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**FINAL DELIVERABLE**

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| **Title** | Linn County Wind Farm Siting Analysis |
| **Completed By** | Zhi Chen, Gia DeBartolo, Michael Delp, Luke Foelsch |
| **Date Completed** | May 2019 |
| **UI Department** | School of Urban & Regional Planning |
| **Course Name** | Field Problems in Planning \| URP:6209:0001 |
| **Instructor** | Scott Spak, Haifeng Qian |
| **Community Partners** | Linn County Planning & Development |

This project was supported by the Provost's Office of Outreach and Engagement at the University of Iowa. The Office of Outreach and Engagement partners with rural and urban communities across the state to develop projects that university students and faculty complete through research and coursework. Through supporting these projects, the Office of Outreach and Engagement pursues a dual mission of enhancing quality of life in Iowa while transforming teaching and learning at the University of Iowa.

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# Linn County Wind Farm Siting Analysis

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School of Urban and Regional Planning
The University of Iowa
May 2019

# Acknowledgements

Our project team would like to express our gratitude to the following people for their contributions to our project:

**The University of Iowa**
- Scott Spak, Urban and Regional Planning Faculty Advisor
- Haifeng Qian, Urban and Regional Planning Faculty Advisor
- Adam Skibbe, Geographical and Sustainability Sciences GIS Administrator
- Andrew Kusiak, Industrial and Systems Engineering

**Linn County Planning & Development**
- Les Beck, Director
- Stephanie Lientz, Planner
- Mike Tertinger, Planner
- James Hodina, Linn County Public Health Department

**Office of Outreach and Engagement**
- Travis Kraus, Assistant Director
- Jordan Brown, Program Coordinator

**Alumni Mentor**
- Mitch Brouse, Planner, Johnson County

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# Executive Summary

Advancements in wind energy technology are allowing utility-scale wind developments to be sited in areas once infeasible. In light of this trend, Linn County has proactively partnered with the University of Iowa Office of Outreach & Engagement and The University of Iowa School of Urban & Regional Planning to prepare a Wind Farm Siting Analysis to aid staff and county officials in the review of potential utility-scale wind developments in rural Linn County. This analysis is a step toward fulfilling the goals and objectives regarding alternative and renewable energy listed in Linn County's Comprehensive Plan, *A Smarter Course: Building on the Past, Embracing the Future of Rural Linn County*.

The analysis includes policy and best practices research, a decision-making guide, a survey conducted regarding public attitudes toward wind energy, a Geographic Information Systems (GIS) parcel-by-parcel analysis of rural Linn County which synthesizes all relevant siting factors, and a fully automated GIS model that allows Linn County staff to repeat the GIS analysis as relevant inputs change in the future. This GIS model will provide spatial and quantitative support for Linn County staff when reviewing applications for utility-scale wind developments. The relevant wind development siting factors are classified into three main categories: Regulatory, Suitability, and Compatibility. The first, Regulatory, determines where wind developments can legally be sited. The two other categories mirror two of the Sec.107-73.4 standards for review in Linn County's Code of Ordinances for reviewing conditional use permit applications. Suitability factors determine the level of a potential site's suitability for supporting wind energy infrastructure and therefore can be used to predict the general areas of Linn County that wind developers will want to site these developments. Compatibility factors determine the amount to which a potential site would be compatible with surrounding land uses. The locations with both high compatibility and high suitability ratings are therefore the most ideal siting locations from both the public and private perspectives.
The major findings of the analysis are as follows:

- **Linn County has the necessary wind resource to sustain utility-scale wind energy developments and 116,630 total acres of land (31.4% of rural land) that can legally host them.** Regulatory constraints require developments be sited in AG or CNR zoned districts, 1,000 feet from any residential property structure, and 100 feet from neighboring property lines. The derivation of granular wind resource maps through industry-leading software has indicated the presence of sufficient wind resource in the county and a spatial analysis based on current county regulatory restraints has identified the areas where such developments can legally be sited.
- **Of the 116,630 acres of land where wind developments are legal, the analysis determined 73,842 acres (63%) have high compatibility, 35,891 acres (31%) have medium compatibility, and 6,897 acres (6%) have low or very low compatibility.** Relevant compatibility considerations include Future Land Use Classification, CCSG fringe areas, airport proximity, and visual impacts. Based on literature research and Linn County's existing assets, these are the most important factors for staff to consider in determining the compatibility of utility-scale wind farm development applications in regard to current land uses.
- **Of the 116,630 acres of land where wind developments are legal, the analysis determined 63,491 acres (54%) have high suitability, 48,357 acres (42%) have medium suitability, and 4,782 acres (4%) have low suitability.** Relevant suitability considerations include wind resource, electric grid proximity, transportation infrastructure, presence of karst formations, and slope. These factors will be considered by potential wind energy developers in siting determinations. Understanding the areas of the county most suited to these developments will allow staff to anticipate where proposed sites will be and to plan accordingly.
- **Although residents' general attitudes toward renewable energy are favorable, the majority of survey respondents stated they would dislike utility-scale wind energy developments in their or their neighbors' land.** These results indicate the type of opposition staff would likely face from county residents in siting these developments.

Based on these findings, Linn County can expect to receive applications for utility-scale wind energy developments in the future and to face opposition from the nearby residents of proposed sites. The most suitable areas are found to be generally be within north-central Linn County, so these are the areas in which staff should expect these applications. Currently, Linn County's structuring of these applications through the Conditional Use Permitting process is adequate to prevent the same type of lawsuit Fayette County faced in July of 2018, but additional measures should be undertaken to further guard against potential lawsuits and incompatible wind developments.
Our recommendations are as follows:

- **Integrate these suitability and compatibility findings into the Conditional Use Permit application review process.** Compatibility and suitability concerns are already baked into Linn County's CUP permitting process. By consulting the maps generated using these compatibility and suitability factors, staff will be aware of which specific factors might be of concern to individual utility-scale wind energy developments based on their location (is the development within a potential karst formation? Is it within an area anticipated for future urban growth?). The answers to these questions will inform any conditions placed on potential approvals.
- **Utilize the GIS model to ensure regulatory, suitability, and compatibility maps are current and up-to-date.** The GIS model can recreate all three of these maps in ArcMap with the push of a button. Input new data as Future Land Use classifications change, residential structures are built, and any of the dynamic variables need updating.
- **Use the extensive policy research included here as a reference guide when future questions arise.** Flip to the section pertaining to whichever topic is in question to gain a baseline understanding of the issue and follow sources cited if a more in-depth understanding is necessary.

As wind energy technology continues to advance, other concerns not contemplated here might arise. Staff should stay abreast of these trends to ensure their review process remains thorough and comprehensive. Alternative and renewable energy is a main element in Linn County's Comprehensive Plan, and as such staff needs to equip themselves with the tools to promote its advancement but not at the expense of land use compatibility. This analysis will help staff to strike the balance between wind energy promotion and the mitigation of potential conflicts in the pursuit of a *Smarter Course* for Linn County.

# 1 Introduction

# 1.1 Project Overview

The Linn County Wind Farm Siting Analysis was developed through a partnership between Linn County Planning and Development, The University of Iowa Office of Outreach and Engagement, and The University of Iowa School of Urban and Regional Planning.

The purpose of the analysis presented in this report is to provide an informed siting process for the optimal placement of utility-scale wind development in Linn County with consideration for regulatory, suitability, and compatibility constraints. Through both the identification and spatial analysis of siting constraints, this project intends to provide Linn County decision makers the resources to effectively evaluate conditional use permits for utility- scale wind energy projects within their jurisdiction.

## Study Area

The wind farm siting analysis included in this report has been performed for Linn County, Iowa. Linn County contains approximately 725 square miles of land located in eastern Iowa. This county is home to Cedar Rapids, the second-largest city in Iowa. Other key features of the county include the Cedar River, the Eastern Iowa Airport, and the Grant Wood's "Fall Plowing" Rural Historic Landscape District.

The majority of land in Linn County is unincorporated with assigned zoning districts outlined in the county's Code of Ordinances. According to this ordinance, utility-scale wind farms are only permitted by conditional use in Linn County's agricultural (AG) and critical natural resource (CNR) zoning districts. These zoning districts cover large portions of the county, presenting the likely potential for future utility-scale wind development in Linn County as advances in wind turbine technology make these projects feasible.

## Project Objectives

The wind farm siting analysis presented in this report has two objectives:

**Objective 1***: Identify and analyze the spatial constraints of siting utility-scale wind farms that may influence the development of these projects in Linn County.*

Strategies:

- Identify and analyze regulatory constraints that inherently exclude areas of the county from utility-scale wind projects.
- Identify and analyze suitability constraints that determine whether potential sites are suitable to support wind energy infrastructure.
- Identify and analyze compatibility constraints that determine whether potential sites are compatible with surrounding land use.

**Objective 2***: Provide Linn County administrators the resources to effectively evaluate conditional use permits for utility-scale wind projects as advances in wind energy technology make these projects feasible.*

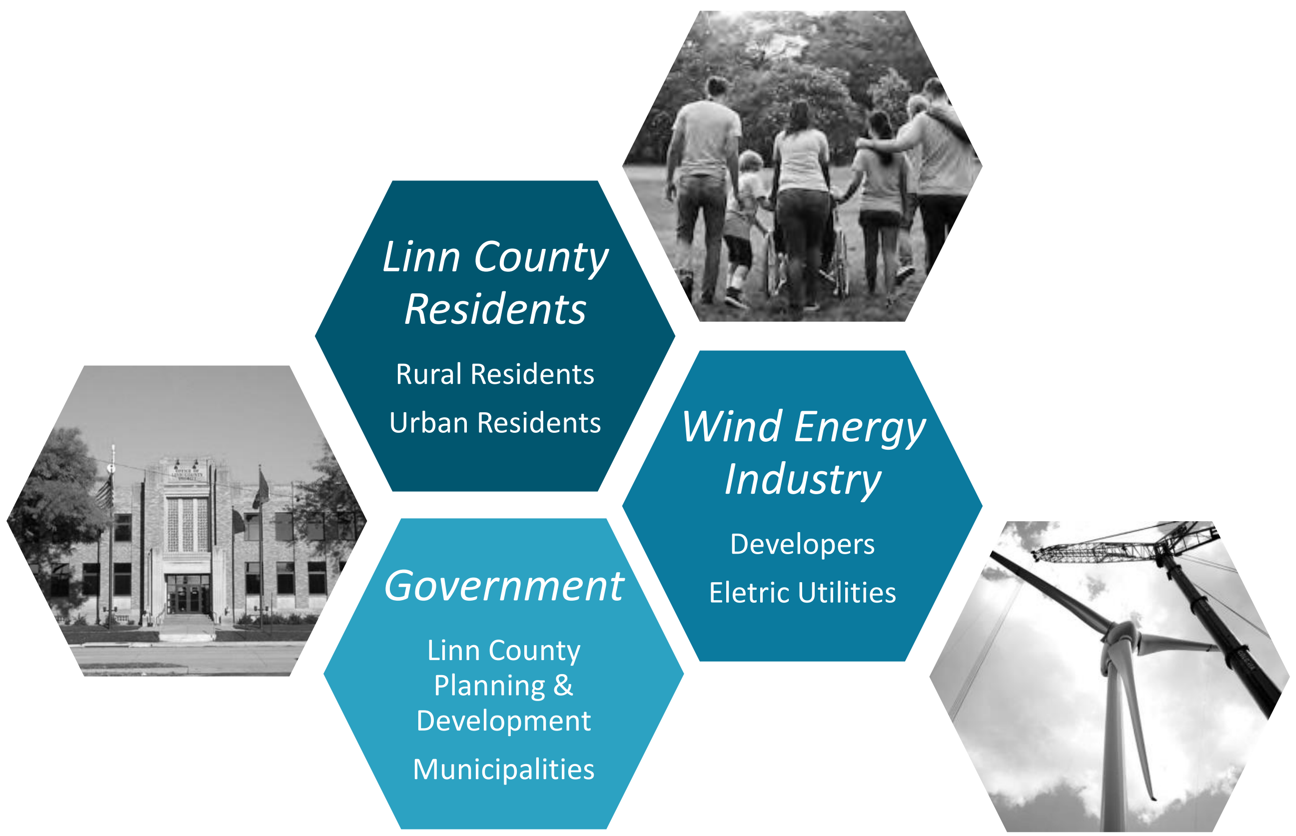
Strategies:

- Provide a set of decision-making matrices that may be integrated into Linn County's current conditional use permit evaluation process.
- Provide a GIS model that may be used and updated by Linn County Planning & Development to analyze the spatial constraints of siting utility-scale wind.
- Provide and summarize the results from a countywide survey examining public attitudes towards utility-scale wind development.
- Provide comprehensive policy research relevant to siting utility-scale wind development.

## Stakeholders

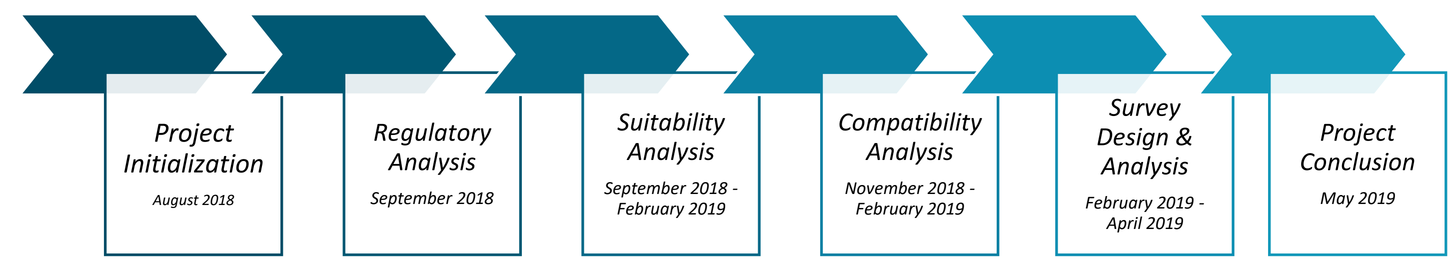
The Linn County Wind Farm Siting Analysis team identified three key groups of community stakeholders to consider when developing utility-scale wind energy projects. These groups are:

- Linn County residents, whether they are in unincorporated or incorporated areas
- Wind energy industry, including developers and electric utility companies like Alliant Energy and MidAmerican Energy
- Government entities on both the municipal and county scale




## Project Schedule

The Linn County Wind Farm Siting Analysis was first initialized in a kick-off meeting with the staff of Linn County Planning and Development on August 14th, 2018. Following this meeting, our team began research and preliminary spatial analysis with a regulatory review. Next, our team conducted suitability and compatibility analyses. In the second half of the project, our team focused on engaging community input through a survey evaluating public attitudes toward utility-scale wind development. The remainder of our project was spent refining the results of our siting research, analyses, and survey to provide Linn County Planning & Development a set of deliverables to improve their conditional use permit evaluation process for utility-scale wind development.



# 1.2 Background

Prior to discussing the methodology behind the Linn County Wind Farm Siting Analysis, it is important to provide relevant background information related to wind energy development. First, this section will discuss the basics of turbine technology and wind energy production. Next, technology and policy trends will be examined on both the national and regional scale. Finally, this section will focus in on Linn County specifically, examining how their comprehensive plan and code of ordinances may influence wind energy development in the county.

## General Wind Energy

There are three categories of wind-based electricity generation: utility-scale wind, distributed or “small” wind, and offshore wind. Utility-scale wind projects, starting from 100 kilowatts (kW), generate electricity for electric utilities or power system operators to distribute to customers through a power grid (American Wind Energy Association n.d.). Distributed or “small” wind projects, below 100 kW, are not connected to a power grid but are used for individual energy consumption (American Wind Energy Association n.d.). Offshore wind projects include wind turbines placed in a body of water, usually on the continental shelf, and are generally larger and more powerful than land-based wind turbines (American Wind Energy Association n.d.).

Wind turbines themselves can be categorized as either horizontal-axis turbines or vertical-axis turbines. Horizontal-axis turbines, as shown in figure 1, are similar to airplane propellers and usually have three blades attached to a horizontal rotor. Vertical-axis turbines, as shown in figure 2, are similar in shape to an egg-beater and have blades attached to the top and bottom of a vertical rotor (U.S. Energy Information Administration (EIA) 2017). The analyses presented in this report only consider horizontal-axis turbines.

The wind energy industry frequently makes use of highly technical, industry-specific language. In particular, the terminology for wind turbines, such as the nacelle, rotor diameter, or hub height, are frequently mentioned. To accustom those unfamiliar with wind energy and wind turbines, the Appendix section Wind Turbine Anatomy provides more detailed information regarding wind turbine anatomy and mechanics.

Wind turbines are classified by the International Electrotechnical Commission (IEC) into classes based on site considerations such as wind speed, gusts, and turbulence (Wiser and Bolinger 2018, 29). Class 3 turbines are designed for low wind speeds (24.6 feet/second or 7.5 meters/second and below), Class 2 turbines for medium wind speeds (up to 27.9 feet/second or 8.5 meters/second), and Class 1 turbines for high wind speeds (up to 32.8 feet/second or 10 meters/second) (Wiser and Bolinger 2018, 29).

*Figure 1: A horizontal-axis turbine.*
*Source: United States Geological Survey*

*Figure 2: A vertical-axis turbine.*
*Source: United States Geological Survey*

## Wind Energy Development

The time range for wind energy development is typically between 3 and 10 years (Costani, et al. 2006). Commercial wind energy projects generally follow 12 steps (Costani, et al. 2006):

- Site Selection
- Land Agreements
- Wind Assessment
- Environmental Review
- Economic Modeling
- Interconnection Studies
- Permitting
- Sales Agreement
- Financing
- Turbine Procurement
- Construction Contracting
- Operations and Maintenance

Interviews with wind energy developers reveal that development may cost between $40-$60/kW and that the average project cost in 2014 was $1,710/kW (Tegen, et al. 2016, 29). The cost of a wind turbine, including transportation, is about 75% of the total installed costs; other costs include grid connection 9%, foundation 6%, and land rent 4% (Ortegon, Nies and Sutherland 2013, 198). The wind turbine tower, rotor blades, and gearbox account for approximately 61% of the total wind turbine cost, including transportation (Ortegon, Nies and Sutherland 2013, 193). Difficulties encountered by wind energy projects have their costs as well: public engagement challenges may increase project costs by as much as 4 times, wildlife studies and research by 4 times, and radar mitigation by 23 times (Tegen, et al. 2016, 29). Generally, a stalled or failed project may increase project costs 2 to 4 times the costs of a successful project (Tegen, et al. 2016, 29).

As shown in figure 3, the area of a utility-scale development that contains the wind farm itself is referred to as the total area. The area that contains any permanent or temporary structures or impermeable surfaces, such as wind turbine pads, access roads, substations, or service buildings, is referred to as the direct impact area (Denholm, et al. 2009, 2).

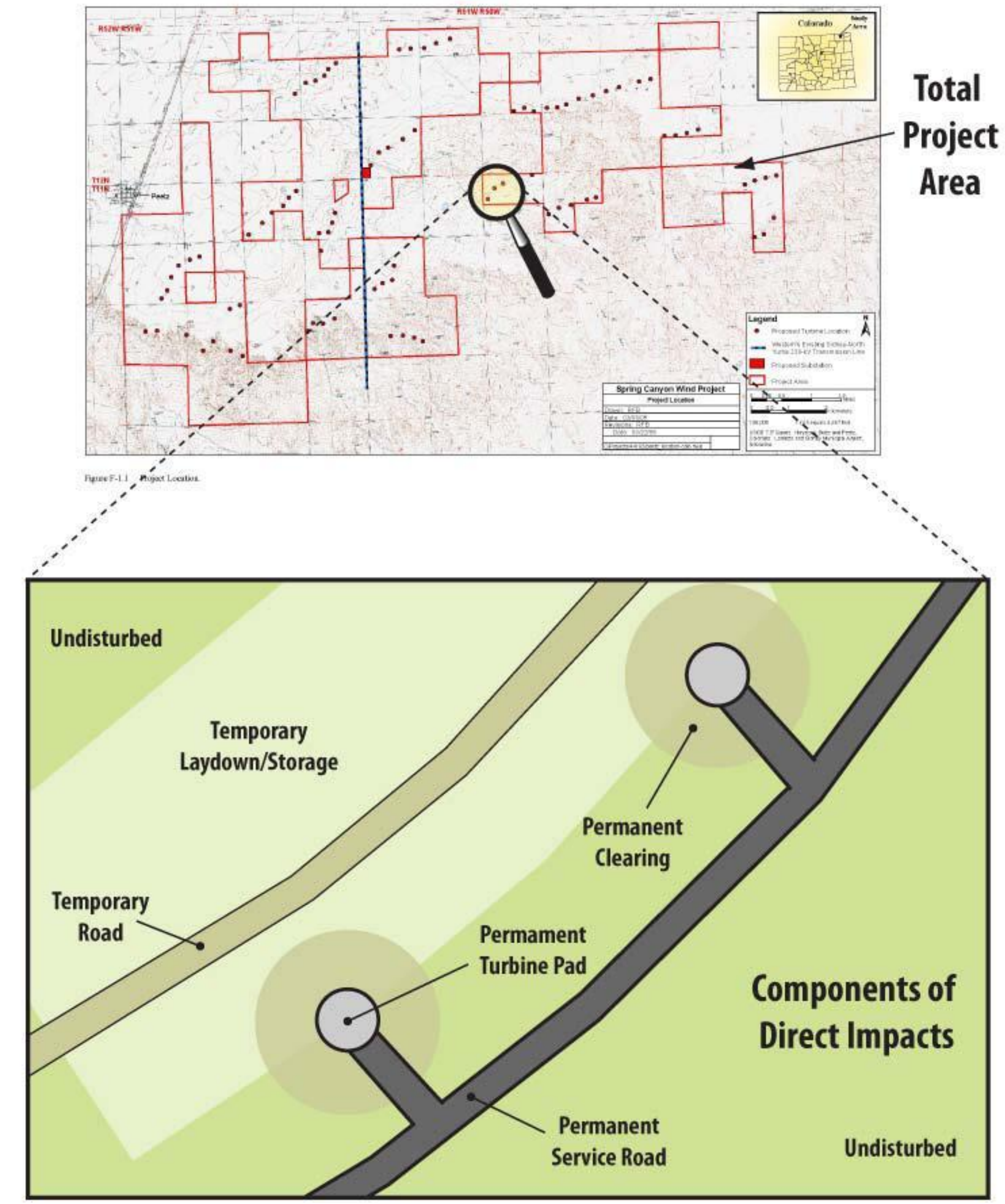



*Figure 3: Illustrations of a wind energy project's total project area and direct impact area.*
*Source: Denholm, et al. 2009*

## National Trends

In 2017, the United States produced 4.01 trillion kilowatt-hours (kWh) in net electricity generation from utility-generators (U.S. Energy Information Administration (EIA) 2018). As shown in figure 4, fossil fuels dominated as the primary source of American electricity in 2017, fueling about 63% of the net electricity generated in the nation. Nuclear energy, by comparison, fueled about 20% of U.S. electricity generation in 2017 while 17% came from renewable energy sources (U.S. Energy Information Administration (EIA) 2018). Of these renewable energy sources, wind energy accounted for 6.3% of the total net electricity generated in the United States in 2017 (U.S. Energy Information Administration (EIA) 2018).

