attempt to offset the costs of repairing and maintaining the roads and infrastructure to equalize this disparity.

### *3.2.2 Vehicle Dimensions*

The height and width of unwieldy turbine components can also cause damage. When trucks and rail cars attempt to pass through tunnels or under bridges that are too small for them to clear, they scrape against the sides, damaging the infrastructure and causing massive amounts of property damage. Idaho and Texas, for instance, have witnessed hundreds of thousands of dollars in damages to interstate overpasses by trucks laden with tall turbine components (Galbraith 2009).

## 3.3 Transporting Oversize Components

### *3.3.1 Road Standards and Specifications*

During route planning, components with unusual dimensions must be given special consideration. A long turbine blade may not be able to clear some of the turns a truck or train would normally take. It is therefore necessary to determine what road clearances the vehicle requires and what turning radius the road it travels must provide, then to plot a route the vehicle will be able to traverse. Following are three cases which provide a basic idea of the scale of necessary vehicle clearances:

Noble Environmental Power (NEP) conducted survey to determine the shipment route for a quantity of 68 1.5 MW wind turbines (2012). The longest vehicle was a 144 ft truck carrying a 37 m blade. NEP believed this vehicle to have a turning radius of 135 ft 8 in., with an overhang up to an additional 10 in. The other vehicles in the study were believed to have turning radii of less than 115 ft. NEP made improvements to intersections near the project site to ensure that each provided a turning radius of at least 120 ft. The blade transports were assisted through these turns with the use of rigging equipment.

URS Corp. prepared an assessment for Ripley-Westfield Wind LLC, identifying possible routes through which to transport turbines to Ripley-Westfield's wind farm in Chautauqua County, NY (2010). The Turbine blades for that installation were expected to be 49 m long, making the vehicles carrying them total 174 ft . It was believed that a turning radius of 150 ft was required to accommodate the vehicles, although it was also assumed that trucks with rear steering axles could manage tighter turns.

A study conducted to determine wind energy possibilities for Warm Springs Oregon found that vehicles carrying turbine blades can reach over 220 ft long, requiring a turning radius of at least 200 ft (Warm Springs 2007). The study also found that access roads needed to be at least 16 ft wide, with 10 ft shoulders on either side.

### *3.3.2 Telescoping Flatbed Trucks*

Another difficulty encountered during the shipping of blades is the truck size required. Truck beds constructed to carry turbine blades are usually tailor-made for one particular size of blade. They are able to carry that specific cargo only, and are therefore inefficient investments for trucking companies that do not do frequently do business shipping turbine blades.

In an attempt to increase the flexibility of these vehicles, German-based transportation firm Goldhofer has developed an extendable flatbed truck. The vehicle can telescope out from 20 m (65.6 ft) to 62 m (203.4 ft), allowing it to carry blades for different sizes of turbines. The trailer's maneuverability has also been improved, with three rows of pendular axles. Depending on the model, the flatbed can carry between 52,900 lbs and 83,700 lbs, (Goldhofer 2010).

### *3.3.3 Double Stacking*

Barges typically do not share the size and weight constraints of trucks and rail cars. Their infrastructure is limited, but, along rivers, lakes, and oceans, they provide an opportunity to carry large shipments.

Stacking frames enable barges to double stack wind components, doubling their carrying capacity and making them a much more competitive mode of transportation. One ATS International (ATSI) project to transport 50 wind turbines opted to transport 40 of the towers by barge, double stacked. Double stacking enabled the firm to move 10 towers at a time and required the use of only four barges (Brown 2012). The barges avoided the bottleneck that would have been caused by a California State Police escort and delivered the towers in only six weeks. The analysis that had been performed beforehand had projected that carrying the same turbines by truck would have taken 16 weeks (WE 2011).

## Chapter 4 Route Planning

### 4.1 Shipping Routes

Large and oddly shaped trucks and trains that are used to transport turbine components often cannot fit through small underpasses or around sharp corners, and heavy shipments may not be able to pass safely over certain bridges and overpasses. Therefore, the exact route over which a shipment travels must be carefully planned before the shipments leave their original manufacturer, in order to ensure they travel along the most efficient path.

In many cases, route planning involves the coordination of at least two transportation modes and, possibly, multiple shipping companies. For instance, because different companies may control different sections of the rail network, sometimes multiple companies must coordinate when transporting turbines over a long distance. Components will also usually be required to pass through at least one major urban center, particularly since inter-modal transfer stations are more likely to be located in these areas. Sometimes trucks can even be required to travel through residential neighborhoods, which may lead to public concern regarding safety issues and noise pollution.