The American electricity market is mainly composed of investor-owned utilities serving residential and commercial customers. There are six types of electricity providers who sell electricity to end-use consumers within the United States: investor-owned utilities account for 51%, power marketers 22%, publicly-owned utilities 14%, and electric cooperatives 11% (U.S. Energy Information Administration (EIA) 2018). In 2017, U.S. net import retail electricity sales to end-use customers were 3,682 billion kWh: 37% of which were to residential, 37% commercial, 26% industrial, and 0.2% transportation (U.S. Energy Information Administration (EIA) 2018).

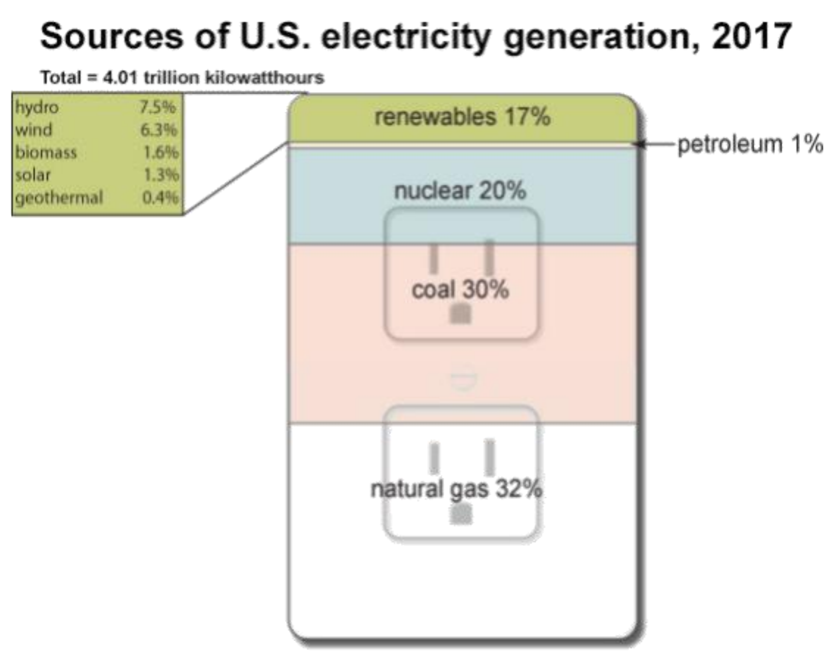



*Figure 4: Sources of U.S. Electricity Generation in 2017*
*Source: U.S. Energy Information Administration*

### Installation and Cost Trends

Globally, the United States currently places second, behind China, in both newly installed wind capacity (7,017 MW installed in 2017; 13% of the new global installed wind capacity in 2017) and cumulative wind capacity (88,973 MW in 2017; 17% of the global wind capacity in 2017) (Wiser and Bolinger 2018, 5). Nationally, wind power comprised 25% of the United States' new energy generation capacity in 2017, ranking as the third-largest source of new energy capacity behind solar and natural gas (Wiser and Bolinger 2018, 4). Advances in new technologies and favorable tax incentives contributed to the recent new wind installations and upgrades of existing turbines (Wiser and Bolinger 2018, 3-4). A distribution of commercial wind turbines by county in 2018 is available in Appendix section Distribution of Commercial Wind in the U.S.

Since 2008, wind turbine prices have experienced a large decline due to increased competition among manufacturers and cost-cutting from turbine and component suppliers (Wiser and Bolinger 2018, 49). Current market data place an average price on wind turbines between $750/kW to $950/kW (Wiser and Bolinger 2018, 49). The Midwest, as part of the Interior Region, has the lowest average project cost of $1,550/kW (Wiser and Bolinger 2018, 52).

Nationally, wind turbines installed in 2017 were generally in areas with lower average wind speeds (a long-term average 80-meter wind speed of 25.3 feet/second or 7.7 meters/second) (Wiser and Bolinger 2018, 31). Federal Aviation Administration (FAA) data on "pending" and "proposed" wind turbines indicate that near-future installations would be situated in similar or slightly better wind resource areas than the 2017 installations (Wiser and Bolinger 2018, 31). These trends appear to be driven by the availability of lower wind-speed turbines with higher hub heights and lower specific power that allow installation in low-wind speed areas to become economically feasible (Wiser and Bolinger 2018, 31). Certain factors, such as siting limitations and regionally different wholesale electricity prices, have shifted attention to projects with access to existing transmission lines, high-priced markets, or sites without a long permit process, even in low-wind resource areas (Wiser and Bolinger 2018, 31). Developers have been taking advantage of a 30% cash grant (or ITC) from 2009 to 2012, which is not dependent on the amount of electricity generated, to develop projects in low-wind resource areas (Wiser and Bolinger 2018, 31).

## Technology Trends

As demonstrated by figure 5, wind turbine technology has advanced remarkably since its advent. In 2017, the average rotor diameter for turbines in the United States was 113 meters, a 4% increase from 2016 and a 135% increase from 1998-1999. The average hub height this same year was 86 meters, a 4% increase from 2016 and a 54% increase since 1998-1999. As turbine design has increased in size, turbine energy generating capacity has increased significantly. The average generating capacity of a newly installed turbine in 2017 was 2.32 MW, an 8% increase from 2016 and 224% increase from 1998-1999 (Wiser and Bolinger 2018). These increases in capacity provide the opportunity for low to average wind resource areas to be ripe for wind energy development.

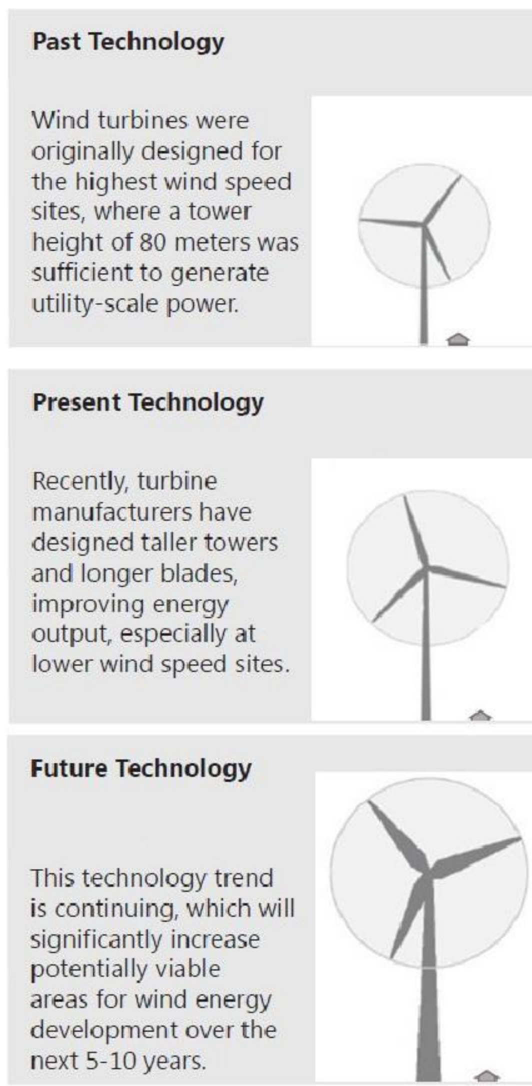



*Figure 5: Technology continues to contribute to taller and larger wind turbines. Adapted from The Northwest Wind Resource & Action Center, 2015*

## Policy and Market Trends

The Production Tax Credit established in 1994 as a part of the Energy Policy Act of 1992 provides a 10-year, inflation-adjusted tax credit that was $24/MWh in 2017 (Wiser and Bolinger 2018, 66). In December 2015, Congress approved a five-year extension through the Consolidated Appropriations Act of 2016 (Wiser and Bolinger 2018, 66). This extension creates a 20% reduction of tax credits for projects starting construction after 2016. Additionally, in 2016, the Internal Revenue Service (IRS) issued Notice 2016-31, which allows four years for project completion after the start of construction without having to demonstrate continuous construction (Wiser and Bolinger 2018, 66). Further federal tax support through tax reform legislation in December 2017 permits both new and old equipment to be fully expensed (100% bonus depreciation) during the year of purchase, though the wind industry has not historically used bonus depreciation (Wiser and Bolinger 2018, 66).

The long-term market trends of electricity net generation presented in figure 6 demonstrate the continued decline of coal sources and increases in both natural gas and renewable energy sources. Figure 7 displays continued increases in electricity consumption by residential and commercial customers as reported by utilities and other energy providers.

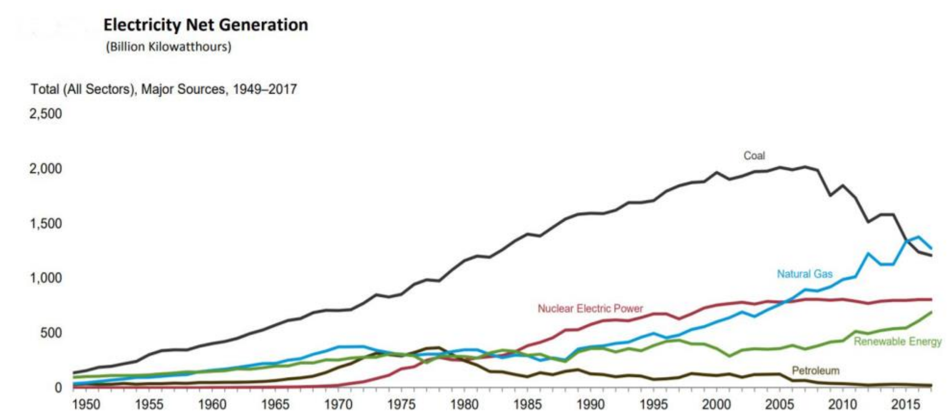



*Figure 6: Electricity net generation by source from 1949 to 2017. Source: U.S. Energy Information Administration, 2018*

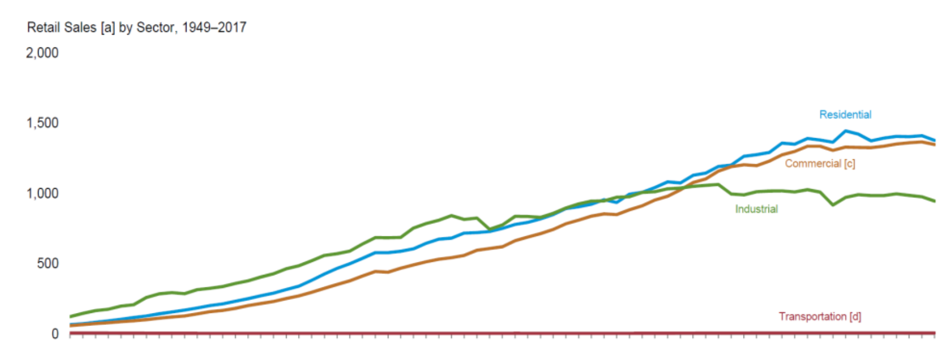



*Figure 7: Change in electricity consumption by sector from 1949 to 2017. Source: U.S. Energy Information Administration, 2018*

## Regional Trends

The state of Iowa currently rates second in the nation for installed wind power capacity. Iowa's relatively robust wind resource and prime location along the electric grid make this state a key player in the wind energy generation industry (Oteri, et al. 2018). Despite having slower wind speeds compared to the rest of the state, eastern Iowa is anticipated to become a stronger candidate for utility-scale wind projects as advances in turbine technology make these projects feasible in locations with low to medium wind speeds.

### Wind Energy Potential in Iowa

Wind energy potential in eastern Iowa is low compared to the rest of the state. As displayed in figure 8, annual average wind speeds at 30 meters in eastern Iowa range from about 4.0 to 7.0 meters per second. As the height of wind speed measurement increases, wind speeds increase as well. This relationship can be observed through the comparison of annual average wind speeds at 30 meters with the annual average wind speeds for the state of Iowa at 80 meters displayed in figure 9. At 80 meters, wind speeds in eastern Iowa are faster, ranging from about 5.5 to 7.5 meters per second. Annual average wind speeds at 80 meters in Linn County range from roughly 6.0 to 7.5 meters per second.

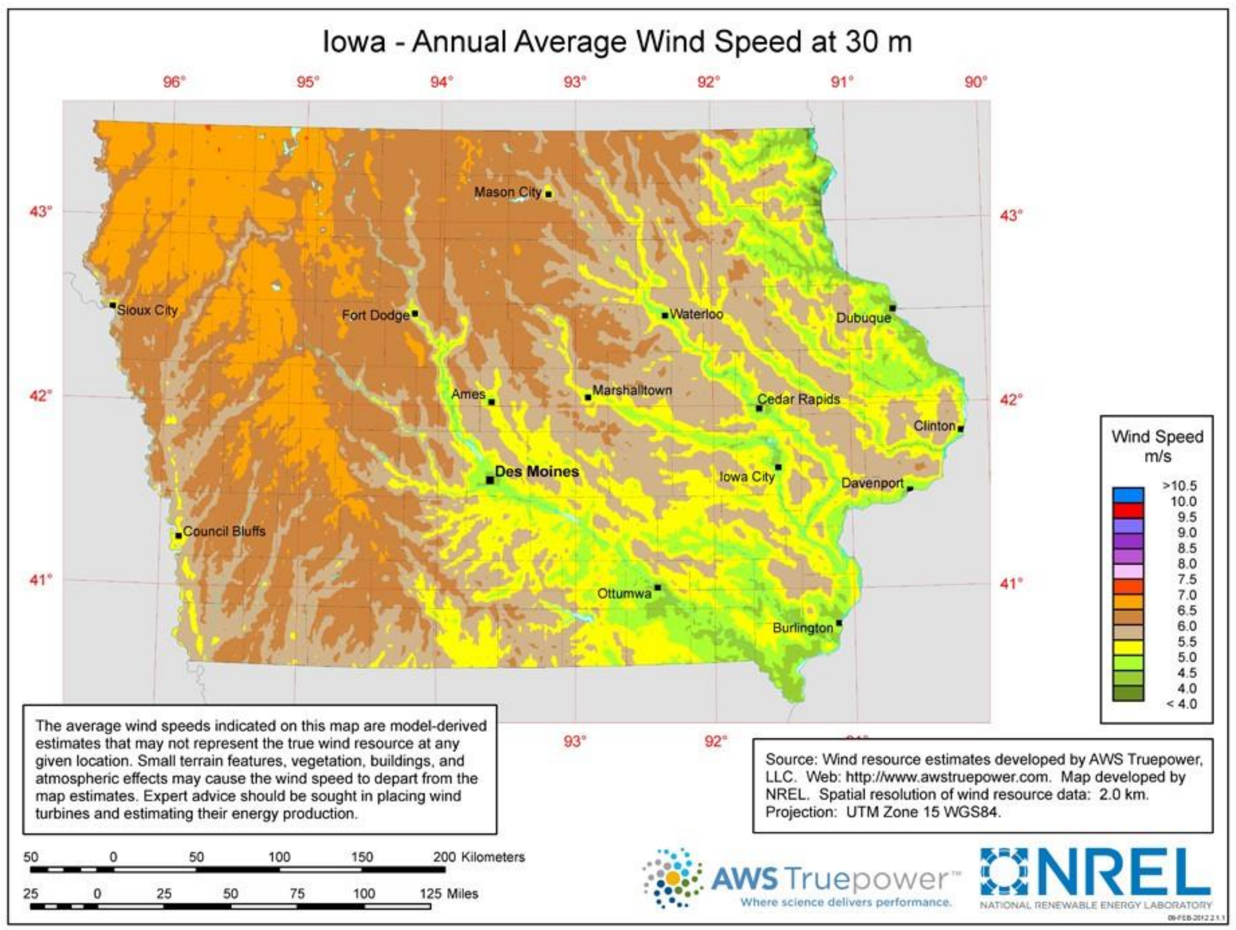



*Figure 8: Annual average wind speeds at 30 meters in Iowa. Source: Office of Energy Efficiency & Renewable Energy*

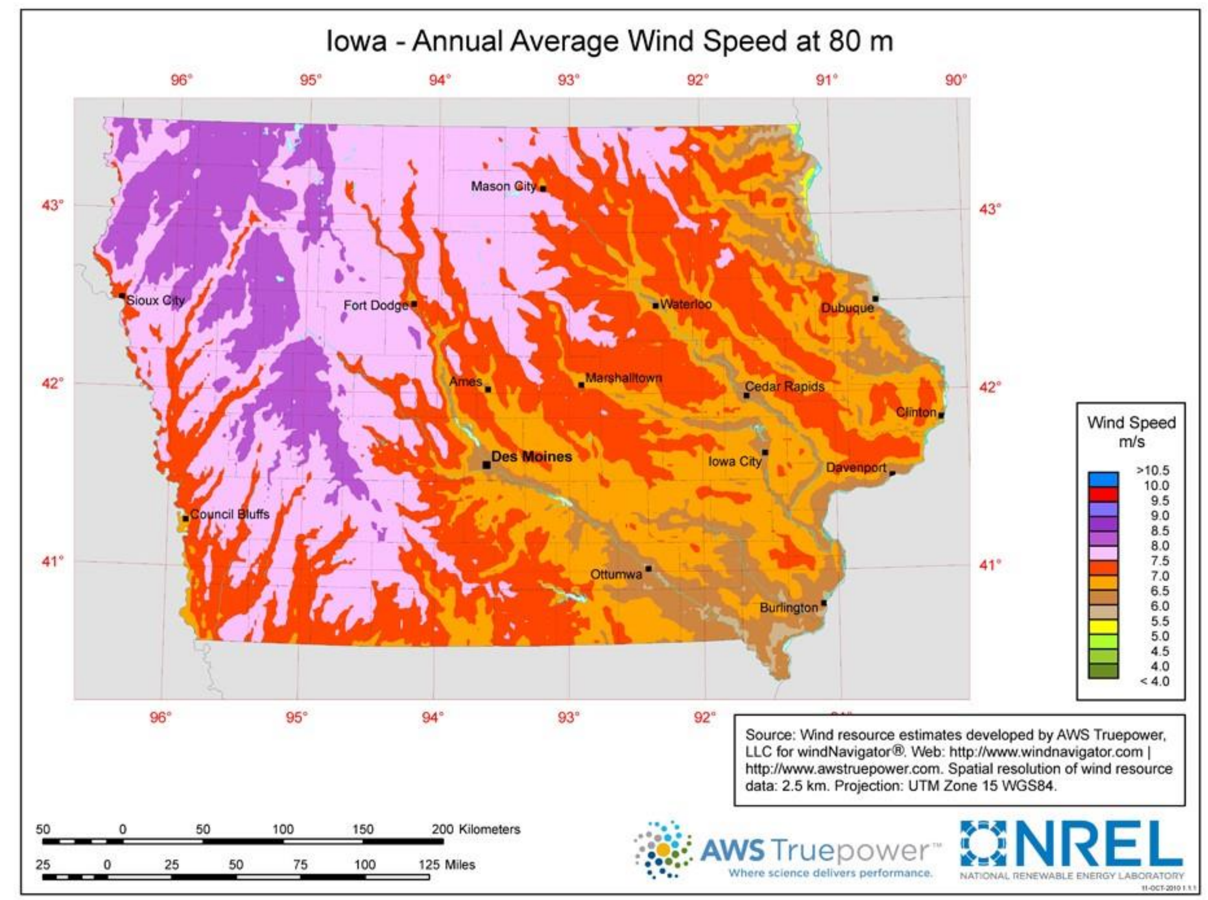



*Figure 9: Annual average wind speeds at 80 meters in Iowa. Source: Office of Energy Efficiency & Renewable Energy*

## Wind Energy Potential in Linn County

Publicly available wind resource data for Linn County is accessible through the National Renewable Energy Laboratory (NREL). This available data, however, is low-resolution and therefore unsuitable for the purpose of the analysis presented in this report. In the interest of obtaining high-resolution wind resource maps specific to Linn County, our planning team has derived wind resource data at three different heights using meteorological data provided by the National Oceanic and Atmospheric Administration (NOAA) and AWS Truepower Openwind software. The results of this process are provided in figures 10-12. These results demonstrate that wind resource in Linn County is highly variable based on both location and elevation. Most importantly, these results prove that Linn County's wind resource at high elevations is suitable for utility-scale wind energy development.

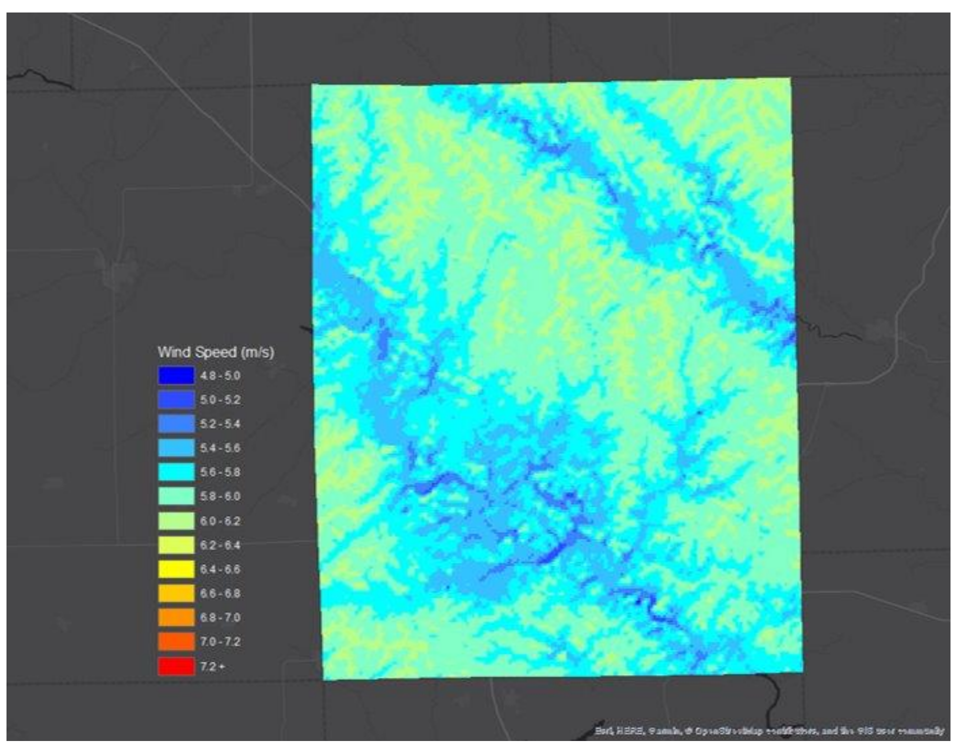



*Figure 10: Wind resource in Linn County at 40 meters*

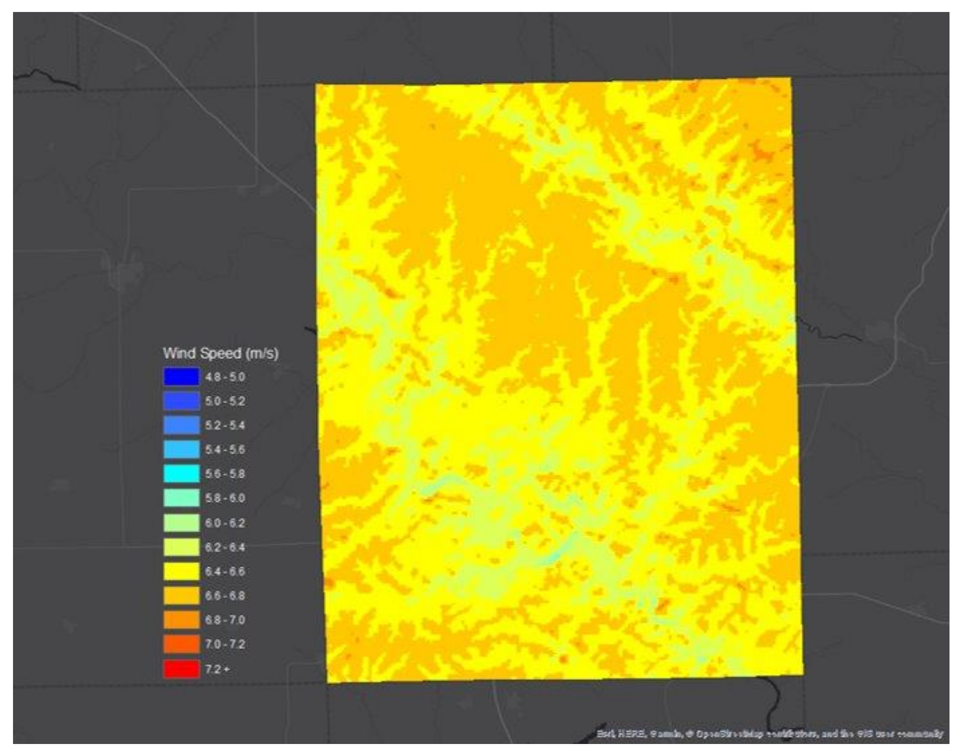



*Figure 11: Wind resource in Linn County at 80 meters*

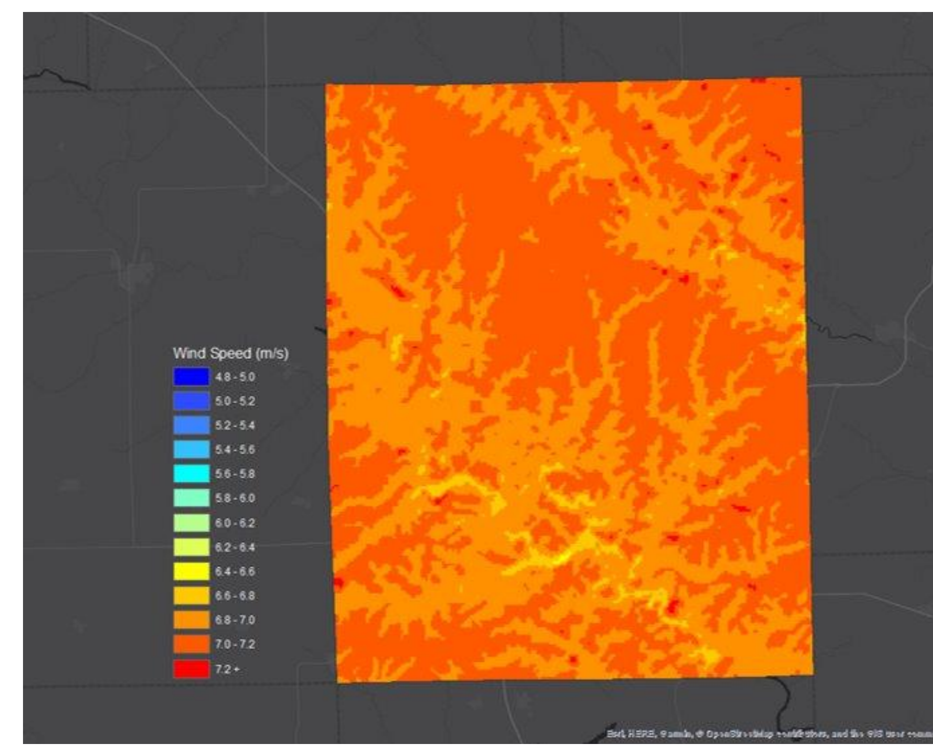



*Figure 12: Wind resource in Linn County at 120 meters*

## Wind Development

As demonstrated by figure 13, the majority of wind energy development in Iowa has occurred in the northwestern portion of the state, as this is where the strongest wind resource is located. Because Eastern Iowa has relatively slow wind energy resource by comparison, taller and stronger turbines are necessary in this region to optimize wind energy generating capacity. Fortunately, advances in wind turbine technology have enhanced wind energy generation potential in slow to medium wind energy resource areas like Eastern Iowa. On average, newly installed wind turbines in Iowa have hub heights of 80 to 100 meters, with the potential to reach up to 125 meters. Larger scale wind projects have already begun to appear in Eastern Iowa, with the majority of wind turbines in this region measuring above 80 meters in height.

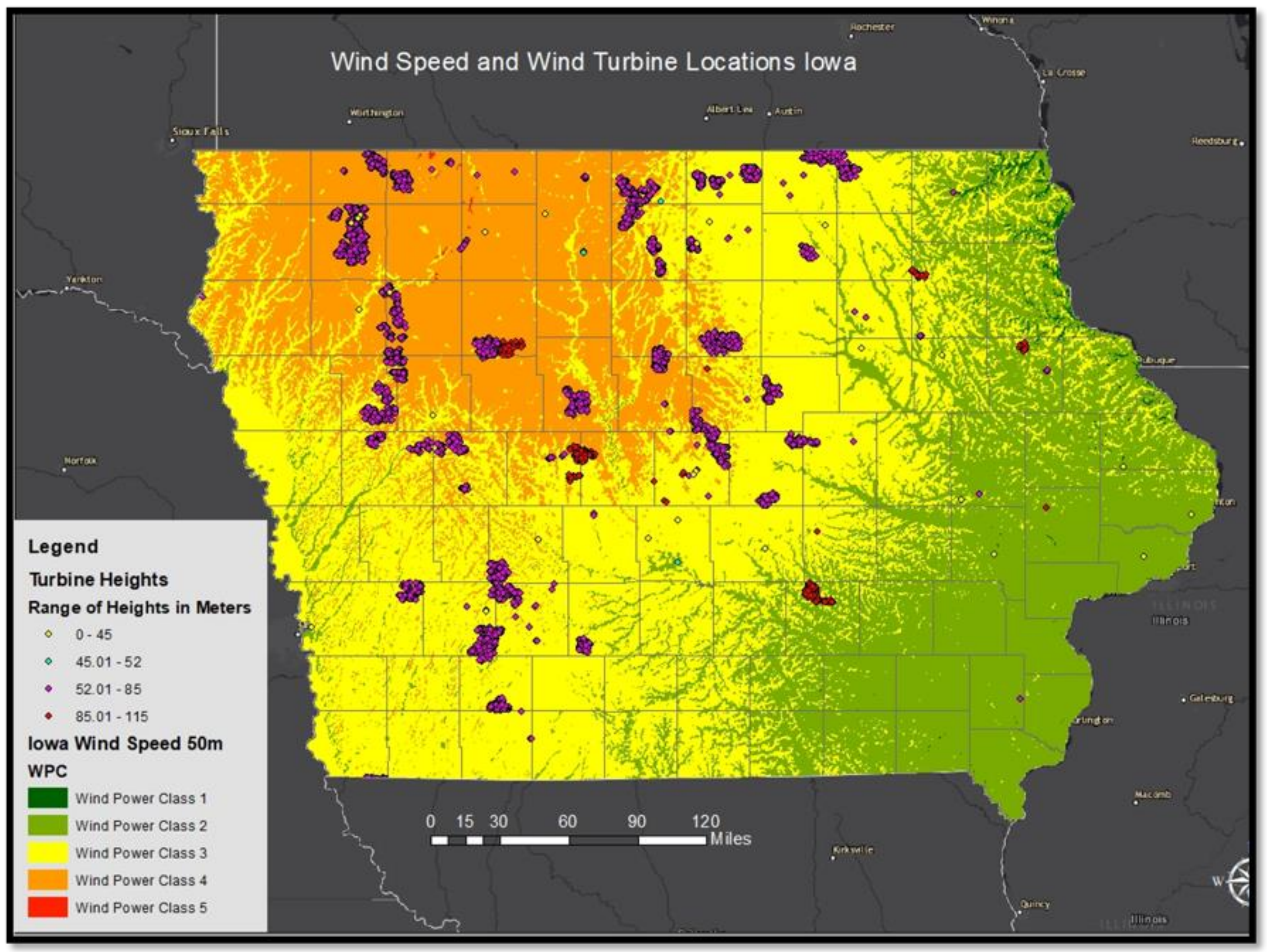



*Figure 13: Turbine heights of wind development in Iowa*

## Policy and Market Trends

In 1983, Iowa became the first state to adopt a renewable portfolio standard by enacting the Alternative Energy Law. This standard requires Iowa's two major utility companies, MidAmerican Energy and Alliant Energy, to own or contract a combined total of 105 MW of renewable generating capacity. To meet these standards, each company has been required to either own renewable energy production facilities located within the state or enter into long-term contracts to purchase electricity from renewable energy production facilities located in the utility's service area. The 105 MW requirement posed under the renewable portfolio was met in 1999 with a total of 242.4 MW of wind power capacity installed in Iowa. Today in 2018, Iowa has reached a total installed wind power capacity of 7,312 MW, ranking second in the nation behind Texas (American Wind Energy Association 2018).

Though both major utility companies in Iowa have already met the requirements under the renewable portfolio standard, MidAmerican Energy and Alliant Energy have since put forward additional goals for renewable generating capacity. In 2016, MidAmerican announced their goal to reach 100% renewable energy production through the investment of $3.6 billion approved by the Iowa Utilities Board (MidAmerican Energy Company n.d.). This investment will be used for Wind XI, a 2,000 MW project anticipated to be completed by the end of 2019. Wind XI is expected to bring MidAmerican's energy production up to 90% renewably sourced energy. A supplementary project, Wind XII, was approved by the Iowa Utilities Board in December of 2018. This project will invest an additional $922 million for 591 MW of installed wind power capacity, ultimately bringing MidAmerican Energy to their goal of 100% renewably sourced energy (MidAmerican Energy News 2018).

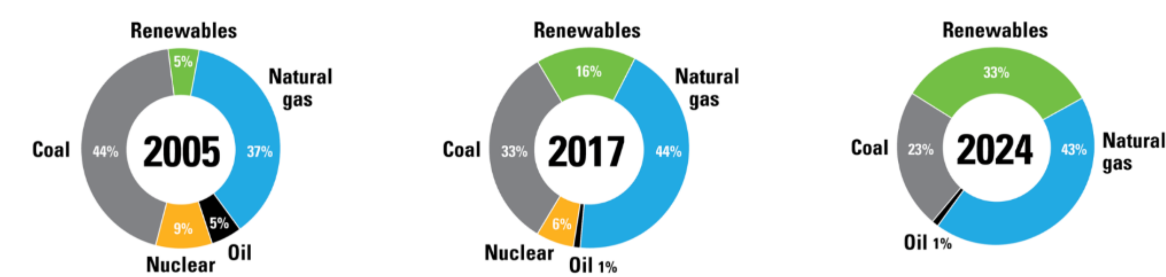



*Figure 14: Alliant Energy's anticipated change in energy mix through 2024*
*Source: Alliant Energy*

Like MidAmerican Energy, Alliant Energy has also set goals to increase renewable generating capacity in the state of Iowa. The company has announced a goal to reach a 30% renewable energy mix by 2024, reducing carbon emissions from fossil-fueled generation by 40%. The company's energy mix resulting from these changes in displayed in Figure 14. By 2050, Alliant will eliminate all existing coal from their energy mix, reducing carbon dioxide emissions by 80%. The primary method by which Alliant hopes to achieve these renewable energy goals is through an increase in wind energy generating capacity. From 2018 to 2020, Alliant will be building up to 1,000 MW of wind energy infrastructure, generating electricity for 430,000 homes in an investment of about $1.8 billion. Upon the completion of this project, Alliant Energy will own and operate approximately 1,299 megawatts of wind generation in Iowa (Alliant Energy n.d.).

## Linn County Comprehensive Plan

Linn County's Comprehensive Plan, *A Smarter Course: Building on the Past, Embracing the Future of Rural Linn County* is organized into seven plan elements, the first of which is Alternative and Renewable Energy (Linn County Planning and Development 2013). Wind is the first alternative and renewable energy source listed within the definition of this plan element. This section states that, "planning for increased use of alternative and renewable energy sources and improved energy efficiency requires an understanding of the size and location of unused local energy resources" (Linn County Planning and Development 2013, 8). This need is one of the many this document intends to meet.

One of the key components, defined as the essential aspects underlying the plan elements, of the Alternative and Renewable Energy element is "Utility Scale Renewable Energy" (Linn County Planning and Development 2013, 8). The Linn County Wind Farm Siting Analysis presented in this report is focused specifically on renewable (wind) energy on the utility scale and is intended to provide the Linn County Department of Planning and Development with site-specific research and analysis to aid in their efforts to "encourage and support the development and use of alternative and renewable energy resources," (Linn County Planning and Development 2013, 9) which is one of the stated goals of this plan element. A stated objective underpinning this goal is to "increase the use of alternative and renewable energy resources in the county." (Linn County Planning and Development 2013, 9) This document works toward fulfilling this objective for Linn County by determining the county's most compatible locations for siting utility scale wind farms, a step necessary in increasing the use of wind as a renewable energy resource.

The second plan element of *A Smarter Course* is Economic Development. Objective 2.6 within this plan objective is to "encourage and support renewable energy production, including all related support businesses" (Linn County Planning and Development 2013, 15). Wind energy as a form of renewable energy production is explicitly mentioned in Linn County' comprehensive plan, and this analysis provides the planning staff with the ability to directly meet this objective. By displaying the compatibility of certain areas in Linn County for siting utility scale wind farms, the siting analysis provides a reference for county planners to encourage this form of renewable energy production only in the areas determined to be the most suitable.

## Conditional Use Permit Evaluation Process

Utility-scale wind development is permitted by conditional use in Linn County in Agricultural (AG) and Critical Natural Resources (CNR) zoning districts. The criteria and procedural requirements of Linn County's conditional use permit process are outlined in section 107-73 of the county's unified development code.

Upon receipt of a complete application for a utility-scale wind development, planning and development staff forward the application to the technical review committee. This committee is to then review the application for conformance to the unified development code, the comprehensive plan, regulations, and design standards. The committee will create a report based on their findings, which is mailed to the applicant, and submitted to the planning and zoning commission and the board of adjustment. At this point, the applicant may disagree with committee recommendations and request further review. In this case, additional review shall be conducted by the board, agency, or commission responsible for the technical review committee itself.

Based on the technical review committee's findings, the planning and zoning commission will forward a written report of their own conclusions and recommendations to the board of adjustment. The board of adjustment is then to conduct a public hearing for the application. Within 45 days of the public hearing, the board must decide whether to approve or deny the application. While deliberating, the board of adjustment shall consider each of the following standards for review:

- Does the proposed use conform to the comprehensive plan?
- Is the site suitable for the proposed use?
- Is the proposed use compatible with surrounding property use?
- Is the adjoining road system adequate to accommodate the proposed use in terms of the present traffic volume versus road capacity and the general condition of the road system?
- Can adequate measures be taken to minimize any potential adverse impacts on adjoining property?

As previously discussed, Linn County's comprehensive plan states the intention to increase the use of alternative and renewable energy resources in the county. Determining whether a utility-scale wind development is suitable or compatible at a given site, however, may be difficult to ascertain without further research and review. For this reason, the siting analysis presented in this report intends to provide the county with the necessary background to make informed decisions regarding site suitability and compatibility when reviewing conditional use permit applications for utility-scale wind projects.

# 1.3 Summary

The intention of the Linn County Wind Farm Siting Analysis presented in this report is to provide Linn County Planning and Development with a set of informed guidelines to encourage the optimal siting of utility-scale wind projects in Linn County. As per the county's comprehensive plan, Linn County encourages an increase in alternative and renewable energy resources including utility-scale renewable infrastructure. As wind energy market and technology trends advance utility-scale wind development into eastern Iowa, the county's ability to prepare for the siting of these projects has become imperative.

This analysis will begin by identifying and analyzing the spatial constraints of utility-scale wind farm development as these constraints relate to Linn County. The next section of this report, titled "Methodology & Analysis", identifies these siting constraints and presents the methods by which these constraints can be spatially analyzed.

# 2 Methodology & Analysis

## 2.1 Overview

This project performed three phases of spatial analyses to determine optimal sites for utility-scale wind turbines in Linn County. These three phases of spatial analysis were determined by consulting Linn County's current review process for conditional use permits. First in phase one, our project examined only areas where applications of utility-scale wind energy systems are already permitted. Second, following Linn County's conditional use permit review process, suitability considerations were evaluated. Lastly, compatibility considerations were evaluated in phase three.

## 2.2 Identification of Siting Factors

The project's spatial analyses were conducted using ArcMap v.10.6 GIS software. The following subsections describe the variables included in the analyses, the justification for their inclusion, and the data sources. The results of each stage of analysis are presented in Section 3 entitled "Analysis" and the specific transformations performed are contained within the Multi-Criteria Decision Support System, the python scripts of which are provided in Appendix section Multi-Criteria Decision Support System – Model Scripts.

### Regulatory

The first phase of spatial analysis is based on regulatory factors that may immediately exclude an area from a wind development project. For the purpose of this analysis, it is assumed that wind developers would proceed to develop only on sites where they are permitted as-of-right to avoid the costs of seeking regulatory exemptions. This initial phase of analysis considers two exclusionary factors found within the Linn County Code of Ordinances – zoning districts wherein utility-scale wind turbines are allowed conditionally and ordinance standards.

#### Zoning Districts

As per Table 107-147-1 of the Linn County Development Code, utility-scale wind farms are allowed as a conditional use only within the Agricultural (AG) or Critical Natural Resources (CNR) zoning districts. The first step of the analysis was to remove all parcels in Linn County that fall outside of the AG or CNR zoning districts. The Rural Zoning shapefile was downloaded from the Linn County Open Data Portal (Linn County Iowa GIS Open Data Portal 2017).

#### Ordinance Standards

Item 3 of Section 107-117 – "Standards for transportation and utility uses" in the Linn County Code of Ordinances specifies that all wind farm structures must meet the most restrictive of five provisions listed. The first provision is that all wind farm structures must be setback at least 100 feet from property lines. The second provision is that they must be separated from a residential structure on adjoining property by at least 1,000 feet. The remaining three provisions listed are dependent upon the specific height of the tower. For this phase of the analysis, our team reasoned that by buffering both property lines and residential structures by their respective setback requirements, the buffers would represent land where wind farms are prohibited uniformly for all wind farm projects, regardless of size or specifications. The Linn County Planning and Development staff provided our team with a shapefile consisting of all residential structures in Linn County with the required 1,000-foot buffer already applied, and the Parcel Ownership shapefile was downloaded from the Linn County Open Data Portal (Linn County Iowa GIS Open Data Portal 2018).

### Suitability

The second phase of spatial analysis is based on suitability factors. These factors determine whether potential sites are physically suitable to support utility-scale wind infrastructure. This second phase considers topographic conditions, distance to electric transmission lines, wind resource potential, and proximity to major transportation lines.

#### Wind Resource

The wind resource of an area is a chief concern when determining suitability of potential wind farm locations. Of the six wind energy development studies reviewed by a 2014 article, all six took into account wind potential as a factor in their analysis (Miller and Li 2014, 970). Although emerging wind turbine technology is allowing turbine placement in areas with weaker wind speeds, wind resource is still an important consideration as "projects sited in higher wind speed areas generally realized higher capacity factors" (Office of Energy Efficiency & Renewable Energy 2017, 43). Wind resource maps were generated using AWS Truepower Openwind software and were at a much higher resolution than any wind resource maps publicly available for the study area. For the purposes of the spatial analysis, the wind resource maps were classified into high, medium, and low categories in order to be implemented into the GIS model.

#### Grid Proximity

Distance from transmission lines, or the electricity grid, has been shown to be another important factor when determining the suitability of wind farm placement as increased proximity reduces the cost of building new transmission lines (Baban and Parry 2001). Wind turbines may be connected to either 115, 230, or 345 kV lines (Taylor and Parsons 2009). The research indicated a lack of consensus in specific cut-offs regarding how close to transmission lines wind developments should be, but generally the nearer the better. A shapefile containing the locations of all transmission lines was downloaded from Homeland Infrastructure Foundation-Level Data (jrayer_geoplatform 2018).

### Transportation Infrastructure

The Minnesota Department of Transportation recommends that local transportation authorities compile information regarding bridges and roads within their jurisdiction and be prepared to share them with any wind energy developers (Minnesota Department of Transportation Research Services Section 2010). The transportation of heavy vehicles and loads over road and bridge infrastructure places additional stress that may not have been accounted for during their design. Therefore, a review of Linn County's road and bridge infrastructure was conducted for any potential wind energy developments.

Data on the bridge and road network within Linn County was obtained from the Iowa Department of Transportation (Iowa Department of Transportation 2018). For bridges, the Federal Highway Administration's operating rating, or capacity rating, was used (U.S. Department of Transportation Federal Highway Administration 1995). For roads, the Iowa Department of Transportation and Linn County Secondary Road Department limits the maximum vehicular weight to 156,000 pounds or 70.8 metric tons and the maximum vehicular height to 15 feet and 5 inches or 4.7 meters, according to their "Annual Oversize/Overweight Permit Application (Iowa Department of Transportation and Linn County Secondary Road Department n.d.). In their "Annual Oversize Permit Application", the maximum total weight is set to 80,000 pounds or 36.3 metric tons (Iowa Department of Transportation and Linn County Secondary Road Department n.d.). Iowa DOT's listing of bridge embargoes were also incorporated, though the only one in Linn County was within the City of Cedar Rapids (Iowa Department of Transportation n.d.). The "Surface Type" attribute from the road network dataset was used to classify roads into either the hard surface roads category, roads composed of bitumen, concrete, or asphalt, or the soft surface roads category, roads composed of earth, gravel, stone, or brick (Linn County Iowa GIS Open Data Portal 2017). Since softer surface roads are more prone to damage, the binary categorization into hard and soft surfaces provide a convenient, initial means of assessing susceptibility to road damage. The Linn County Land Records Data File Geodatabase provided the other elements such as municipalities, county boundary, and railroads (Linn County Iowa GIS Open Data Portal 2017).

Multi-factor wind-development siting analyses similar to the Linn County siting analysis use proximity to major transportation links as a factor (Hofer 2016). For the overall spatial analysis, this factor was used and integrated into the GIS model. Railroad lines and major roads (interstates, state highways, U.S. highways, and U.S. business highways) were combined and areas nearer these major transportation lines were deemed higher suitability. The railroad data was acquired from the Iowa DOT open data site (Iowa Department of Transportation 2018) and the road centerline data from the Linn County Open Data portal (Linn County GIS Open Data 2017).

### Slope

Slope is a necessary criterion as it affects ease of wind turbine construction and maintenance, with steeper slopes being less ideal (Tegou, Polatidis and Haralambopoulos 2010). Although this is not a major concern for this particular project due to Linn County's generally flat topography, there are still some areas that surpass the ideal slope steepness of 7 degrees or greater. Slope data was derived in GIS through the conversion of elevation contour lines retrieved from the Linn County Open Data site (Linn County Iowa GIS Open Data Portal 2017).

### Karst Presence

Karst is an area of land particularly susceptible to erosion due to its concentration of highly soluble rock (DNR, Iowa 2018). Because of this, Karst risk is a factor commonly addressed in wind farm siting as it can lead to "wind turbine tilting and even toppling" (Bangsund and Johnson, Evaluating Karst Risk at Proposed Windpower Projects 2013, 27). This data was downloaded from the Iowa Geodata site (DNR, Iowa 2018).