#### *4.1.1 Congestion*

The increased amount of traffic in urban areas and busy highways leads to roadway congestion. Congestion occurs on roads and ports when they are used by more vehicles than their capacity can tolerate; it can also occur at ports that do not have sufficient capabilities to efficiently transfer freight from one mode to another (e.g., from truck to ship), thus forcing carriers to wait in line. In either of these situations, the congestion causes delays, and usually wastes fuel.

In an effort to reduce the time spent transferring goods, the port of Vancouver installed two heavy duty cranes to more easily transfer oversize freight. A pair of powerful cranes can quickly and safely move tower segments and blades from one mode to the next. Cranes are being adopted at more and more ports and shipping hubs.

Congestion can also occur in sections of the infrastructure that have space constraints, such as tunnels and overpasses. Even when oversize vehicles are able to clear these spaces, they may have to slow down to do so. For example, one BNSF rail shipment of turbine tower sections was forced to decelerate to 3 mph when crossing a particular bridge, forcing other trains to wait, and causing congestion on the rail lines (Jordan 2009).

#### *4.1.2 The Public*

Most of the public attention aimed at the development of the wind farm industry centers around the wind farms themselves, but concerns over turbine transportation also exist. Most of these concerns seem to center around noise pollution from oversize vehicles passing through neighborhoods. Since heavily populated neighborhoods may also have tight corners and narrow streets, trucks should avoid urban areas whenever possible. When these areas are unavoidable, corporate and public interests should seek collaboration to attempt some form of compromise.

When a wind farm was planned in Belfast, Maine, the icy conditions of Maine roads in winter were deemed an unsafe risk for oversize trucks; it was decided that the bulk of the shipments would be delivered during the summer months. Locals voiced concerns that the increased traffic would cause congestion on local roadways, harming the tourism industry as a result of the crowded roads. Eventually it was decided that trucks carrying tall nacelles would move through the town only at night, thereby avoiding the tourists (Galbraith 2009). In other

situations this solution might not have been possible, as some companies prefer not to ship at night since the lowered visibility may increase accidents.

## 4.2 Safety

Although heavy trucks—those with a gross vehicle weight over 10,000 lbs—are actually less likely to be involved in an accident than are lighter trucks, accidents involving heavy trucks are 2.6 times more likely to result in a fatality than are crashes involving only light vehicles (NCHRP 2004). Unwieldy trucks, such as those carrying turbine blades, can also be more difficult to control.

The selected mode of transportation can also impact safety. Table 4.1 compares the vehicle miles traveled by transportation mode in 2008 with the fatalities that occurred. It should be noted that these are overall statistics, not the statistics for freight traffic alone.

**Table 4.1** Fatalities and VMT by mode, 2008 (BTS 2010)

Mode	Fatalities in 2008	VMT in 2008 (millions)
Highway	37,261	2,973,509
Railroad	800	582
Water	109	Unknown
Pipeline	8	Unknown

VMT = Vehicle Miles Traveled

## 4.3 Logistics

### *4.3.1 Location of Manufacture*

As the distance that turbine components must be shipped increases, their transportation cost also increases. The United States is a net importer of turbine components: between 2003 and 2008, imports increased from \$356 million to \$2.5 billion, while exports increased much more

modestly, from only \$0.7 million to \$22.1 million (David and Reed 2009). It has been predicted that producing all turbine components domestically would create overall project cost savings of 3%-5%, causing transportation costs to comprise only 2%-5% of all project costs (Ozment and Tremwel 2007). It should be noted, however, that the life expectancy of a turbine is 20 to 25 years, and that their replacement costs comprise a much greater percentage of the project budget than do transportation costs (David and Reed 2009). Therefore, some wind farm operators may continue to use imported parts derived from manufacturers with a preexisting reputation for quality, rather than taking a chance on a new manufacturer. However, American and International manufacturers alike have begun to open factories in the U.S. Currently, approximately 12 blade manufacturing plants in the U.S. are already in operation or are in the planning stages. Of these, 11 have been either opened or announced since 2003 (David and Reed 2009). Table 4.2 displays information on the nacelle manufacturing plants located in the U.S., along with the locations of the manufacturer's headquarters.