Karst formations may be a concern to the structural stability of wind turbines and should be evaluated as early in a wind energy project as possible. Karst may result in wind turbines tilting or toppling (Bangsund and Johnson 2013, Johnson, Bangsund and Hines 2013). Even minute differential settlement of 1.18 inches (3 centimeters) across a 49.2 feet (15 meters) wide wind turbine foundation may require attention (Bangsund and Johnson 2013, Johnson, Bangsund and Hines 2013).

## Compatibility

The third phase of spatial analysis is based on compatibility factors, mainly from the perspective of Linn County decision makers and residents. These factors determine whether a proposed wind farm project would be compatible with surrounding land uses. This final phase considers land use factors, visually sensitive areas, noise concerns, potential shadow flicker, ecological concerns such as wetlands and wildlife, and incorporates public input.

### Land Use

In conjunction with zoning districts, Linn County also categorizes its land using a Future Land Use Classification. Of the six classifications, the Agricultural Area (AA) has been deemed the most suitable for wind farm siting as the other classifications represent critical natural resource areas or what essentially amounts to future growth areas. These future growth areas are not ideal for utility-scale wind farms due to their close proximity to municipalities; however, their underlying zoning districts of AG or CNR permit wind farm development applications. Rather than exclude these areas outright, any area with a Future Land Use Classification as anything other than AA has been determined to have low suitability. The Rural Zoning shapefile downloaded in the first stage of the analysis also contained Future Land Use Classifications, and all parcels not classified as AA were symbolized as having low compatibility.

Four municipalities in Linn County have adopted a City / County Strategic Growth (CCSG) Plan and Agreement with the county, which serves as a "coordinated guide for continued planning and development in order to manage growth" (ECICOG, Linn County, and Springville 2003). These agreements function as fringe area agreements, so conditional use permit applications for sites that fall within two-miles of these municipalities require the review of both the county and municipality staff. Therefore, anywhere within these two-mile buffers was deemed as a low compatibility area. To derive these buffers, a shapefile was first downloaded from the 2018 TIGER/Line shapefiles containing the locations of all areas categorized as "places" by the U.S. Census Bureau (U.S. Census Bureau 2018). Then the four cities in Linn County with CCSG agreements, those being Palo, Springville, Bertram, and Ely, were selected and exported to their own feature class.

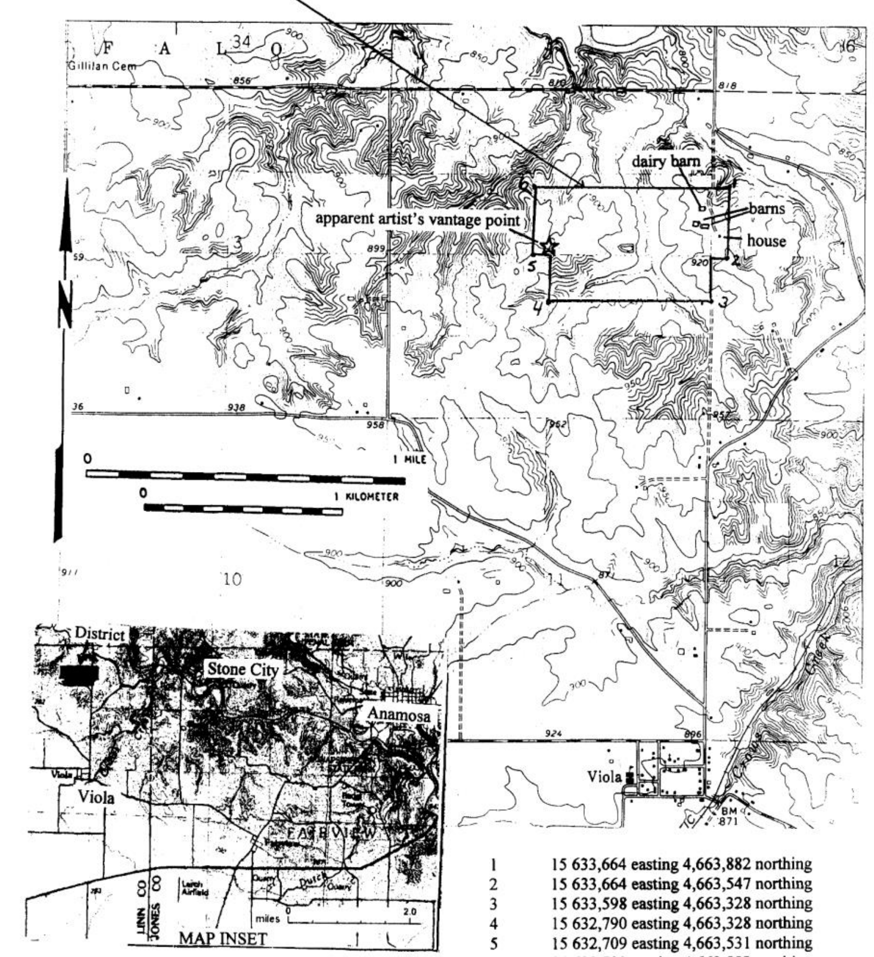
## Airport Proximity

The Federal Aviation Association (FAA) requires notice be filed for any construction greater than 200 feet in height or exceeding certain angles within 20,000 feet of airport runways (Federal Aviation Administration n.d.). Even though the construction of most wind farms will require an FAA evaluation regardless, a number of wind farm siting analyses apply a 20,000-foot buffer around all airports within the study area to determine compatibility (Tegou, Polatidis and Haralambopoulos 2010) (Miller and Li 2014).

A dataset showing locations of all airports in the country was downloaded from the FAA's Open Data website (Federal Aviation Administration 2018). Cleaning the data to remove a private airstrip north of Center Point and a closed airfield outside of Robins, only the Eastern Iowa Airport and the Marion Airport remained. Using ArcMap's Buffer tool, a buffer of 20,000 feet was applied to these two airports, with any area falling within the buffers being rated as having low compatibility.

## Visually Sensitive Areas

A visually sensitive site in the study area was identified by Linn County staff as Grant Wood's "Fall Plowing" Rural Historic Landscape District. As shown in figure 15, this 123-acre area on the National Register of Historic Places is located in the northwest corner of Linn County. The landscape district is depicted in Grant Wood's 1931 "Fall Plowing" painting and the east-facing viewshed still in existence and recognizable today was deemed by Linn County staff as important to protect from the visual intrusion of wind development. Because the viewshed of concern is east-facing, only the area to the east of the historic landscape district was deemed as having low compatibility. The shapefile for the protected district was retrieved from a shapefile of National Register of Historic Places Cultural Resources downloaded from the ArcGIS website (Matt Stutts 2017).


NPS Form 10-900-a
OMB Approval No. 1024-0018
United States Department of the Interior
National Park Service

National Register of Historic Places
Continuation Sheet
Additional
Section number Documentation Page 16

Grant Wood's "Fall Plowing"
Rural Historic Landscape District
Linn County, IA



| | |
|---|---|
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| 2 | 15 633,664 easting 4,663,547 northing |
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| 5 | 15 632,709 easting 4,663,531 northing |
| 6 | 15 632,709 easting 4,663,882 northing |

*Figure 15: The Grant Wood's "Fall Plowing" Rural Historic Landscape District*
*Source: United States Department of the Interior*

## Noise

The potential for noise resulting from wind energy generation is a common concern of those already uncertain about the compatibility of wind development. As shown in figure 16, the perceived level of noise resulting from a wind turbine is a direct function of distance from the turbine. The Iowa Environmental Council recommends a decibel standard of no lower than 50 dB for residential properties (Baer, Kernek and Johannsen 2018). One report recommended a planning guideline of 40 dB as an ideal design goal and 45 dB as an appropriate regulatory limit (Stanton 2012).

Using AWS Truepower Openwind software, noise impacts resulting from 40 meter, 80 meter, and 120 meter wind turbine operation were modeled in Linn County. The outputs of this model demonstrated that these noise impacts were relatively the same at each elevation. The results were filtered based on decibel level to create a buffer containing noise impacts greater than 45dB. This buffer, measuring about 0.1 miles from an operating turbine of any height, is considered a zone of significant impact. Because this buffer is entirely contained within the 1,000-foot setback required by the Linn County unified development code, noise impacts will not be included within this analysis.

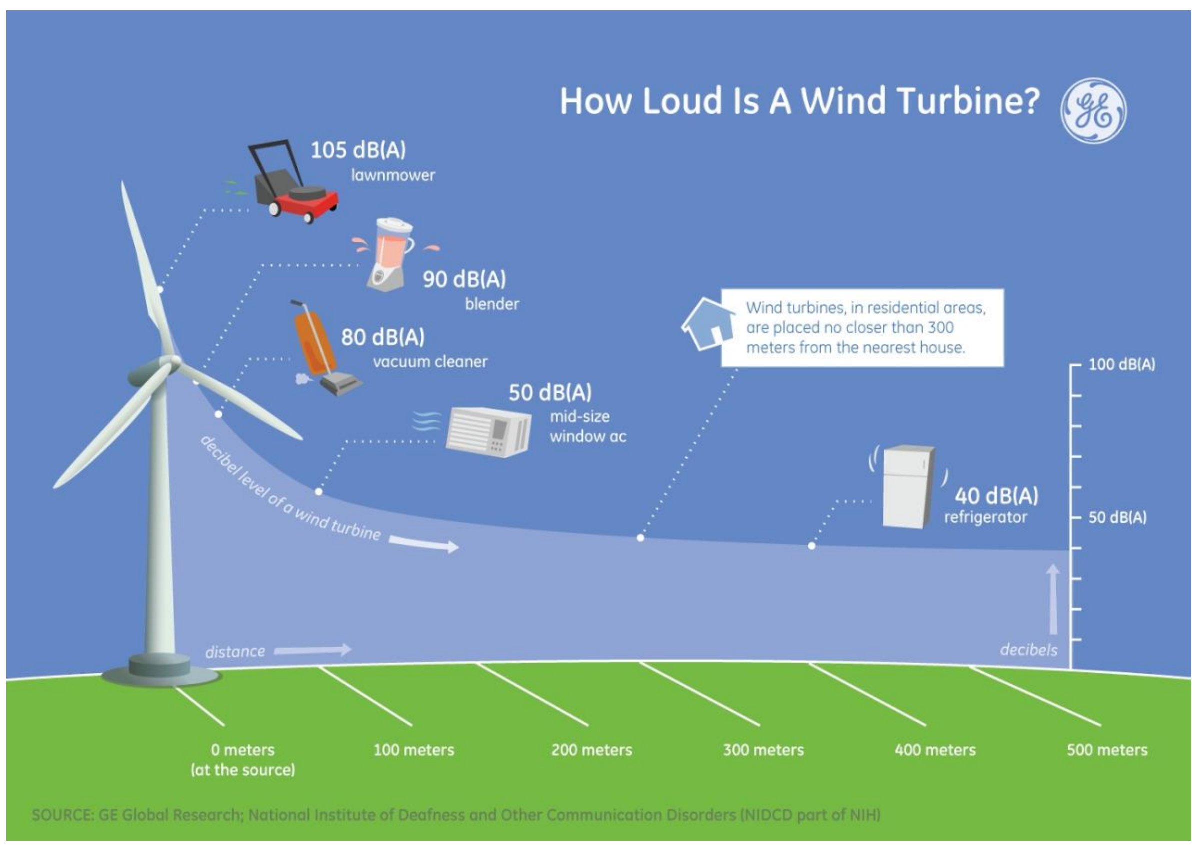



*Figure 16: Sound levels resulting from wind turbines Source: GE Global Research*

## Shadow Flicker

Shadow flicker is the effect of the sun shining through the rotating blades of a wind turbine, creating a moving shadow. As shown in figure 17, these impacts are limited to a butterfly-shaped zone surrounding a wind turbine. Shadow flicker caused by wind turbines do not pose a significant risk to health (Parsons Brinckerhoff 2011, Australian Government National Health and Medical Research Council 2010), though may be considered an annoyance to neighbors. Significant impact levels of shadow flicker are commonly defined as more than 30 hours per year on abutting residences (Priestly, Allen and Lampeter 2011).

Using AWS Truepower Openwind software, shadow flicker impacts resulting from 40 meter, 80 meter, and 120 meter wind turbine operation were modeled in Linn County. Similar to noise, the model outputs demonstrated that these shadow flicker impacts were relatively the same at each elevation. The results were filtered based on shadow flicker level to create a buffer containing impacts greater than 30 hours per year. This buffer, measuring about 0.7 miles from an operating turbine of any height, is considered a zone of significant impact. Because the density of residential development within this zone will be site-specific, shadow flicker cannot be adequately included within this analysis. For more information regarding best management practices to mitigate shadow flicker impacts, reference the policy research provided in section 3.4.

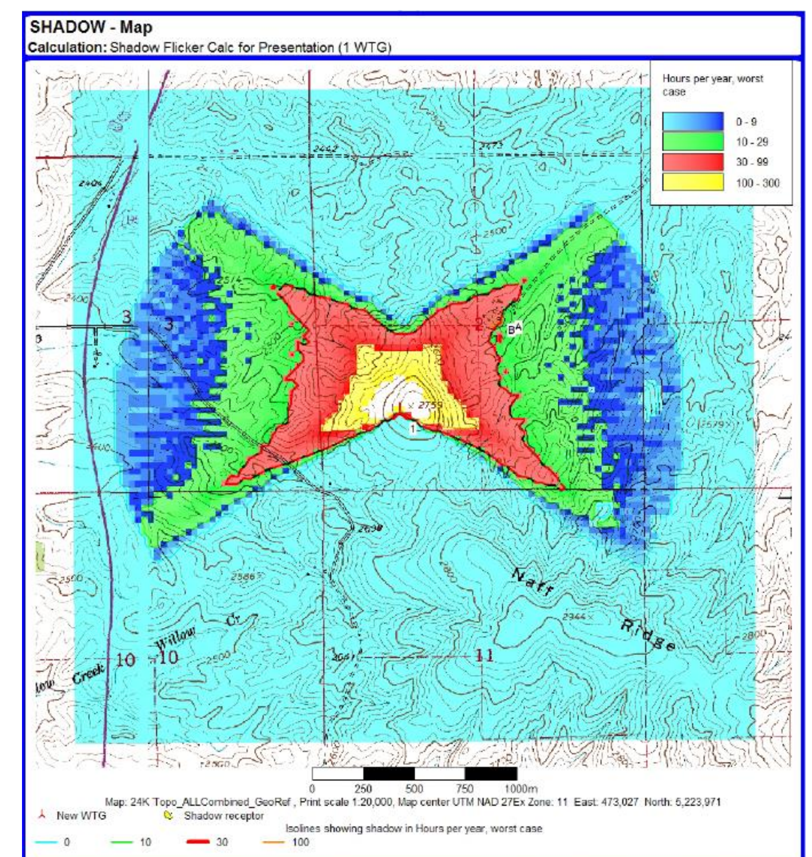



*Figure 17: Shadow flicker impacts from wind turbines*
*Source: Priestly, Allen, and Lampeter, 2011*

## Bird and Bat Migration

The potential for wind projects to have negative impacts on wildlife is another common concern of those uncertain about the compatibility of utility-scale wind development. Bird and bat species are of particular concern, as their flight patterns make them vulnerable to turbine collision and fatalities. For this reason, it is generally recommended that wind turbines not be placed within migratory corridors, especially those of endangered or threatened species. A map of major bird corridors in Iowa is provided in figure 18. According to the U.S. Fish and Wildlife Service (USFWS), there are no threatened or endangered bird species in Linn County. Two bat species, the threatened Northern Long-eared Bat and the endangered Indiana Bat, are listed by USFWS as species that likely inhabit Linn County.

Due to data limitations, our planning team was not able to include bird corridors and bat habitats within this siting analysis. While the USFWS does have spatial data of both bird corridors and bat habitats, this data is not made publicly available and was therefore inaccessible. In the event that staff is able to gain access to this data, it is recommended that corridors and protected habitats be deemed low compatibility for utility-scale wind development. For more information regarding best management practices to mitigate negative impacts to wildlife, reference the policy research provided in section 3.4.

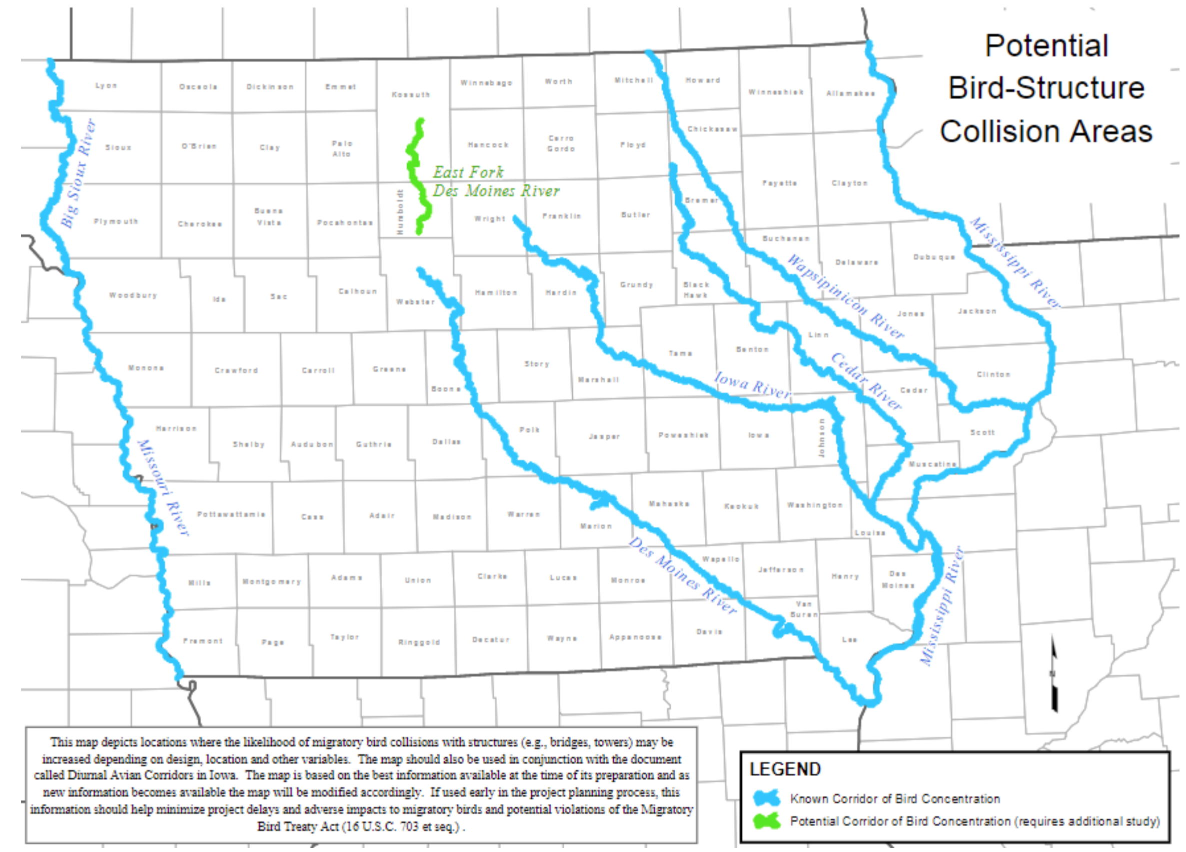



*Figure 18: Known corridors of bird concentration in Iowa*
*Source: U.S. Fish and Wildlife Service*

# 2.3 Spatial Analysis of Siting Factors

The spatial analyses concerning regulatory, suitability, and compatibility dimensions from the chapter above are reported in the following sections. The data sources are listed as well as the transformations performed. First, the results of the spatial analyses for the regulatory phase will be reviewed, then the suitability phase, and finally the compatibility phase.

## Regulatory

1. ### Ordinance Standards

To generate the necessary 100-foot property line setback, it was first necessary to merge all contiguous parcels under the same ownership and subsequently apply a -100-foot buffer from the joined property lines. The mandatory 1,000-foot setback from residential structures is symbolized in map 1 to the right, and this area was erased from the remaining parcels.

2. ### Zoning Districts

Map 2 on the right shows all rural property zoned either AG or CNR, the only zoning district where utility-scale wind farms are allowed to be sited. The parcel line setbacks and the residential property setbacks were removed from this layer, and the output map on the next page shows the area in Linn County that satisfy all regulatory constraints.

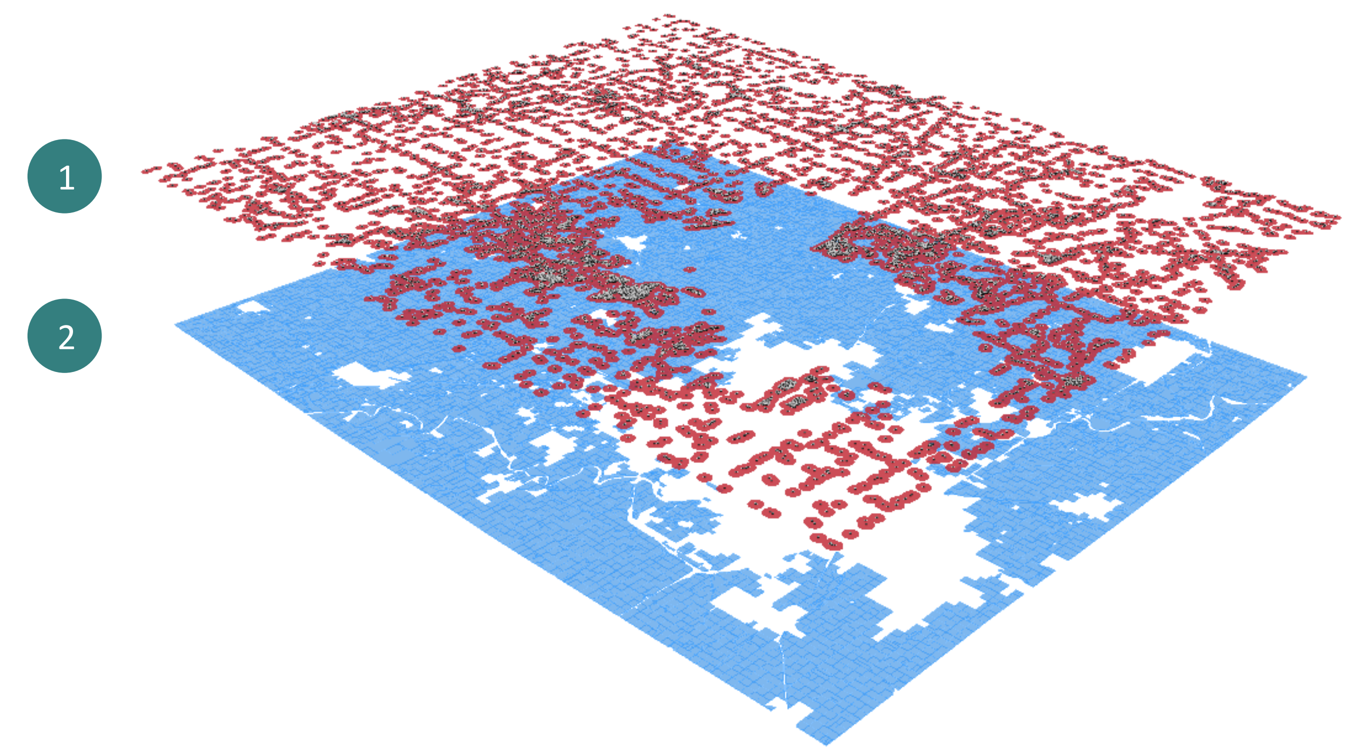



*Figure 19: Visualization of regulatory analysis*

## Allowed Regulatory Parcel Results

The map to the right shows the final output after all regulatory factors are applied. There are 116,630 total acres in Linn County that legally allow for the sting of utility-scale wind developments. This is about 25% of Linn County's total acreage of 463,777 and about 31% of all 371,717 rural acres in Linn County. Significant parcels exist within Linn County that would pass the regulatory requirements and also have viable wind speeds.

These parcels are derived from the regulatory constraints put in place by the Linn County Zoning Ordinance. This allows for the siting of large-scale wind energy with a conditional use permit within (AG) agricultural and (CNR) critical natural resource areas. A mandatory 1,000 foot buffer from residential structures and excluding all incorporated areas within Linn County.

Significant parcels exist for large-scale wind energy throughout the county at the regulatory level.

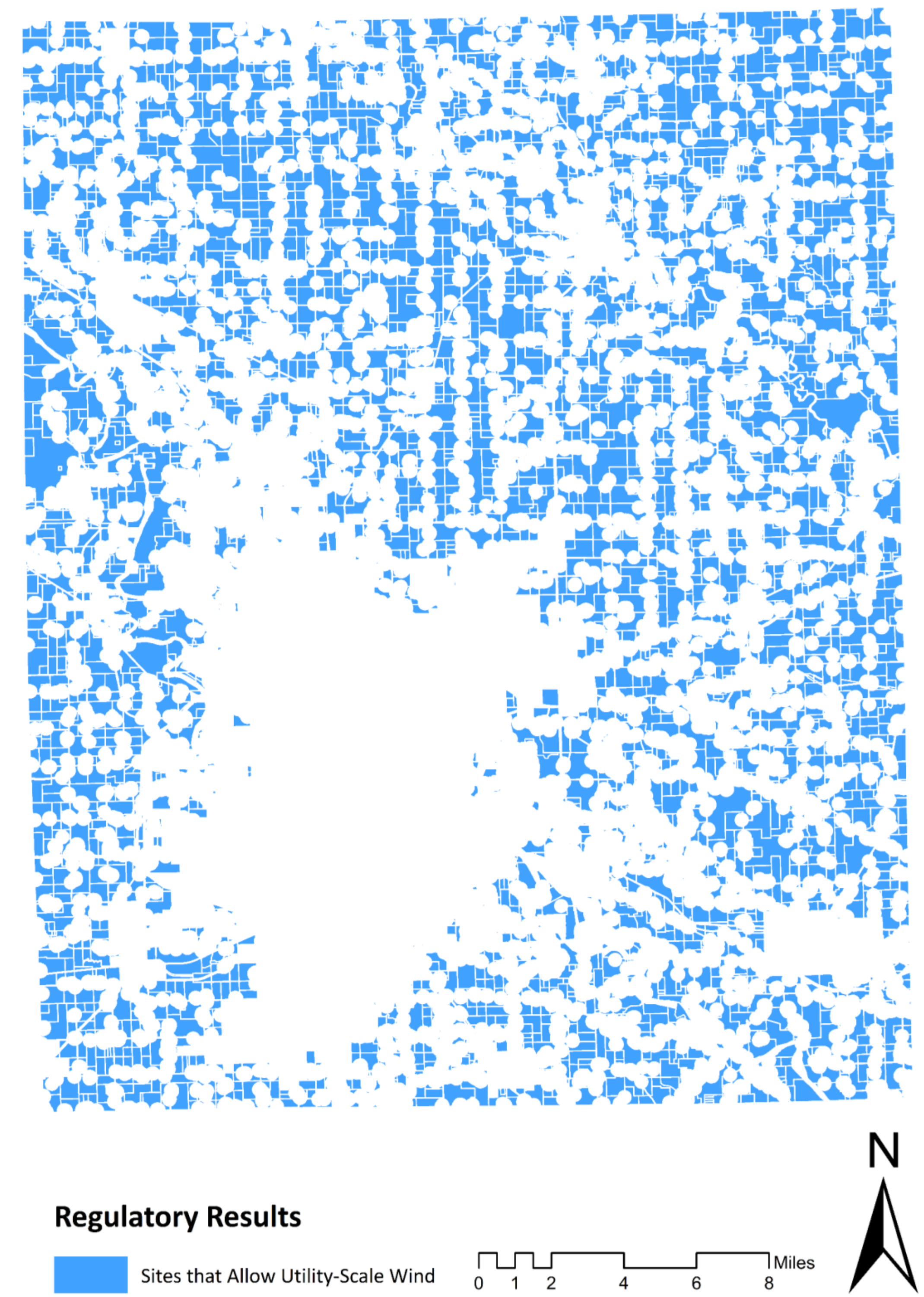



*Figure 20: Results of regulatory analysis*

# Suitability

## 1. Transportation

This factor includes major road infrastructure and operational rail lines, with areas closer to these lines being rated with higher suitability than areas farther away. These major transportation lines cover the majority of the county, with only small pockets in the northeast and northwest being rated as poor suitability in terms of distance to transportation infrastructure.

## 2. Grid Proximity

Initial research indicates that a wind energy project site is more suitable for development the closer it is to existing electricity transmission infrastructure, such as electric transmission lines. Linn County has existing electric transmission lines traversing the county from both the north-south and east-west directions. Most potential wind energy sites within Linn County may be served by the existing electric infrastructure; however, there is no consensus in the research on the exact distances between potential wind energy sites and existing electric transmission infrastructure.

## 3. Karst Presence & Slope

The derivation of slope and karst began with a data file containing Linn County topography retrieved from the Linn County GIS Data Portal (Linn County Iowa GIS Open Data Portal 2017). A digital elevation model was generated by converting the topographic contour layer to a surface raster using ArcMap's Topo to Raster tool. The slope map was then derived from the digital elevation model layer using ArcMap's Slope tool.

The optimal slope required for wind farms and turbine placement is between 0 to 7 degrees (Miller and Li 2014). A majority of Linn County and almost all the parcels included in the regulatory analysis meet these requirements. Only a few areas are greater than the required 7 degrees or less. These areas are primarily close to river valleys and municipalities.

Karst in the environment can be determined from dissolved bedrock of limestone and dolomite near the ground surface (DNR, Iowa 2018). Areas of karst often have sinkholes, springs, and streams where the surface flow is lost to groundwater due to the dissolution of carbonate rock by the groundwater (DNR, Iowa 2018).

## 4. Wind Resource

Using meteorological data provided by the National Oceanic and Atmospheric Administration (NOAA) and AWS Truepower Openwind software, high-resolution wind resource patterns were derived for Linn County. In order to optimize the wind resource maps for use in the model, they were classified into high, medium, and low quantiles.

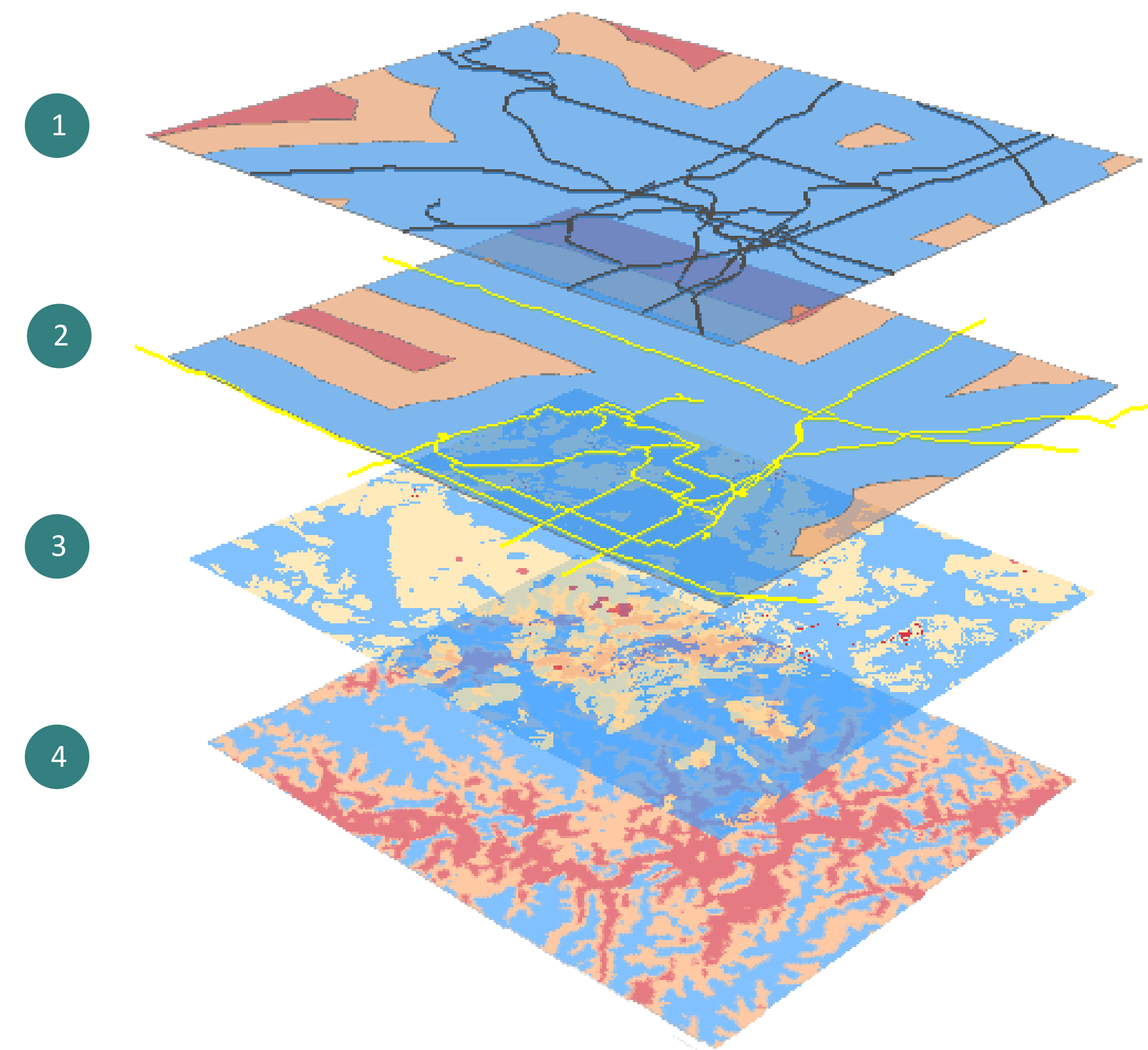



*Figure 21: Visualization of suitability analysis*

## Suitability Results

Figure 21 depicts the combination of all suitability factors previously described. The level of suitability ranges between nine distinct categories from high to low, with the lowest three categories deemed as low suitability, the middle three as medium suitability, and the highest three as high suitability. These results were then clipped to the results of the regulatory analysis as shown in figure 22.

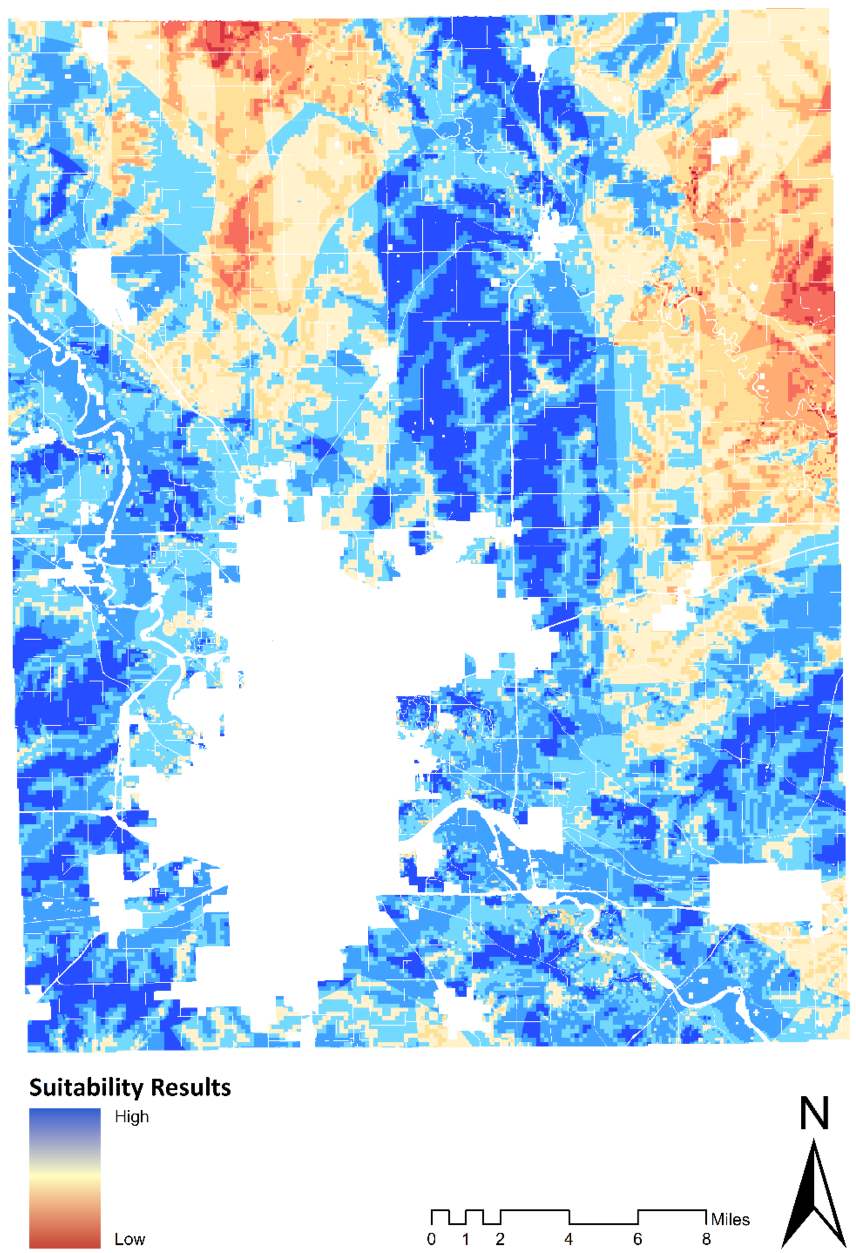



*Figure 22: Results of suitability analysis*

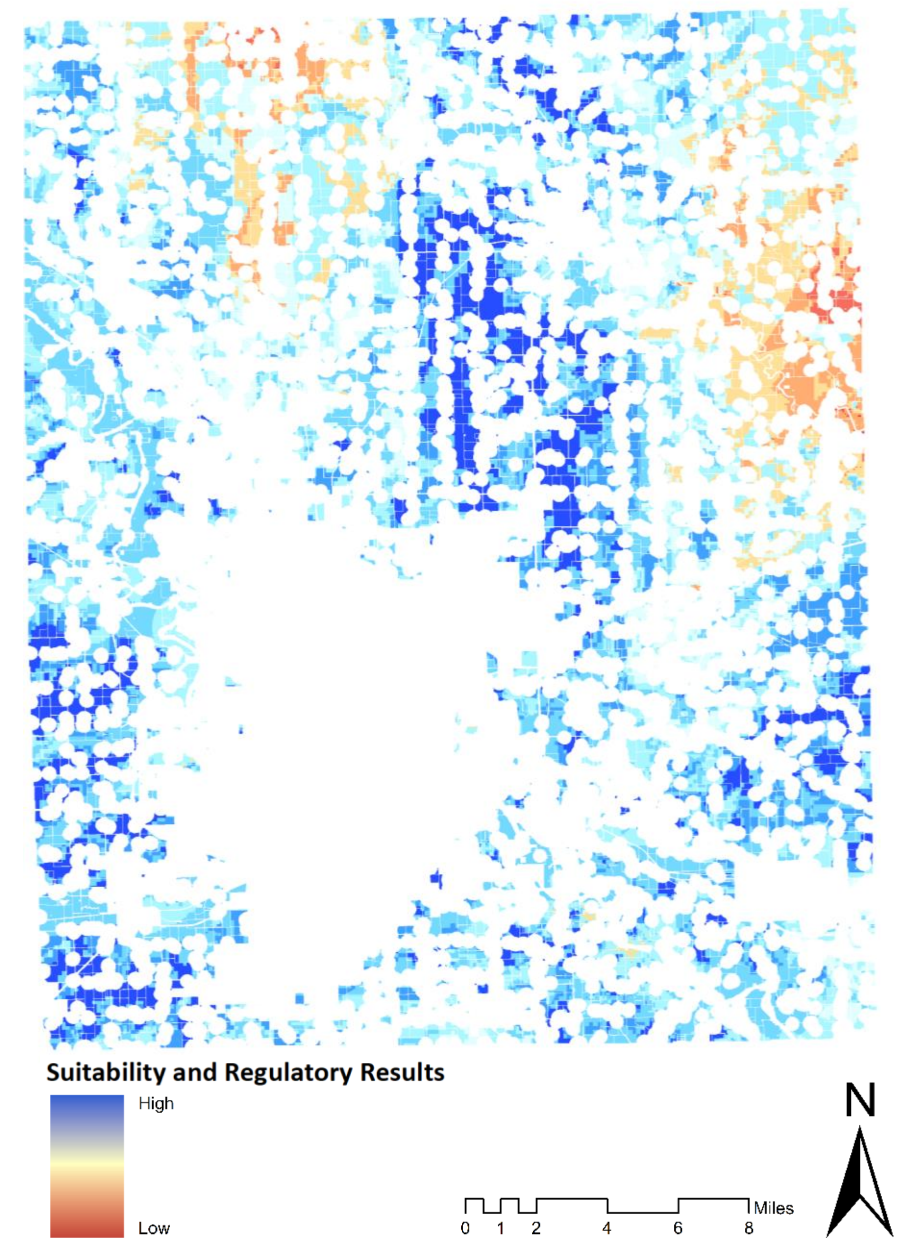



*Figure 23: Results of suitability analysis clipped to regulatory output*

# Compatibility

## 1. Airport Compatibility

Linn County's two airports are the Eastern Iowa Airport and the Marion Airport. These are located within the municipal boundaries of the City of Cedar Rapids, and Marion. Buffers were added to our GIS spatial mapping and excluded any parcels present in the FAA required minimum distance. A utility scale wind farm in Linn County will require an aeronautical study to access any risks to air defense and homeland security radars. These airports were taken into consideration in the regulatory process and the final possible parcels.

## 2. City/County Strategic Growth Plan and Agreement (CCSG)

A two-mile buffer was applied to these four municipalities using ArcMap's Buffer tool, and any area falling within these buffers were classified as having a low suitability rating.

## 3. Land Use

Buffers were applied to future land-use growth areas. The remaining parcels are allowed zoning areas under Linn County Zoning Ordinance. These include the CRNA (Critical Natural Resource) and AA (Agricultural Area) zoned parcels. The removed areas within this map include Municipalities Metro Urban Service Areas.

The low compatibility areas are parcels that are capable of hosting wind farms but are closer in proximity to CNR zones and future land-use areas. Two-mile buffers were included for the CCSG agreements between the Linn County, Palo, Ely, and Springville.  Wind farms are allowed within these CCSG areas but would need Linn County and the township to sign off on any conditional use permit. CNR zoned parcels are included, but conflicts with flyways and ecosystems pose risks. Metro Urban Service Areas were used as a filter to exclude wind farms from future areas of growth. This reduces the risk of future land-use conflicts as the metro and townships grow.