**Table 4.2** Nacelle manufacturing plants in the U.S., 2009 (David and Reed 2009)

Company	Plant Location	Turbine Size (MW)	Production Capacity (Turbines)	Status	Headquarters
Acciona Windpower	Iowa	1.5 and 3.0	400	Operational	Spain
Clipper Windpower	Iowa	2.5	more than 400	Operational	U.S.
CTC/DeWind	Texas	2	500	Operational	U.S.
Emergya Wind Technologies	Arkansas	750 or 900 kW	NA	Expected to begin production in 2009	Netherlands
Nordex	Arkansas	2.5	300	Expected to begin production in 2010	Germany
Fuhrlander	Montana	2.5	NA	Expected to begin production in 2009 or 2010	Germany
Gamesa	Pennsylvania	2	500	Operational	Spain
General Electric	California, Florida, South Carolina	1.5 and 2.5	NA	Operational	U.S.
Nordic Windpower	Idaho	1	240	Expected to begin production in 2009	U.K.
Siemens	Kansas	2.3	650	Expected to begin production in 2010	Germany
Vestas Wind Systems	Colorado	NA	1400	Expected to begin production in 2010	Denmark

#### *4.3.2 Transferring Modes*

One of the reasons that shipping freight by barge or rail is less common than shipping by truck is that water and rail shipments are typically slower. This is partially due to the amount of time it takes to transfer goods from one carrier to another. For example, when a load of tower segments is shipped by barge and then transferred to a truck, the process of moving the segments from the barge onto the truck takes time. The amount of time can be extended if the port is busy

enough to cause congestion delays, as the barge must wait before its cargo can be unloaded. The process can also be slowed if the port's infrastructure is not set up to handle the large and heavy segments. Combined, these issues can cause long delays partway through the shipping process. However, if segments were taken by truck all the way from the manufacturer to the purchaser, these delays would be avoided.

Well-positioned transfer stations can greatly reduce the cost and time requirements of shipping turbine parts, allowing turbines to be carried most of the way by rail or water, then switched to truck transport for the last phase of the journey. BNSF has attempted to establish inter-modal stations within 150 miles of the destination wind farm (BNSF 2010).

## Chapter 5 Legislative Environment

### 5.1 Legislative Environment

Twenty-nine states and the District of Columbia require that a certain percentage of their energy be produced from renewable resources such as solar, geothermal, and wind power (EESI 2010). Kansas, for example, currently produces more than 10% of its energy from wind power, and is working toward the goal of producing more than 20% of its power from wind by 2020 (KWI 2011). In order to meet these goals, legislators enact a variety of incentives, most of which are targeted at the wind farms, themselves, and affect the transportation industry tangentially. For example, tax credits granted for wind turbine construction may increase the amount of turbine components shipped.

There are a number of other regulations, however, that have a more direct impact on wind component transportation. For instance, the limitations and requirements to oversize vehicles apply to many turbine shipments. Following is a brief discussion of some of the regulations transporters must face. Most of these restrictions apply to the trucking industry only; railroads are privately owned, and therefore are not subject to the same degree of legislative control as are federal and state funded roads.

### 5.2 Permits, Tariffs, and Taxes

#### *5.2.1 Oversize Vehicles*

As previously stated, the odd dimensions and heavy weight of turbine components boost many of the trucks that carry them into the oversize category. Requirements for obtaining an oversize vehicle permit can vary widely by state. Oversize vehicles must obtain oversize permits for every state through which they will travel. This process can take time and can become very

complicated in cases of interstate shipping, when components will pass through a large number of states.

There are benevolent reasons underlying the permits. Studies have shown that heavier vehicles have a higher probability of causing fatalities when they are involved in crashes; therefore, state governments prefer to keep a close eye on oversize trucks. Many transportation companies have expressed a desire for more standardized oversize permit requirements in order to make the process less time consuming.

### *5.2.2 The Heavy Vehicle Use Tax*

The Heavy Vehicle Use Tax (HVUT) is a federal tax on vehicles with a gross weight (combined weight of both the vehicle and the heaviest load that it carries during the year) of 55,000 lbs or more. The amount of the tax varies depending on the gross weight of the vehicle. A 55,000 lb vehicle is charged \$100; trucks weighing 75,000 lbs or more are taxed \$550; and vehicles weighing between 55,000 lbs and 75,000 lbs are charged an amount between \$100 and \$550, relative to the weight of the vehicle (IRS 2011). Logging vehicles and vehicles travelling fewer than 5,000 miles per year are exempt, but these exemptions do not foreseeably impact the turbine transportation industry.

### *5.2.3 Oregon Weight-Mile Tax*

Rufolo, Bronfman, and Kuhner (1999) examined Oregon's weight-mile tax on trucks over 26,000 lbs in an attempt to reduce the amount of damage to roads and to offset the costs of road repair. Road damage increases with vehicle weight; for example, a truck weighing 48,000 lb would cause 12 times the damage that a 4,000 lb truck would. Despite this, in many cases light and heavy trucks pay similar fees. This places a disproportionate burden on the lighter trucks where the heavy trucks cause more of the road damage but do not pay much more of the cost. In

an effort to address this, the state of Oregon put forth a per-mile tax amount based on truck weight and the number of axles.

The researchers examined survey data obtained from a variety of companies that shipped oversize truckloads through Oregon. It was found that the tax had a negligible impact. Almost every surveyed firm stated that the tax had no impact on the quantity of oversize trucks they sent through Oregon. Firms also stated that the tax made no difference on the number of axles installed on their trucks.

Many fleets disliked the weight-mile tax because it was difficult to monitor. Compliance necessitated additional staffing, and was therefore costly to administer. A number of smaller short-haul companies, however, preferred the weight-mile tax. These companies believed that if the weight-mile tax was changed to a diesel fuel tax with higher registration fees, they would be burdened disproportionately by the new tax.

#### *5.2.4 Tariffs*

Freight that crosses international borders will be subject to tariffs, inspections, and a variety of other regulations. Imports to the U.S. are typically charged a tariff amount ranging between 0-3%, depending on the component being shipped. Towers, for example, are not charged a duty.

Outside the U.S., tariffs range from nonexistent (e.g., in Australia, Canada, Japan, Mexico, and South Africa) to 16% (e.g., in India). The European Union imposes a 2.7% tariff on imported wind components. China and South Africa imposes an 8% tariff, and Taiwan imposes a 10% tariff (David and Reed 2009).

## 5.3 Route Regulations

### *5.3.1 Permitting*

Once a carrier has planned an appropriate shipment route, the route must be approved by the local government, which will then issue a permit. The permit will specify the route, the days and times that the trucks are to travel, and the permissible per-axle weight. Obtaining a permit can take anywhere between one week to one month.

### *5.3.2 Escort Vehicles*

Frequently, oversize vehicles are required to be accompanied by escort vehicles, with one escort in front and one behind. The front escort vehicle is topped with a pole that is the same height as the top of the oversize shipment. The tip of the pole contains a sensor. If the escort passes under a pass that is too low for the truck, an alarm will sound and the convoy can change route without damaging the cargo, the vehicle, or the surrounding infrastructure. The rear escort travels behind the truck and prevents cars and other vehicles from passing. Some states also require that turbine shipments have additional police escorts.

### *5.3.3 Roadway Design Standards*

Roadway design guidelines govern speeds limits, lane widths, horizontal curve lengths, and a variety of other factors that may impact the transport of turbine components. Different locations have different standards. Kansas roadway standards will be discussed in chapter 6.

## 5.4 Incentives

A variety of government incentives exist to encourage wind farm operators and manufacturers of turbine parts; examples include tax credits, loan guarantee programs, property tax abatements, and support for worker training. It appears that thus far there are no wind-industry-specific incentives that apply to vehicles used for the transportation of equipment.

Government incentives have an impact on the amount of capital the wind industry is willing to invest to increase or repair its facilities, and how much it is willing and able to spend on transportation. Most of the incentive programs supporting the wind industry are tagged with expiration dates. Industry investors note these dates, and fluctuations in demand for the transportation of parts can vary accordingly. For example, the Advanced Energy Tax Credit provided a tax credit to manufacturers expanding their facilities to build turbine components; the tax credit was introduced in 2010 and expired in 2011, and is no longer available to manufacturers wishing to expand; without this incentive for expansion, it could be assumed that manufacturers will be less likely to do so.

## Chapter 6 Wind Energy in Kansas

### 6.1 Wind Farms in Kansas

Being a flat and windy state, Kansas provides many opportunities for the wind industry. Between 2008 and 2011, Kansas nearly tripled its wind power generating capacity. The state was able to generate nearly 1000 MW of power from wind (CN 2009). Tables 6.1 and 6.2 provide basic information on wind farms currently or soon-to be operating in the state of Kansas.