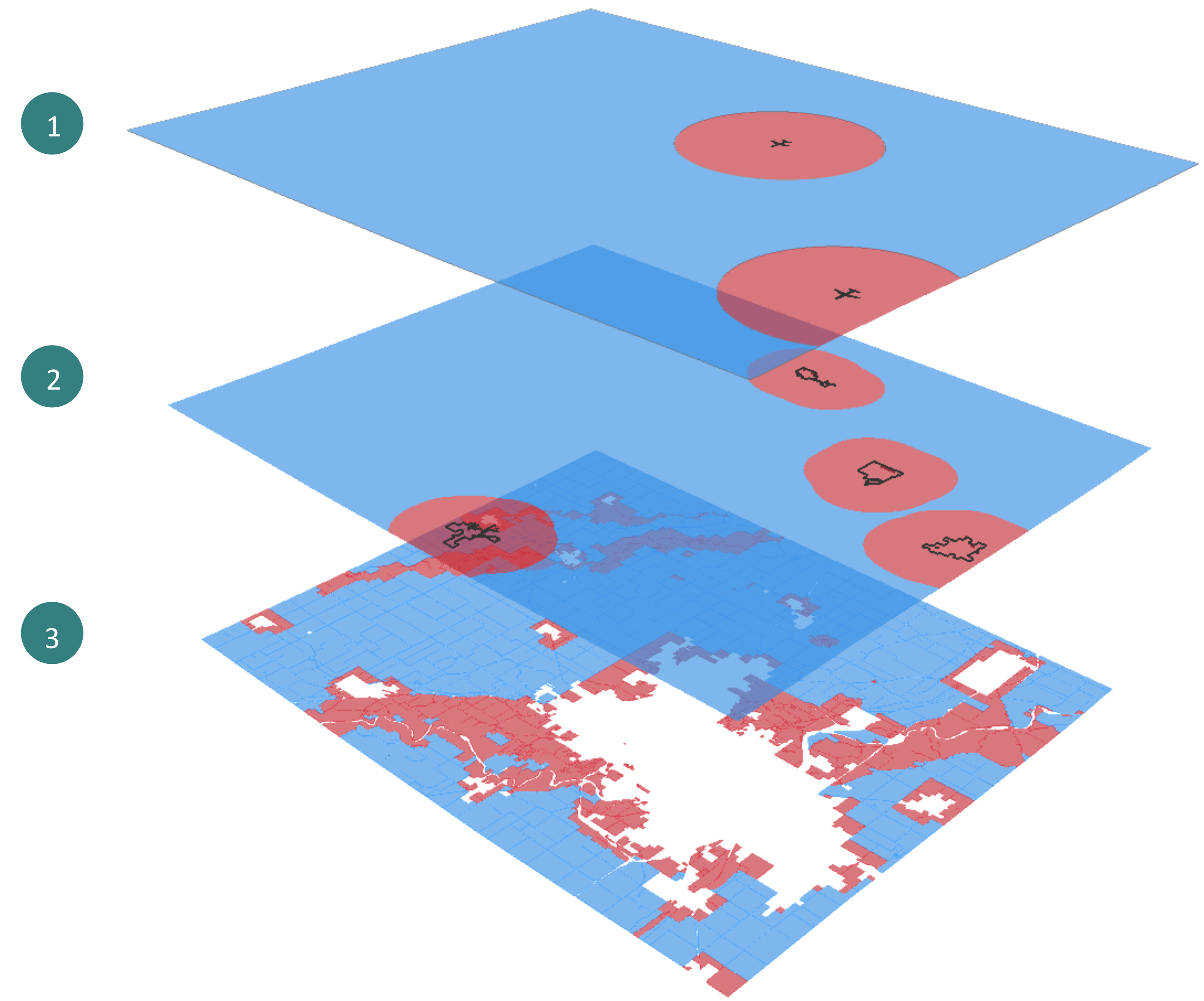



*Figure 24: Visualization of compatibility analysis*

## Compatibility Results

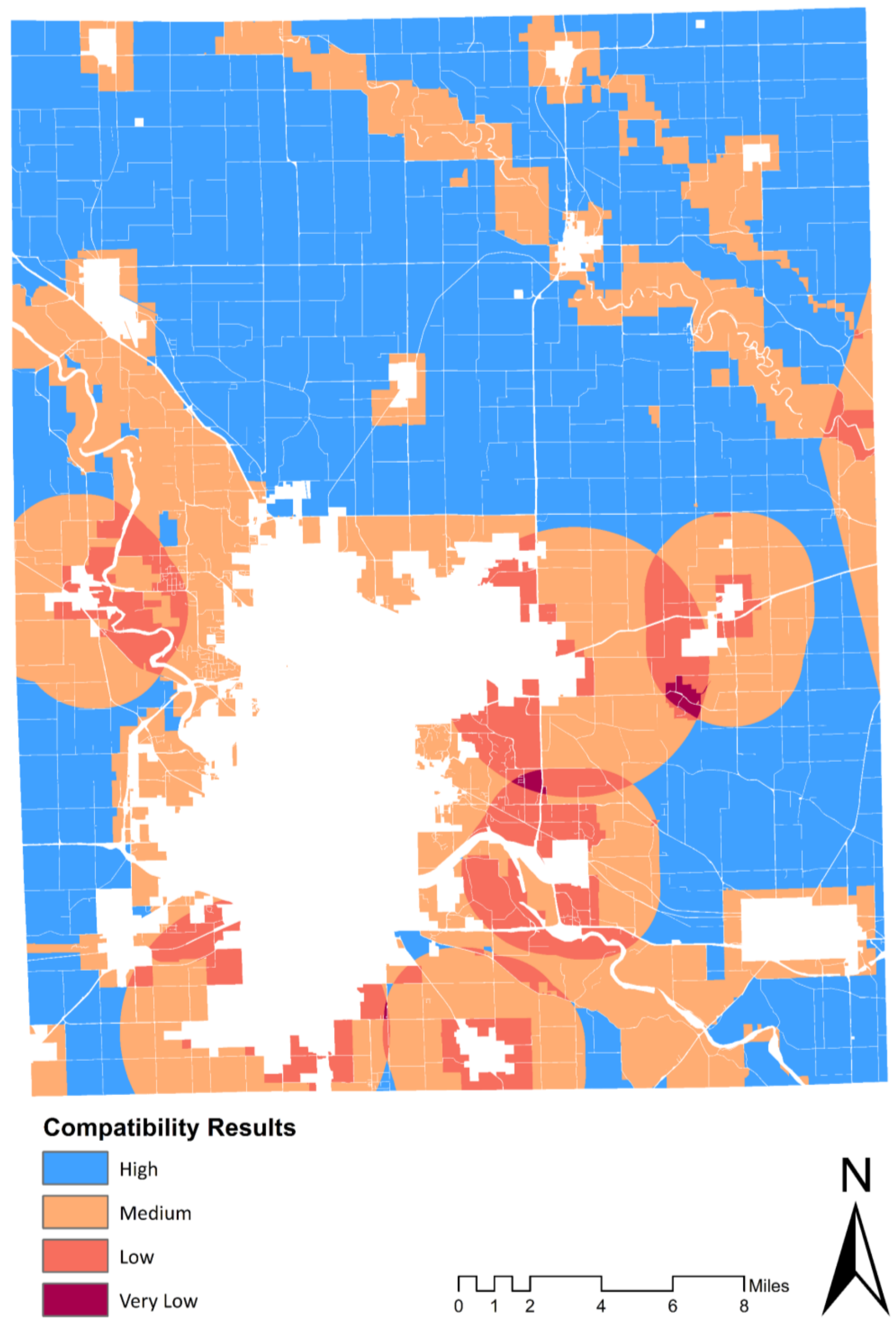



*Figure 25: Results of compatibility analysis*

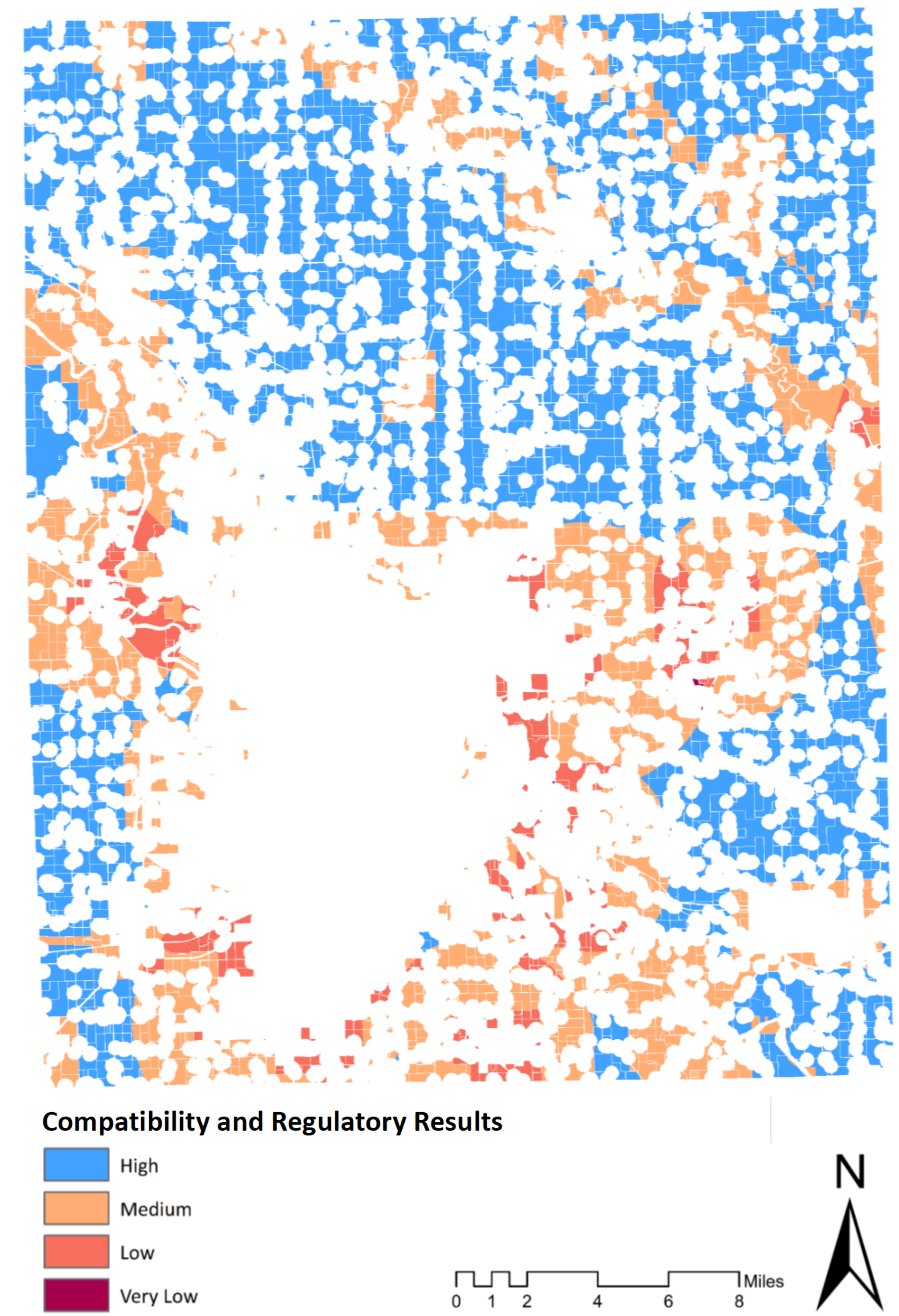



*Figure 26: Results of compatibility analysis clipped to regulatory output*

## 2.4 Summary

The spatial constraints presented in this siting analysis prove that the siting of utility-scale wind projects can be logistically challenging. A failure to consider the regulatory, suitability, and compatibility constraints of utility-scale wind farm development could have unfavorable repercussions for the many stakeholders involved. By developing a spatial understanding of how these projects may impact Linn County, this project seeks to assist Linn County officials in making informed decisions regarding the placement of future utility-scale wind farm development. In the interest of doing so, the next section of this report, titled “Results” provides a set of deliverables for Linn County Planning & Development to assist them with planning for utility-scale wind development in their county.

# 3 Results

# 3.1 Conditional Use Permit Evaluation Guide

The Conditional Use Permit Evaluation Guide is a set of decision-making matrices designed for integration into Linn County's conditional use permit standards for review to strengthen the county's current evaluation process. The two proposed matrices presented in figure 27 and 28 each seek to address one of the highlighted review standards:

- Does the proposed use conform to the comprehensive plan?
- Is the site suitable for the proposed use?
- Is the proposed use compatible with surrounding property use?
- Is the adjoining road system adequate to accommodate the proposed use in terms of the present traffic volume versus road capacity and the general condition of the road system?
- Can adequate measures be taken to minimize any potential adverse impacts on adjoining property?

Both the suitability and compatibility matrix contain a set of relevant factors for consideration that have been chosen based on the research presented in section 2.1 of this analysis. Each factor has additionally been assigned a metric by which the factor can be evaluated by staff to determine the overall suitability and compatibility of a conditional use permit application for utility-scale wind development.

| STANDARDS FOR REVIEW | FACTORS | HIGH | MEDIUM | LOW |
|---|---|---|---|---|
| Site Suitability | Wind Resource | Fastest 1/3 | Medium 1/3 | Low 1/3 |
| | Grid Proximity (distance from transmission lines) | < 16,000' | 16,000-32,000' | > 32,000' |
| | Slope | < 7 degrees | - | > 7 degrees |
| | Karst Presence | No | Possible | Yes |
| | Transportation (distance from Interstates, Railroads, and U.S. or State Routes) | <16,000' | 16,000-32,000' | > 32,000' |

*Figure 27: Site suitability matrix*

| STANDARDS FOR REVIEW | FACTORS | | HIGH | MEDIUM | LOW |
|---|---|---|---|---|---|
| Site Compatibility | Future Land Use Classification | | "AA" | - | Other |
| | City/County Strategic Growth (distance from municipal boundary) | | > 2 mi | - | < 2 mi |
| | Airport Proximity | | > 20,000' | - | < 20,000' |
| | Visual Impact (distance from historic landscape district) | 40m turbine | > 3 mi | - | < 3 mi |
| | | 80m turbine | > 5 mi | - | < 5 mi |
| | | 120m turbine | > 7 mi | - | < 7 mi |
| | Shadow Flicker | | 0 hours/year | 0-30 hours/year | > 30 hours/year |
| | Wildlife Corridors and Habitats | | No Conflict | Potential Conflict | Definite Conflict |

*Figure 28: Site compatibility matrix*

## 3.2 Multi-Criteria Decision Support System

The Multi-Criteria Decision Support System (MCDSS) is a system of three GIS models that replicate the spatial analyses developed for this project. The models were created using the ModelBuilder in ArcMap 10.6, and the final Python script for each model is contained in Appendix section Multi-Criteria Decision Support System – Model Scripts. This section will explain how to run each model. The model will be delivered via a folder that will have the most current data available at the time this report was completed, and the models have relative pathways stored for the input data, so the workflow process should automatically link to the data in these folders. The folders include "DynamicInputs", containing data that is apt to change in the future such as rural zoning or residential structures, "StaticInputs", containing data unlikely to change in the future such as slope or karst presence, and "Outputs", which contains geodatabases for intermediate and final data.

### Regulatory Model

The first model generates the areas of rural Linn County where utility-scale wind developments are legally allowed to be sited based upon current regulatory constraints. The structure of the model is shown in figure 29.

When the model is run via ArcMap's Catalog window the interface shown in figure 30 on the following page appears. Included with it is a brief explanation of each parameter included in the Regulatory Model, and the model itself has this information stored within it as well.

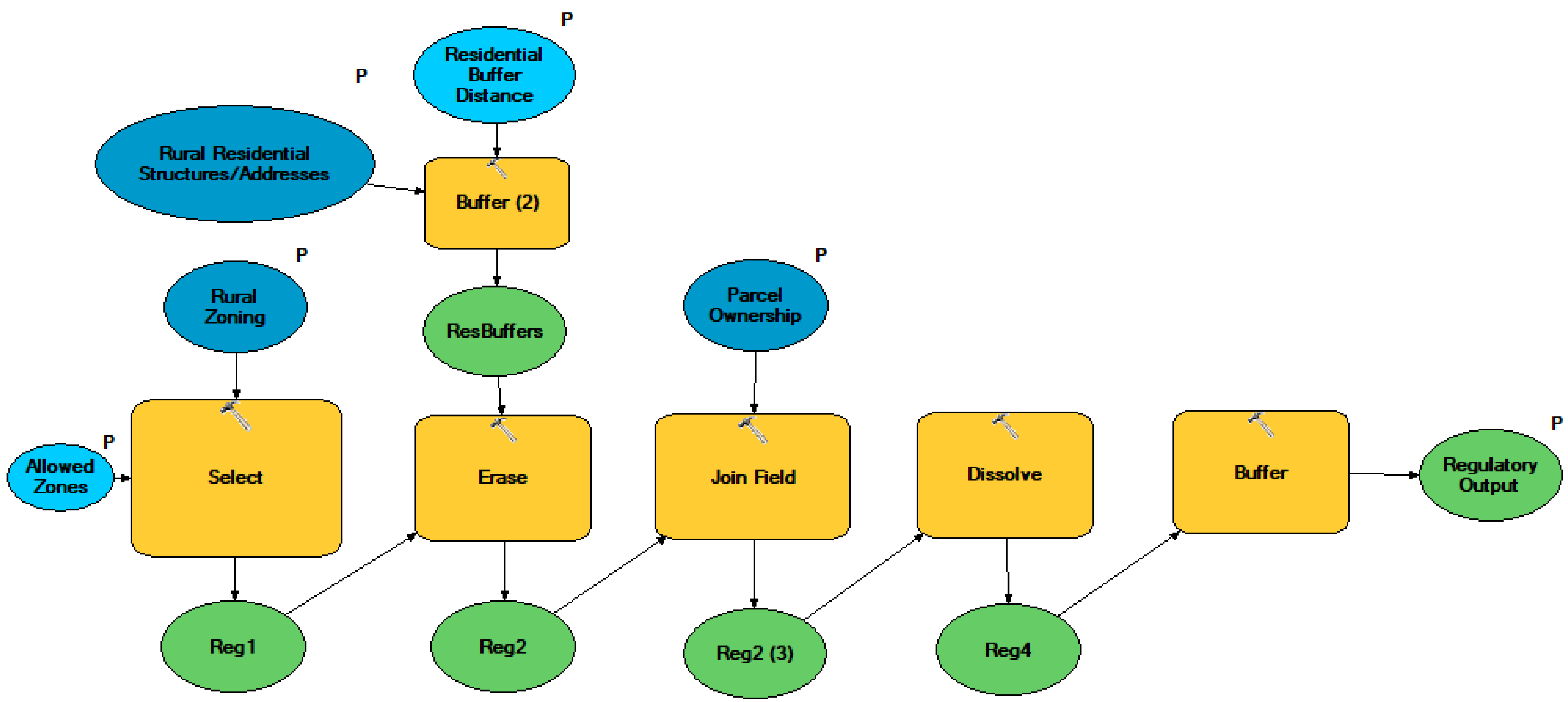



*Figure 29: Regulatory model*

- **Rural Zoning**
    - This is a shapefile of the most up to date zoning classifications of all parcels in unincorporated Linn County. This is the starting point for every model, and the regulatory model begins by selecting only those zones where utility-scale wind developments are allowed conditionally.

- **Allowed Zones**
    - This is an expression to choose which zones currently allow utility-scale wind developments conditionally. At the time of the model's creation, this use was conditionally allowed in AG and CNR zones so this is the default expression when the model is run. To change this, simply hit the SQL button to the right of the field and adjust the expression. If, for example, the ordinance is updated to only allow utility-scale wind development in AG zones removing CNG zones as potential sites, this can be adjusted in the expression.

- **Parcel Ownership**
    - This shapefile was downloaded from Linn County's Open Data site and includes the deed holders for each parcel. The model joins this data to the remaining rural zoning shapefile via PPN, so parcels with the same owners can then be merged together to subsequently apply the necessary 100' buffer from property lines of parcels under dissimilar ownership.

- **Rural Residential Structures/Addresses**
    - This shapefile contains the locations of all rural residential structures and can be either point or poly. The mandated buffer distance from these structures are applied via the expression parameter immediately following this parameter, and the resulting buffer is erased from the remaining allowable sites.

- **Residential Buffer Distance**
    - This is the buffer distance that will be applied to the residential structures. At the time of the model's creation, this distance was set at 1,000' in Linn County's Unified Development Ordinance, so this is the default distance. It can be adjusted to test how changes to this distance will affect regulatorily-allowed sites for utility-scale wind developments.

- **Regulatory Output**
    - This is the resulting output of the regulatory model. The default save location is in the "FinalOutputs" geodatabase within the "Outputs" folder, but the save location can be adjusted to fit user preference.

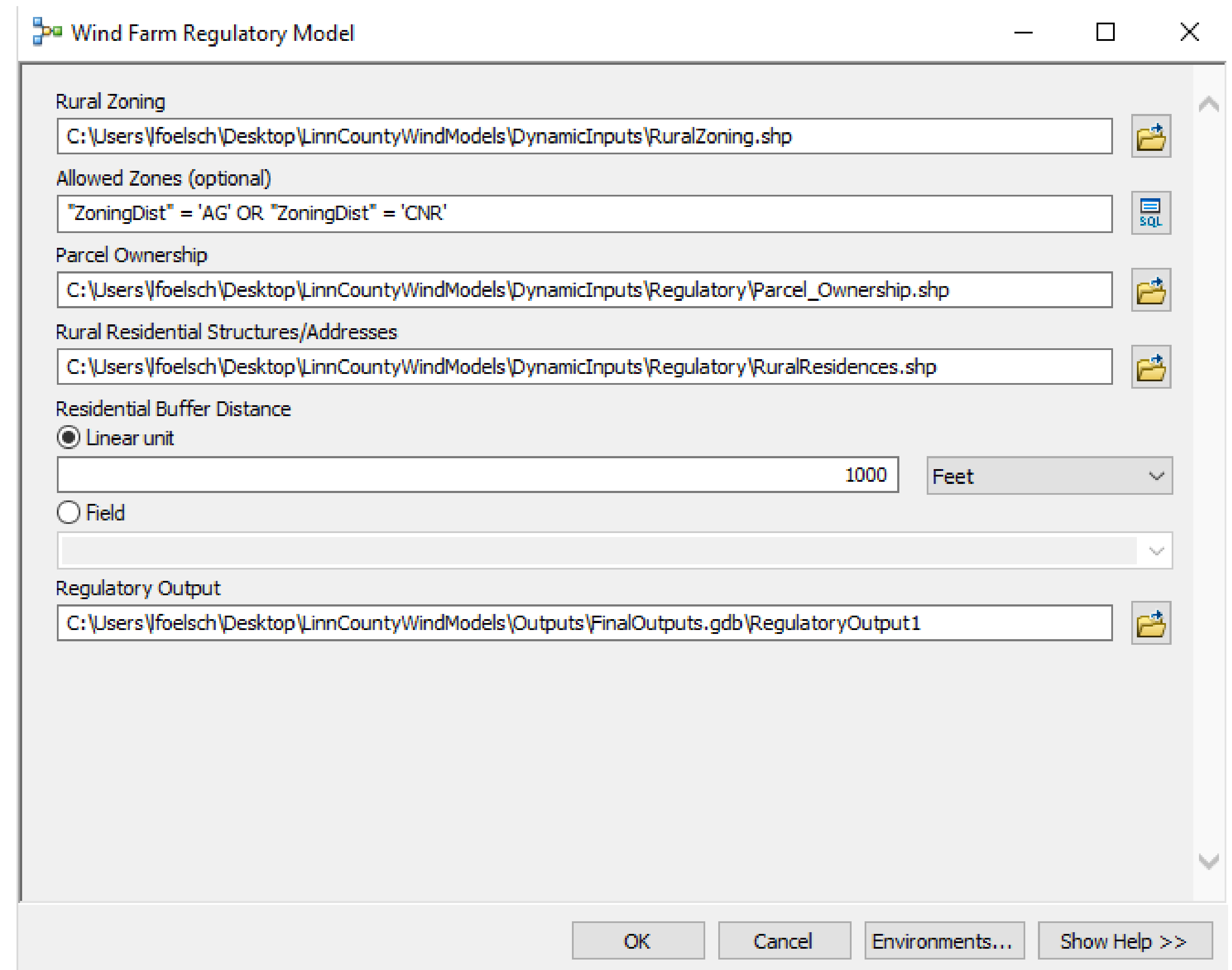



*Figure 30: Regulatory model ArcGIS interface*

## Suitability Model

The second model considers a number of factors that affect where utility-scale wind developments are likely to be located. These factors include economic, topographic, and wind resource factors to determine site suitability for wind developments, and the model can be used to help staff anticipate areas of the county that are ideally situated for these developments. The structure of the model is displayed in figure 31.

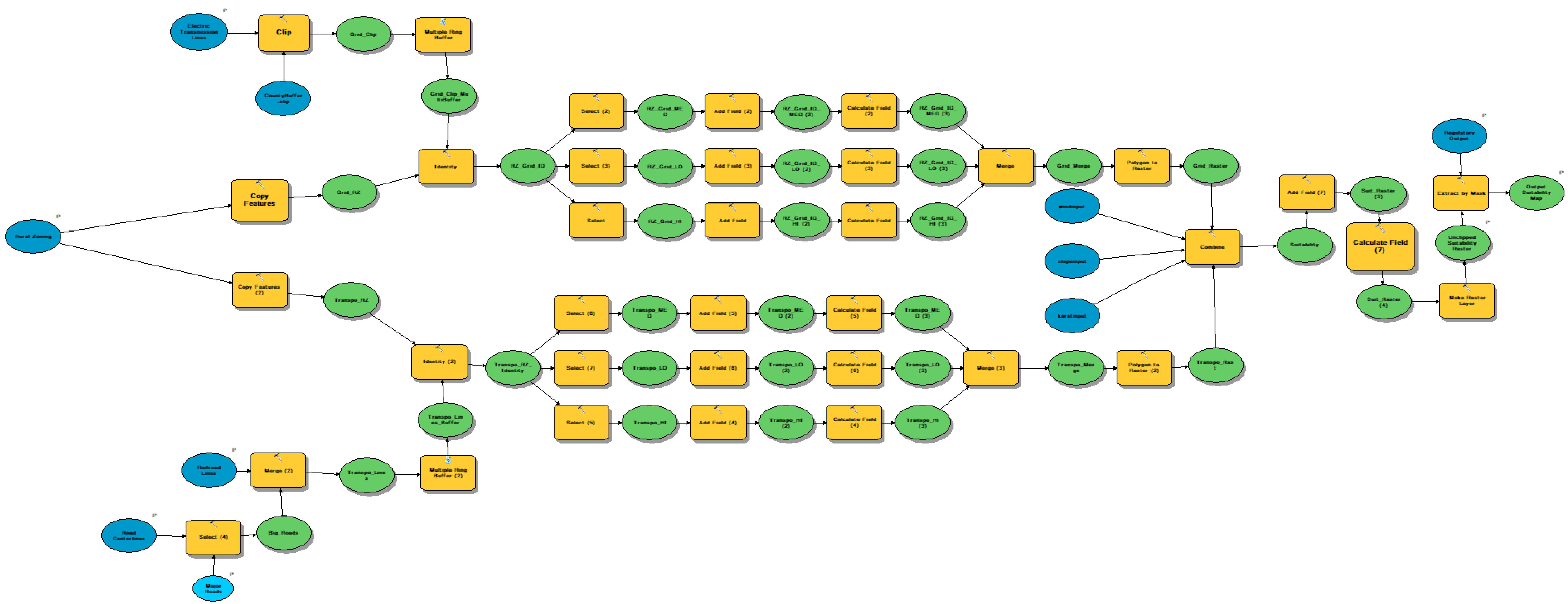


*Figure 31: Suitability model*

When the model is run via ArcMap's Catalog window the interface shown in figure 32 appears. Below is a brief explanation of each parameter included in the Suitability Model, and the model itself has this information stored within it as well.