**Table 6.1** Wind farms operating in Kansas (KEIN 2012)

Name	County	Size (MW)	Turbine Type	Turbine Model	First Year of Operation
Gray County	Gray	112	Vestas	V47	2001
Elk River	Butler	150	GE	1.5	2005
Spearville	Ford	100	GE	1.5	2006
Smoky Hills, Phase I	Lincoln/ Elsworth	100.8	Vestas	V80	Feb. 2008
Smoky Hills, Phase II	Lincoln	150	GE	11.5sle	Dec. 2008
Meridian Way	Cloud	204	Vestas	V90	2008
Flat Ridge	Barber	100	Clipper	Liberty	2009
Central Plains	Wichita	99	Vestas	V90	2009
Greensburg	Kiowa	12.5	Suzlon		2010
Caney River	Elk	200	Vestas	V90	2011
Total		1228.3			

**Table 6.2** Kansas wind farms under construction (KEIN 2012)

Name	County	Size (MW)	Turbine Type	Turbine Model	First Year of Operation
Post Rock	Ellsworth	201	GE	1.5	2012
Ironwood	Ford/ Hodgeman	168	Siemens	2.3	2012
Flat Ridge 2	Barber/ Kingman/ Sumner/ Harper	419	GE	1.6	2012
Spearville 3	Ford	100.8	GE	1.6	2012
Total		888.8			

An effect of the increasing demand for wind power, present-day Kansas roadways are travelled by seven times the number of trucks carrying loads of extremely heavy wind tower components than they were five years ago. In 2010, KDOT recorded more than 7,500 truck loads of 150,000 pounds or more consisting of wind tower components. This was a dramatic increase compared to the fewer than 1,000 trucks of that weight class that were recorded in 2006.

It should be noted that there are some restrictions to where wind farms can be built in Kansas, as a number of counties have restricted their development. The basis of these restrictions ranges from noise levels to environmental protection policies that prohibit building infrastructures that would be damaging to the natural tall grass prairie. Specific policies can be found in the Kansas Energy Council's Wind Energy Siting Handbook.

Among other advantages, Kansas is also centrally located; the state is situated within next-day shipping of almost 70% of the U.S. (KWI 2011), making it a favorable location for out-of-state parts shipping. Manufacturers have been attracted by this advantage, and more companies are currently opening or altering plants in Kansas to produce turbine parts.

### *6.2.1 Manufacturing in Kansas*

A survey of manufacturers in Kansas, conducted by Caimbridge Systematics (2009), found that only 57 of 227 (27%) respondents currently serviced the wind industry. Of these 57 manufacturers, only 11% stated that more than 25% of their business came from the wind industry. 12% stated that between 10%-25% of their business came from wind; 18% stated that 5%-10% of their business came from wind; and 16% stated that 1%-5% of their business came from wind. The majority, 28%, stated that less than 1% of their business came from wind, while 16% were unsure how much of their business came from the wind industry (AMI 2009). The survey did not include information on which parts these suppliers produced.

The survey also showed that among the 57 suppliers serving the wind industry, it was most common for manufacturers to produce 10-660 kW turbines; 25 manufacturers produced these medium range turbines; 21 of the 57 produced turbines of more than 660 kW; and 19 produced turbines smaller than 10 kW (AMI 2009). Some manufacturers produced more than one kind of turbine.

### *6.2.2 Incentives to Build in Kansas*

Enacted in 2009, the Solar and Wind Manufacturing Incentive provides up to \$5 million in financing to solar and wind component manufacturers in Kansas. This financing is available to support research, development, engineering, or manufacturing projects, but there are restrictions: A qualifying project must result in at least \$30 million in new investments in Kansas and hire at least 200 new employees within five years. Furthermore, the average annual compensation for Kansas employees must be at least \$32,500. The funding is paid for using the payroll taxes of the new employees. Without renewal by the legislature, this opportunity will expire at the beginning of July, 2013 (DSIRE 2012).

The Federal Energy Tax Credit provides a tax credit of 30% for small wind farms with a capacity of 100 kW or less (DSRE 2011). The Renewable Electricity Production Tax Credit allows energy producers to claim a 2.2 cent credit per kW hour generated for the first 10 years that the energy production facility is in service (DSRE 2012).

## 6.2 Road Standards

Tables 6.3 and 6.4 show some of the design standards for Kansas roads. The minimum horizontal curve radii are well within the requirements established for blade carrying trucks that were examined in chapter 3.