- **Regulatory Output**
  - This is the resulting output map from the most recent regulatory model iteration. The final suitability map is clipped to this output, so it displays the suitability only of areas where these turbines are legally allowed to be sited.

- **Rural Zoning**
  - This input is for the most recent rural zoning shapefile for Linn County. The model starts with this rural zoning file and makes copies for each factor in the model to subsequently transform and manipulate. This is to ensure each factor is working from identical starting points.

- **Road Centerlines**
  - This is a line shapefile for the current road network in Linn County. This file is later merged with the railroad lines to create an overall transportation network consisting of transportation links adequately substantial for transporting large wind turbine components during the construction process.

- **Major Roads (optional)**
  - This SQL expression selects which roads from the "Road Centerlines" file are kept and merged with the railroad lines. If staff determines different roads than those in the default setting should be included, this parameter allows that adjustment. The default roads included are Interstates, State Highways, US Business Highways, and US Highways.

- **Railroad Lines**
  - This is a shapefile of existing and operational railroad lines in Linn County. This file is merged with the road network selected in the previous parameter, and a buffer is applied to this combined transportation network, with areas in closer proximity receiving a higher suitability rating than areas farther away.

- **Electric Transmission Lines**
  - This input requires a shapefile of existing transmission lines, which are lines that transmit electricity. When creating this model, data for this input could only be found at the state-level. To account for this, the model clips the transmission line shapefile to a pre-made 2-mile buffer around Linn County to remove unnecessary data.

- **Unclipped Suitability Raster**
  - This parameter allows you to select the save location for the full and unclipped suitability output raster.

- **Output Suitability Map**
  - This parameter allows you to select the save location for the final suitability map that is clipped to the Regulatory Output selected as the first parameter in the model's interface.

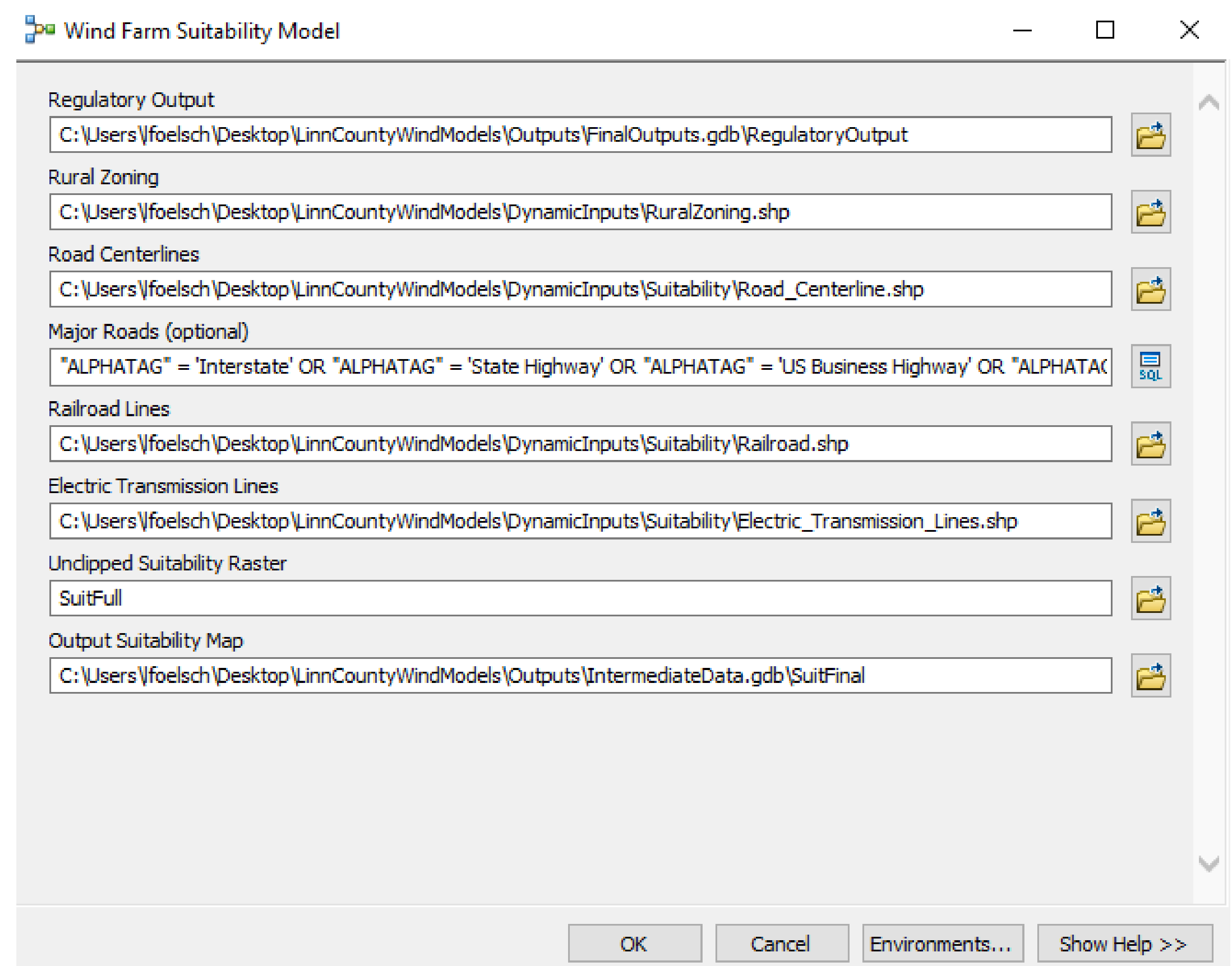



*Figure 32: Suitability model ArcGIS interface*

# Compatibility Model

The third and final model considers a number of factors that pertain to land use compatibility of utility-scale wind developments. These factors include public airport proximity, fringe area agreements, and future land use classification to determine site compatibility for wind developments, and the model can be used to help staff determine which areas of the county would be most ideal for these developments. The structure of the model is displayed in figure 33.

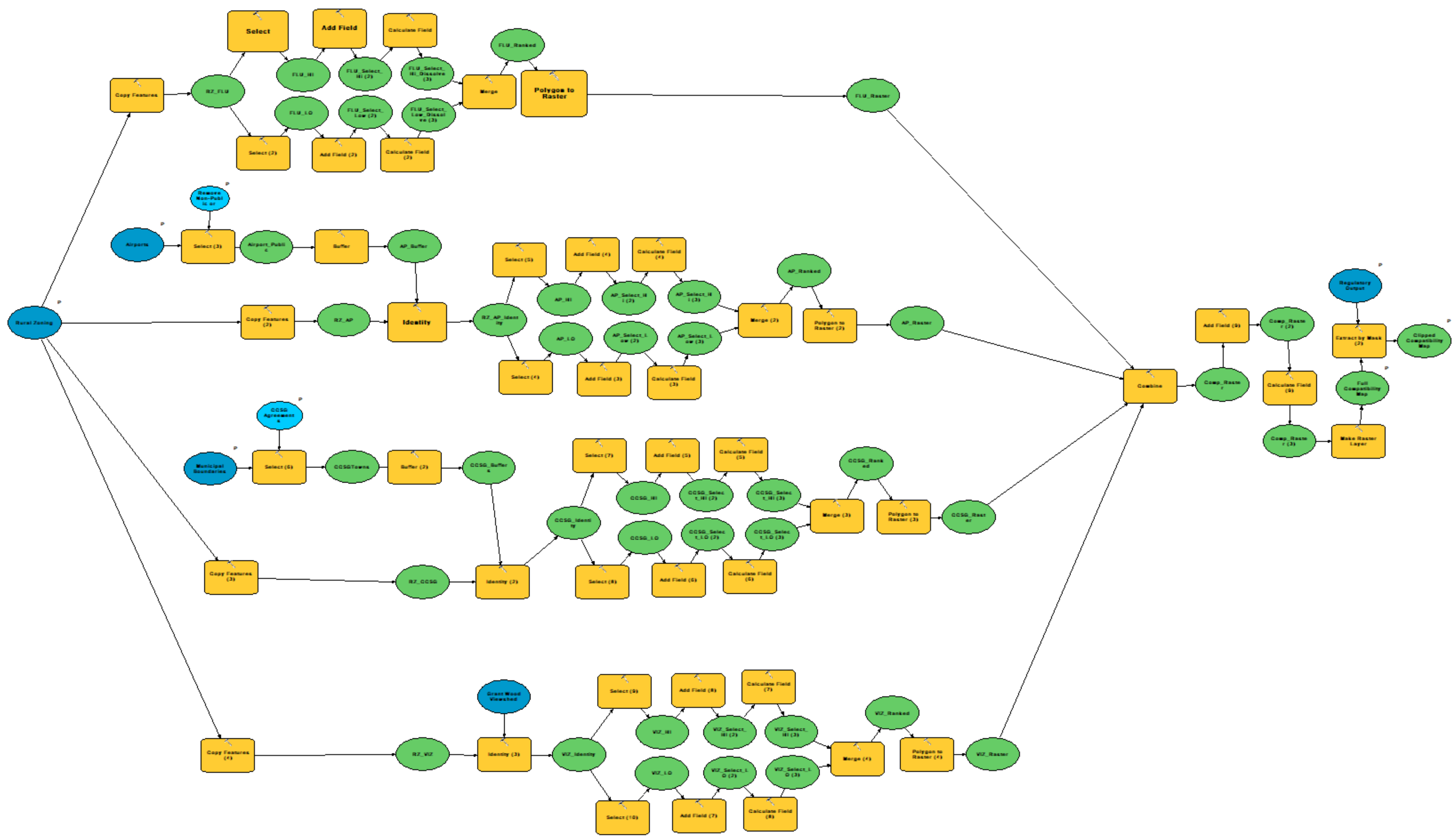



*Figure 33: Compatibility model*

When the model is run via ArcMap's Catalog window the interface shown in figure 34 appears. Below is a brief explanation of each parameter included in the Compatibility Model, and the model itself has this information stored within it as well.

- **Regulatory Output**
  - This is the resulting output map from the most recent regulatory model iteration. The final compatibility map is clipped to this output, so it displays the compatibility only of areas where these turbines are legally allowed to be sited.

- **Rural Zoning**
  - This input is for the most recent rural zoning shapefile for Linn County. The model starts with this rural zoning file and makes copies for each factor in the model to subsequently transform and manipulate. This is to ensure each factor is working from identical starting points.

- **Airports**
  - This a point shapefile of active airports in Linn County. This input is buffered by 20,000', with any area within this buffer marked as low compatibility. As the only data available during the creation of this model was point location of airports, using a polygon shapefile with the actual runways of these airports would make this model more precise, and polygon data should be able to be used for this parameter with no issues.

- **Remove Non-Public or Defunct Airports (optional)**
  - When this model was created, the airport location shapefile from Linn County's Open Data was used. This shapefile included a point for McBride Airport, which later was determined to have been defunct and non-operational since at least 2012. To account for this, this expression parameter was added. If future airport shapefile inputs are updated to omit McBride Airport, this parameter expression can simply be left blank.

- **Municipal Boundaries**
  - These are the boundaries for all municipalities in Linn County. This file is used to select municipalities that have CCSG agreements, and therefore 2-mile extraterritorial jurisdiction.

- **CCSG Agreements (optional)**
  - This expression parameter is used to select which municipalities from the previously entered Municipal Boundaries parameter currently have CCSG agreements. At the time of the model's creation, the municipalities with CCSG agreements were Bertram, Ely, Palo, and Springville, so these are the default settings. If this changes in the future, this expression can be used to update the model to reflect this.

- **Full Compatibility Map**
  - This parameter allows you to select the save location for the full and unclipped compatibility output raster.

- **Clipped Compatibility Map**
  - This parameter allows you to select the save location for the final compatibility map that is clipped to the Regulatory Output selected as the first parameter in the model's interface.

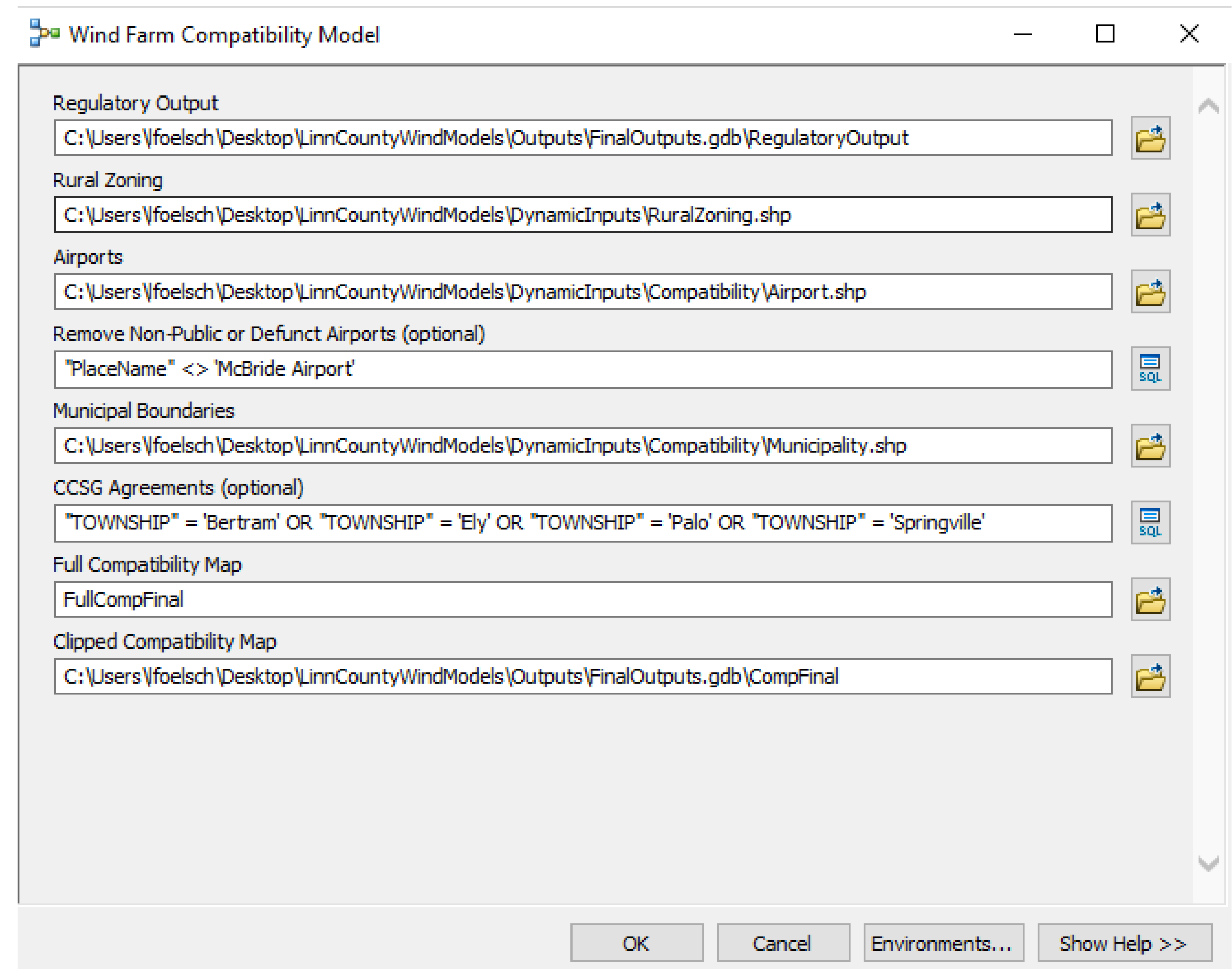



*Figure 34: Compatibility model ArcGIS interface*

# 3.3 Survey Evaluating Public Opinion

## Online Survey

The survey objectives were to gather stakeholder information and public perception of renewable energy and large-scale wind farms within Linn County. This was done by using Qualtrics survey software to construct and build an online survey that could be distributed through Linn County's social media platforms and to members of the Iowa Farm Bureau.

## Survey Design and Timeline of Distribution

The survey contained 18 questions gauging respondents' knowledge of renewable energy and wind energy, perception of benefits, perception of risks, demographics, and location data. The survey went live on February 25th and ended on March 27th with 252 recorded responses. Linn County social media, ENews Letter, Gazette article, and distribution through the Iowa Farm Bureau accounted for the responses.

## General Survey Results

**Do you live in Linn County?**

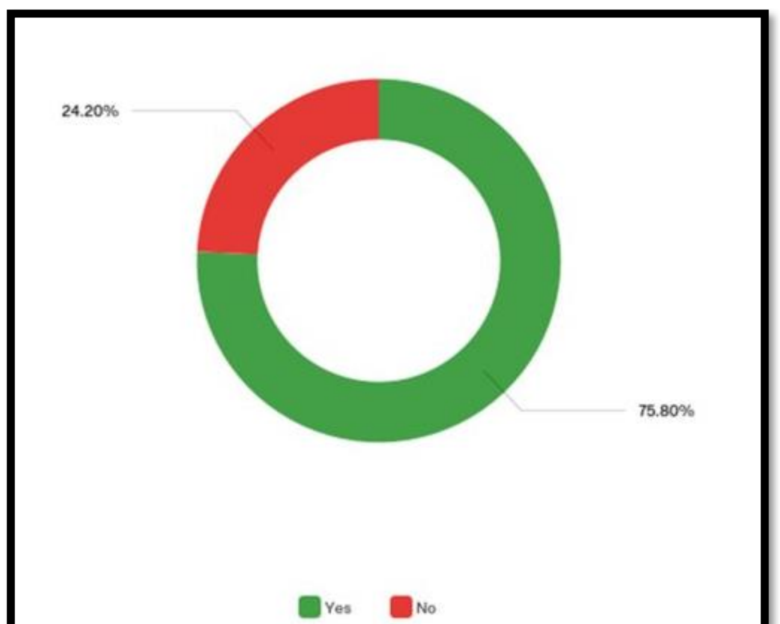



*Figure 35: Respondents from Linn County (green) and outside of Linn County (red)*

**Do you live in incorporated or unincorporated Linn County?**

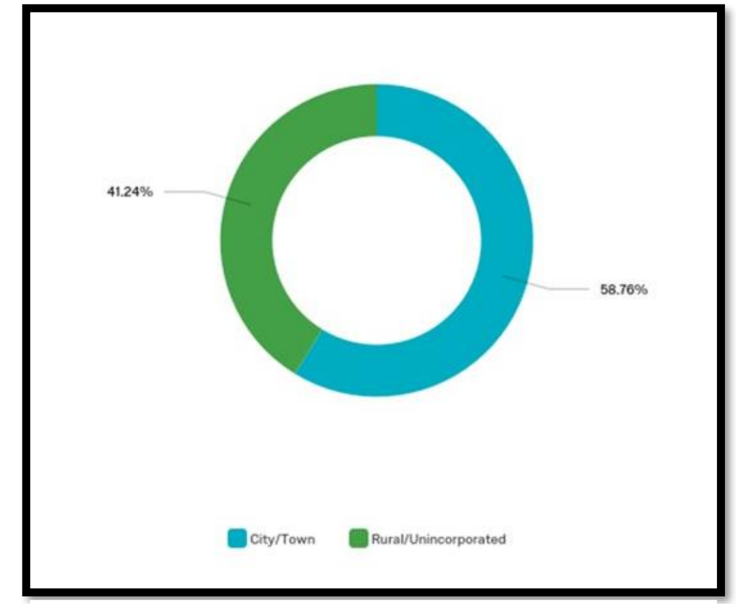



*Figure 36: Respondents from incorporated Linn County (blue) and unincorporated (green)*

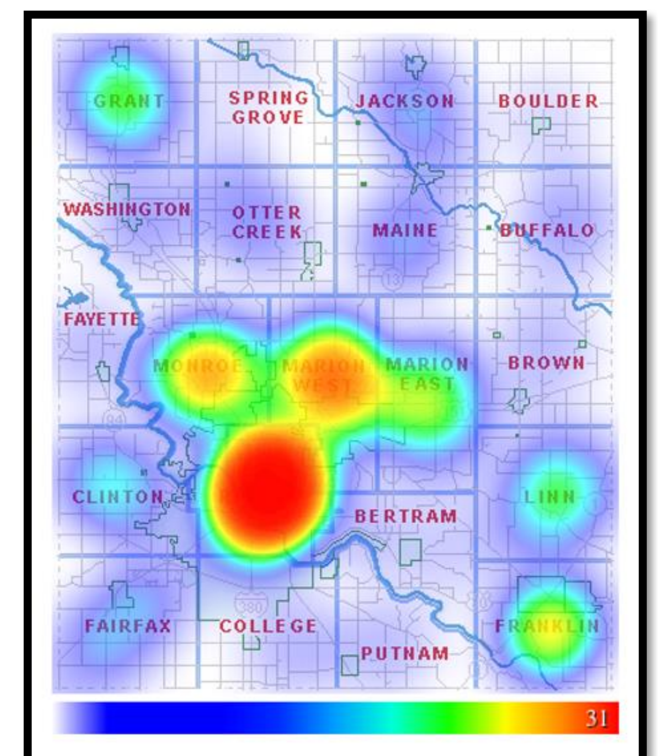



*Figure 37: Spatial distribution of survey respondents*

# Significant Survey Findings

## Attitudes towards Renewable Energy and Wind Energy

The survey responses were 72% favorable towards renewable energy, 10% unfavorable, and 18% neutral. This indicates that a majority of Linn County residents are supportive of general renewable energy in the county. This could be in part to the Solarize Linn County campaign that provided solar information sessions and accounted for 607.22 kilowatts to be installed 104 homes (Solar 2017).

General responses on the support or opposition of large-scale wind energy within Linn county were 57% opposed, 22% neutral, and 21% in support. This can be an avenue for educational and public outreach events to change negative perception on wind energy within the county.