**Table 6.3** Minimum horizontal curve radius on Kansas roads (KDOT 2011)

Road Type	Avg. Daily Traffic	Minimum Horizontal Curve Radius (ft)
A	Any	2,210
B	Less Than 875	960
B	875 - 1,749	1,200
B	1,750 - 3,499	1,810
B	More Than 3,500	2,210

Road Type A are rural interstates and major rural highways constructed to interstate specifications  
 Road Type B are all other rural state highways.

**Table 6.4** Other design standards for all Kansas roads (KDOT 2011)

Minimum Lane Width	12'
Vertical Clearance over Highways	16'4"
Vertical Clearance over Local Roadways	15'4"
Vertical Clearance over Railways	23'6"

## Chapter 7 Conclusions and Recommendations

### 7.1 Summary

In addition to the problems faced in all freight transportation scenarios, shipping turbine components to wind farms is further plagued by the ever-increasing size of such components. Larger turbines allow a greater amount of power to be produced from less input. Some turbine components can be further segmented for transportation, but many pieces are still very large and unwieldy.

This report has investigated a variety of considerations that should be taken into account when making a transportation plan for wind turbine components. A number of these considerations are summarized below, as are areas where future research could prove to be beneficial.

### 7.2 Existing Strategies

#### *7.2.1 Location of Manufacturer*

Because transportation costs represent a smaller percentage of overall project costs than do equipment replacement costs, wind farms may be inclined to purchase turbines from distant manufacturers if they believe the quality of those parts to be superior. Nonetheless, manufacturers should investigate whether nearby wind farms can be persuaded to purchase turbine components from them and reduce transportation costs. As turbines continue to increase in size, reducing the distance which very large components, such as blades, must travel may become a necessity.

#### *7.2.2 Infrastructure Investments*

Alterations and improvements can be made to existing roads and facilities to make them more accommodating to wind industry freight. Areas attempting to encourage wind energy

development should consider how well their road design standards can accommodate larger vehicles, particularly in regards to turning radii. Such considerations include where appropriate standards can be changed and/or turns widened to simplify the passage of oversize vehicles.

Ports and multi-modal facilities that receive significant traffic from the wind industry or are located near developing markets should consider the installation of infrastructure to move the large and heavy turbine components such as blades and tower sections. Heavy duty cranes have been shown to be particularly effective for the loading and unloading of heavy equipment.

It has also been shown that increasing the number of axles on a truck limits the damage it causes to the infrastructure. Taking this into account, some states base a portion of their fees on per-axle weight, rather than overall weight, in the hopes of reducing overall wear on their roads. The effectiveness of this practice is difficult to quantify, however, it is relatively inexpensive to enforce, making it a fairly low risk practice to implement. This low risk coupled with the possible benefits make it a tactic well worth considering..

### *7.2.3 Logistics*

The relative values of all available modes of transportation should be examined. Water and rail transportation are typically much less expensive than truck transport, particularly when escort vehicles would be required. Because rail lines are privately maintained, it may also take less time to deliver oversize components by rail than it would to obtain the necessary oversize permits for all the states through which they would be traveling.

Freight transported by barges over oceans and rivers does not include the same size and weight limits as trucks and rail shipments. The greater carrying capacity of barges can greatly reduce the number of vehicles needed to transport all the pieces of a turbine, making transport by barge much less expensive. The ports that load and unload the components must be equipped to

handle them. If the necessary infrastructure is in place, waterways may provide the best option for transport over long distances.

It is also necessary to consider the time period during which shipments are being sent. Roadways, particularly farther north, may be closed to oversize traffic during winter months due to concerns over increased accident risks, and some rivers may close during droughts. It could also be beneficial to consider the hours of the day during which the components are shipped. For example, some truck shipments have opted to travel at night or during the main working hours in order to take advantage of the low road traffic that occurs at those times.

### 7.3 Future Research

#### *7.3.1 Vehicle Improvements*

The authors discovered information on manufacturers who are attempting to develop lighter-than-air aircraft for use in freight transportation. If air travel could be economized for turbine components, it could provide an excellent option for moving such components from origin to destination without transferring modes. This could potentially greatly reduce congestion and improve shipping time, and should therefore be investigated further.

Increasing the maneuverability of long rail cars and trucks is another area that requires further study. Blade transport vehicles that could clear tighter turns would increase the flexibility in passable routes.

#### *7.3.2 Freight Improvements*

Finally, breaking turbines into even smaller pieces during transportation requires further study. Smaller pieces could be divided among a greater number of vehicles, which would increase the overall cost of the shipment but could also reduce the weight and improve the maneuverability of the individual vehicles carrying them.

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