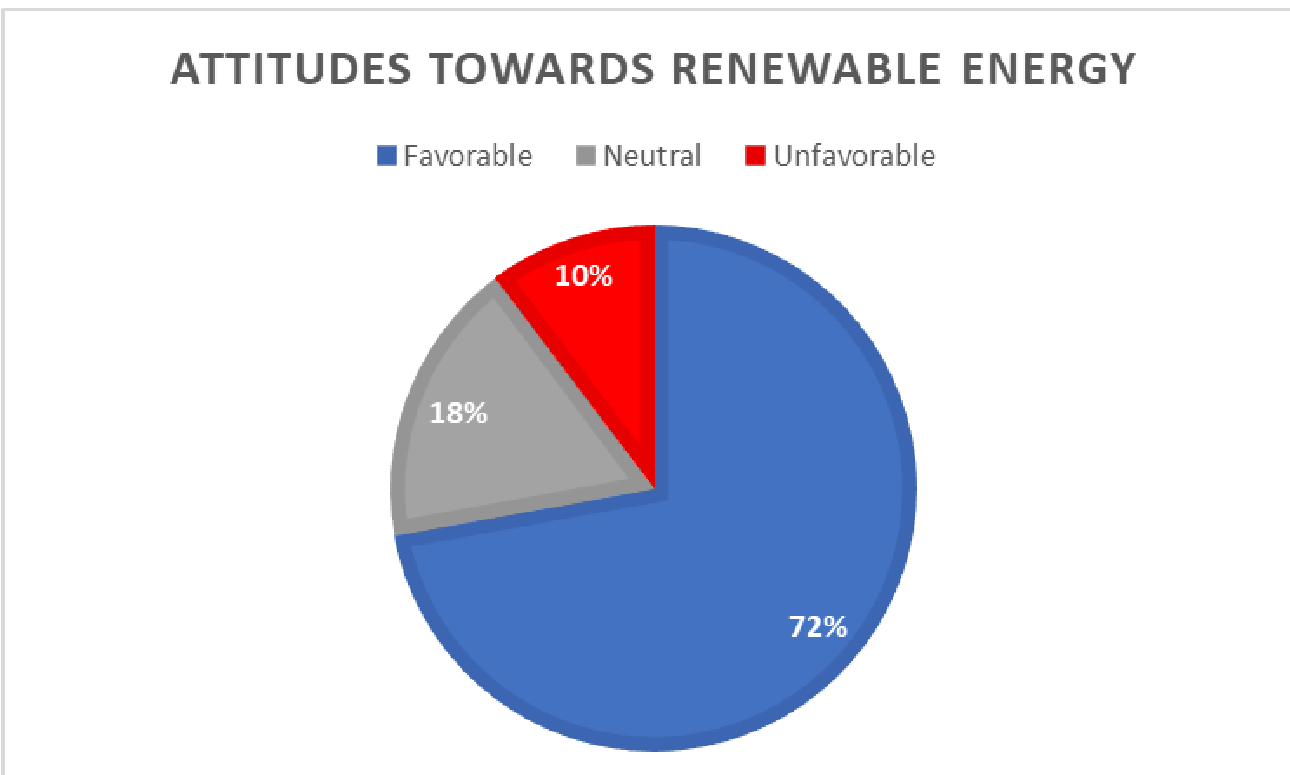



*Figure 38: Survey attitudes towards renewable energy*

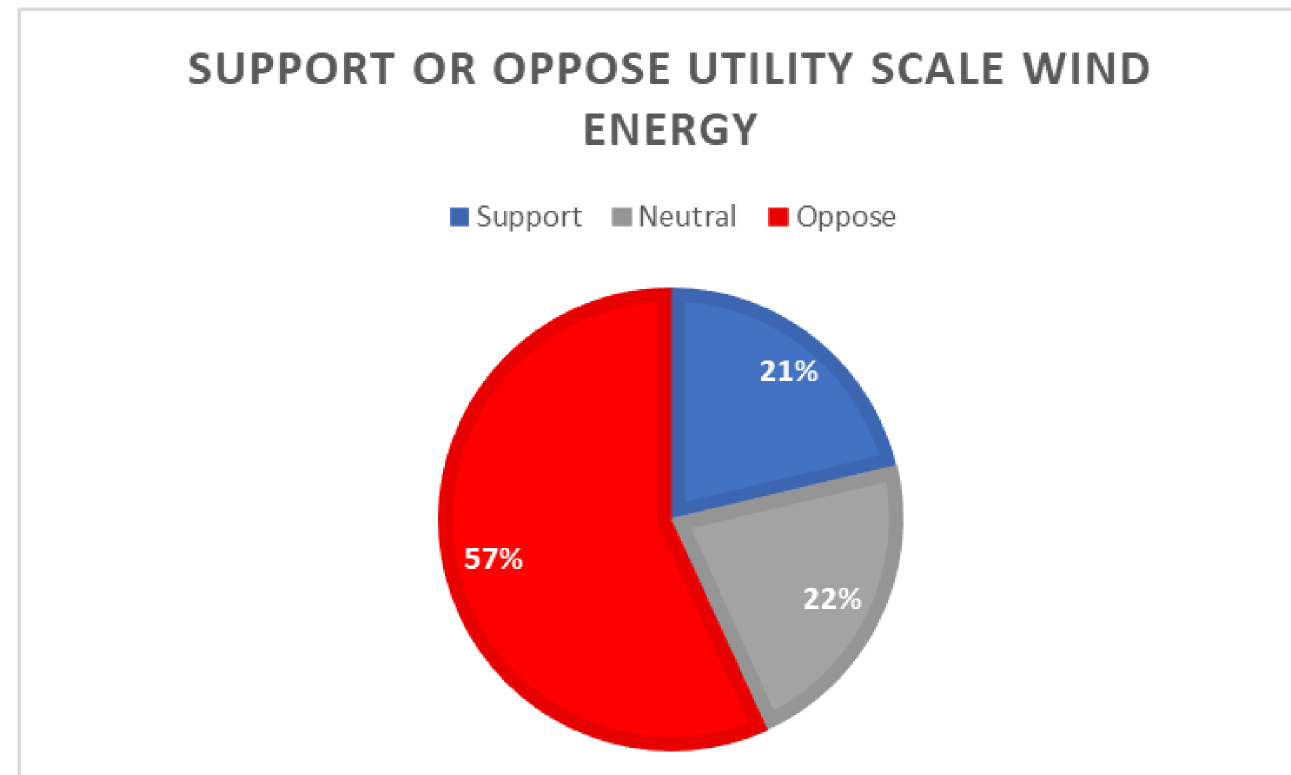



*Figure 39: Respondents that support or oppose utility-scale wind energy*

## General Interest in Hosting Wind Farms and Neighbor Hosting

This part of the survey looked into the combined rural and city/incorporated interest and opinion of hosting wind farms and their neighbor hosting wind farms. 62% of respondents wouldn't be interested in hosting wind farms, and 38% would likely be interested. This furthers the uncertain perception towards large-scale wind farms, and give opportunities for educational events.

The respondents' perception of their neighbor hosting wind farms is 52% dislike, 31% neutral, and 17% like. This is likely to the perceived negative externalities and no compensation for compromise of their viewshed.

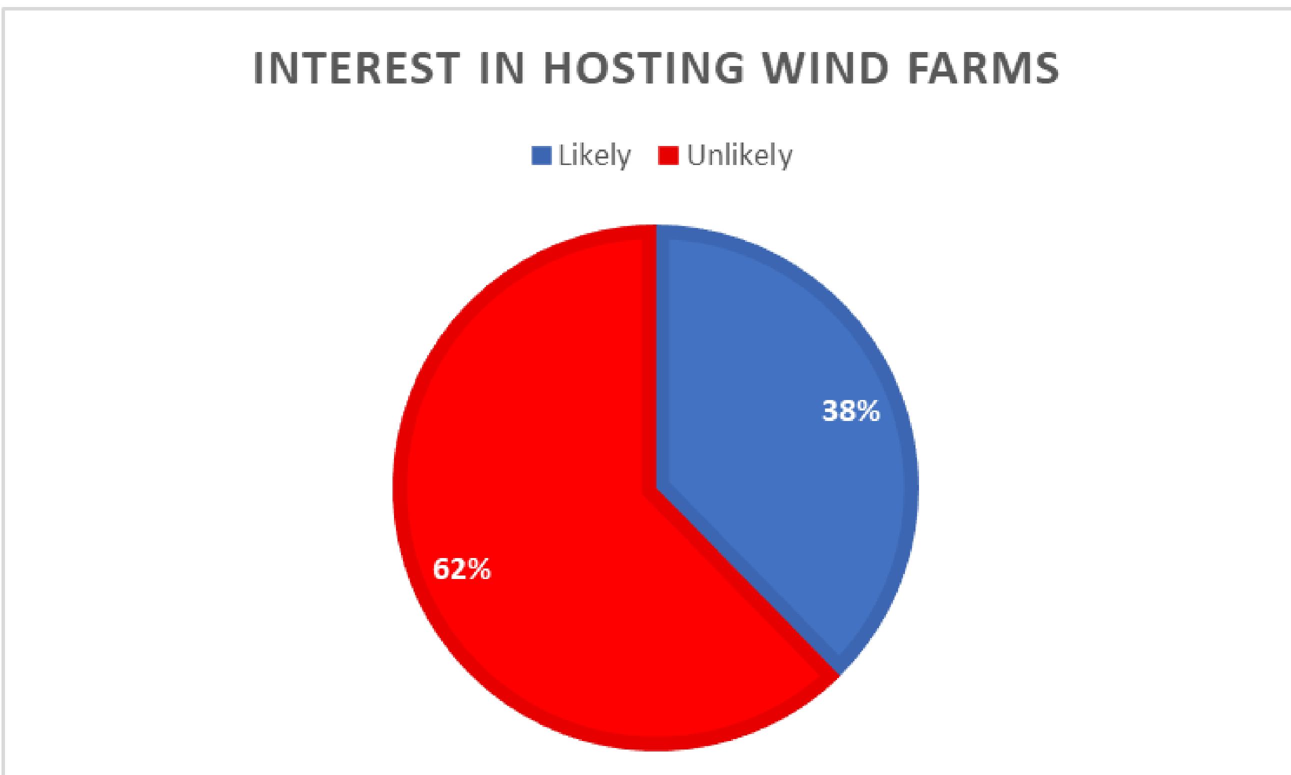



*Figure 40: Respondent interest in hosting wind farms*

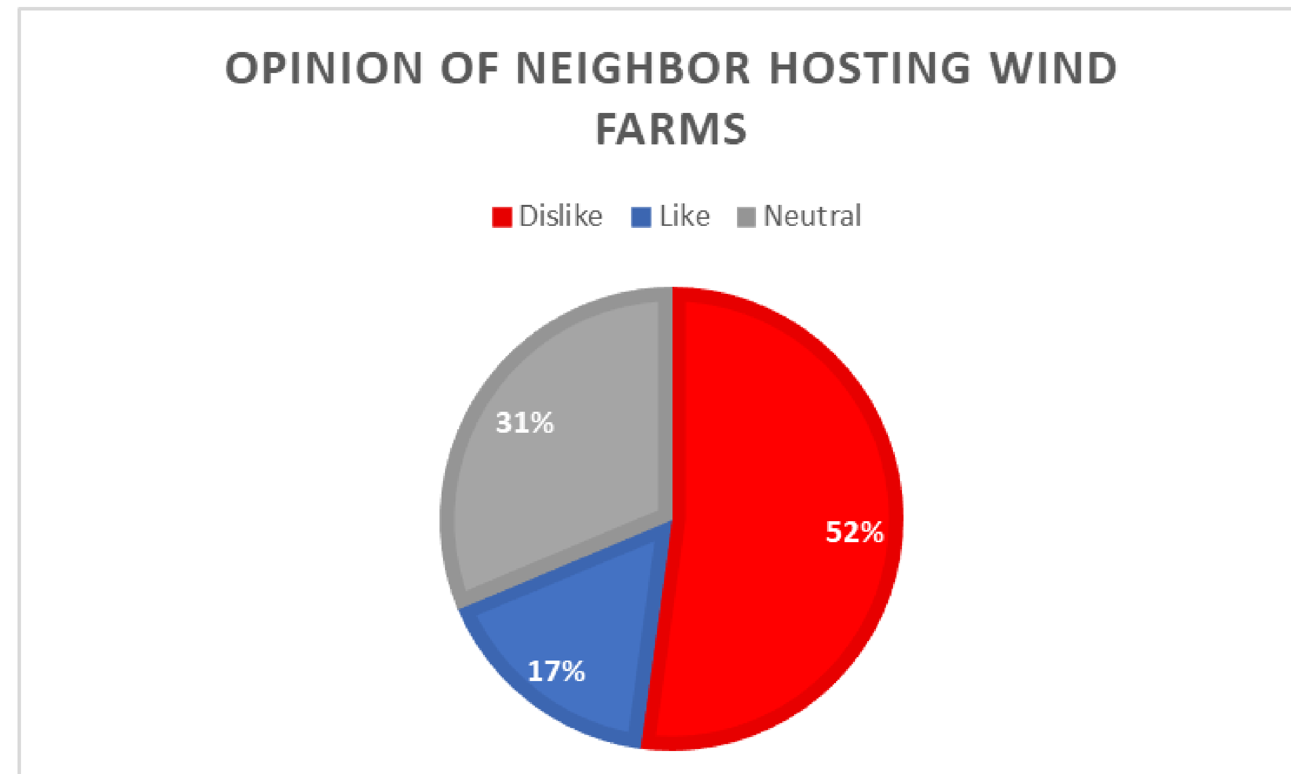



*Figure 41: Respondent opinion of neighbor hosting wind farms*

## Rural vs. City/Incorporated Perception on Wind Farm Siting

Survey responses from rural and city/incorporated residents were analyzed to see the difference in perception of these large-scale utility farms. Rural opinion on their neighbor hosting a wind farm was 67% dislike, 25% neutral, and 8% dislike. The majority of rural residents are opposed to their neighbors hosting a wind farm.

City/Incorporated opinion on neighbor siting a wind farm is more positive than the rural respondents with 40% dislike, 36% neutral, and 24%. The 36% being neutral is open for educational events and public outreach.

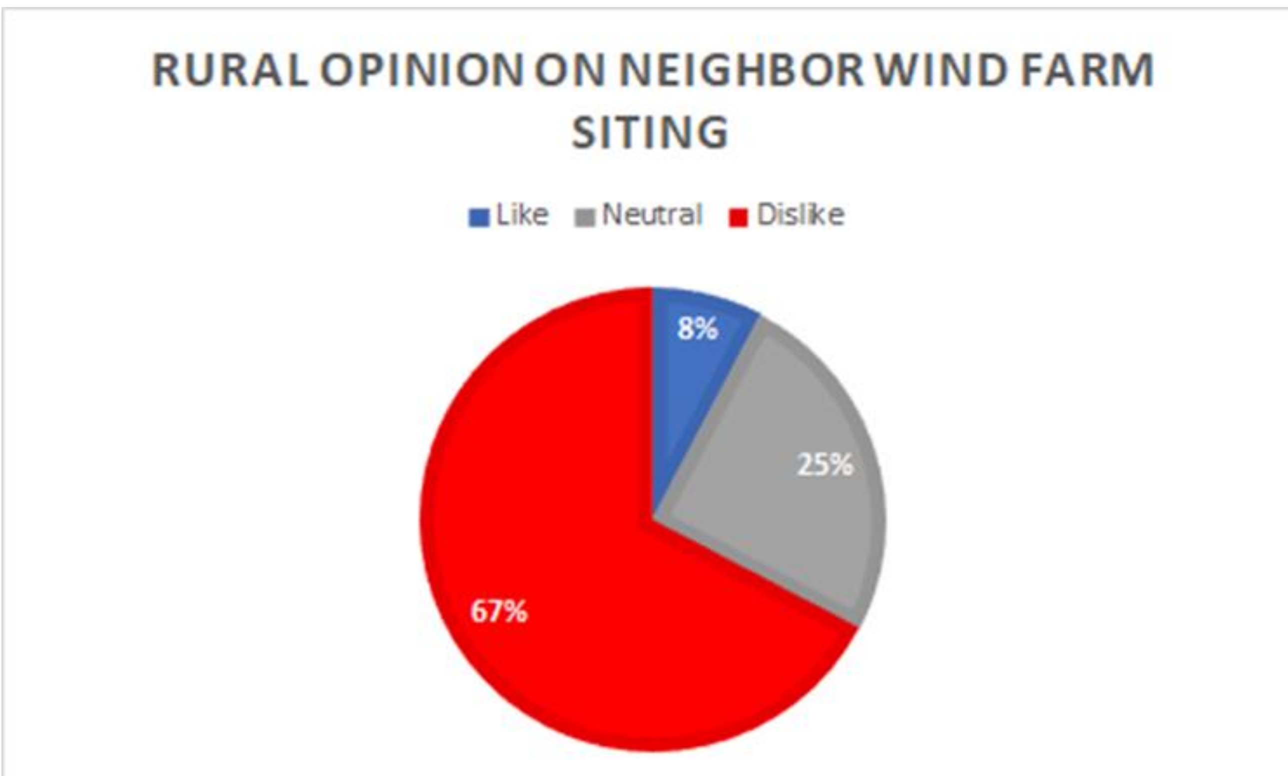



*Figure 42: Rural opinion on neighbor wind farm siting*

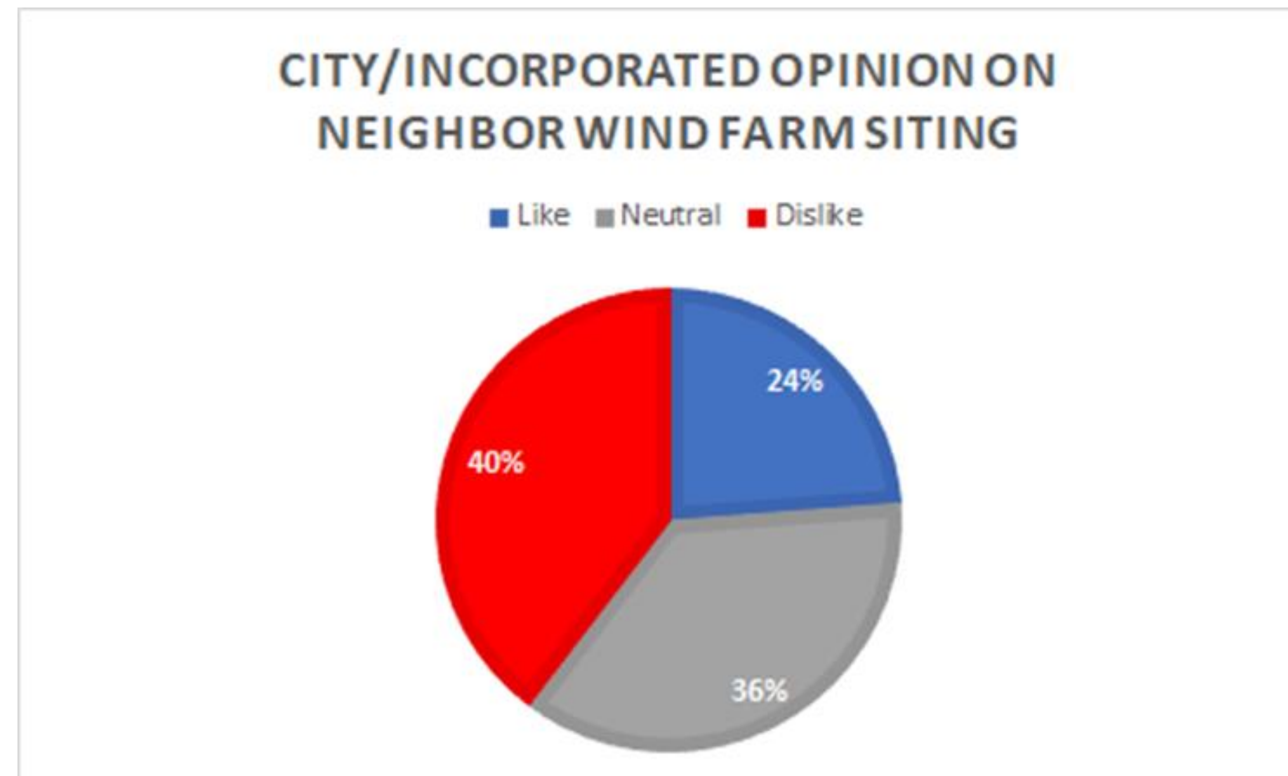



*Figure 43: City/incorporated opinion on neighbor wind farm siting*

## Rural vs. City/Incorporated Opinion on Land-Lease Agreements

Land-lease agreements are the monetary payments landowners get for hosting wind farms on their properties. These payments can range depending on the size and quantity of wind turbines on the land. Rural opinion was mostly negative with 66% unlikely to host, 15% neither likely or unlikely, and 19% likely. This could be based on the lack of knowledge on the amount of money provided from the land-lease agreements.

City/incorporated opinions on land-lease agreements are mostly positive with 55% likely to hose, 6% neither likely or unlikely, and 39% unlikely.

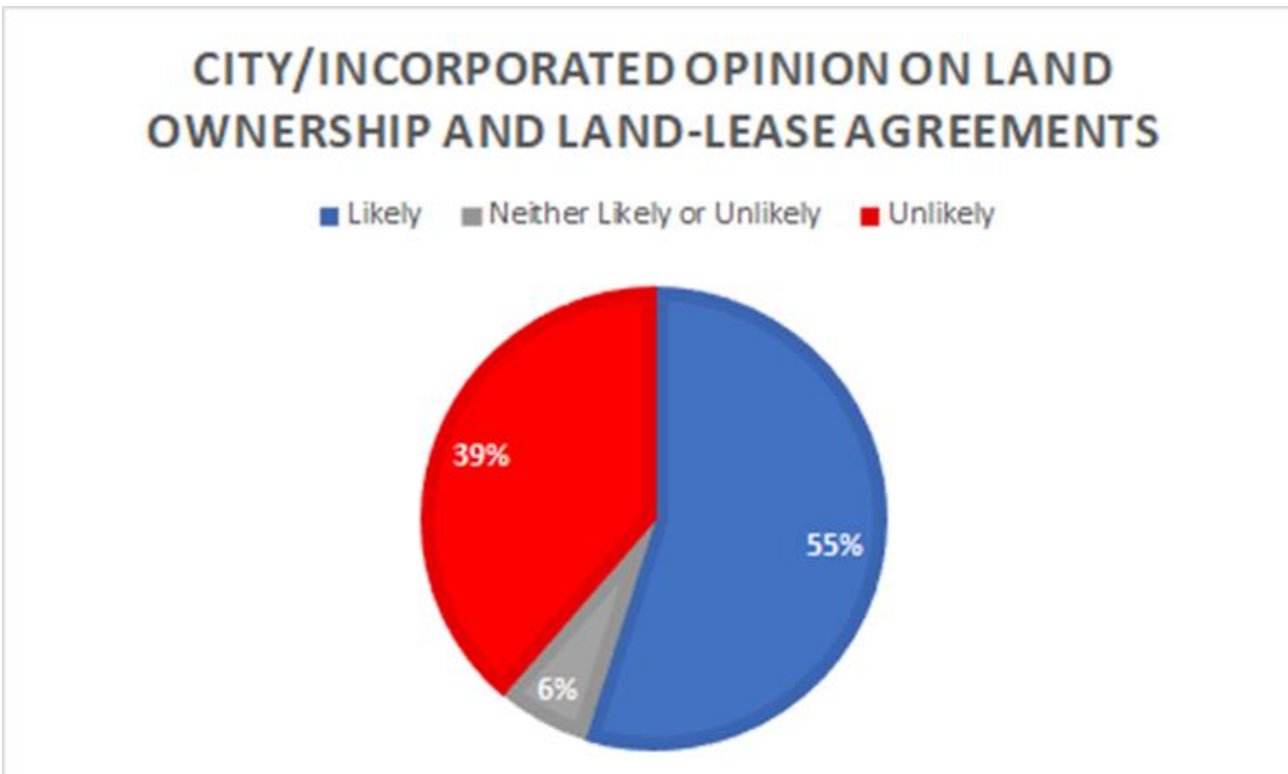



*Figure 44: City/incorporated opinion on land-lease agreements*

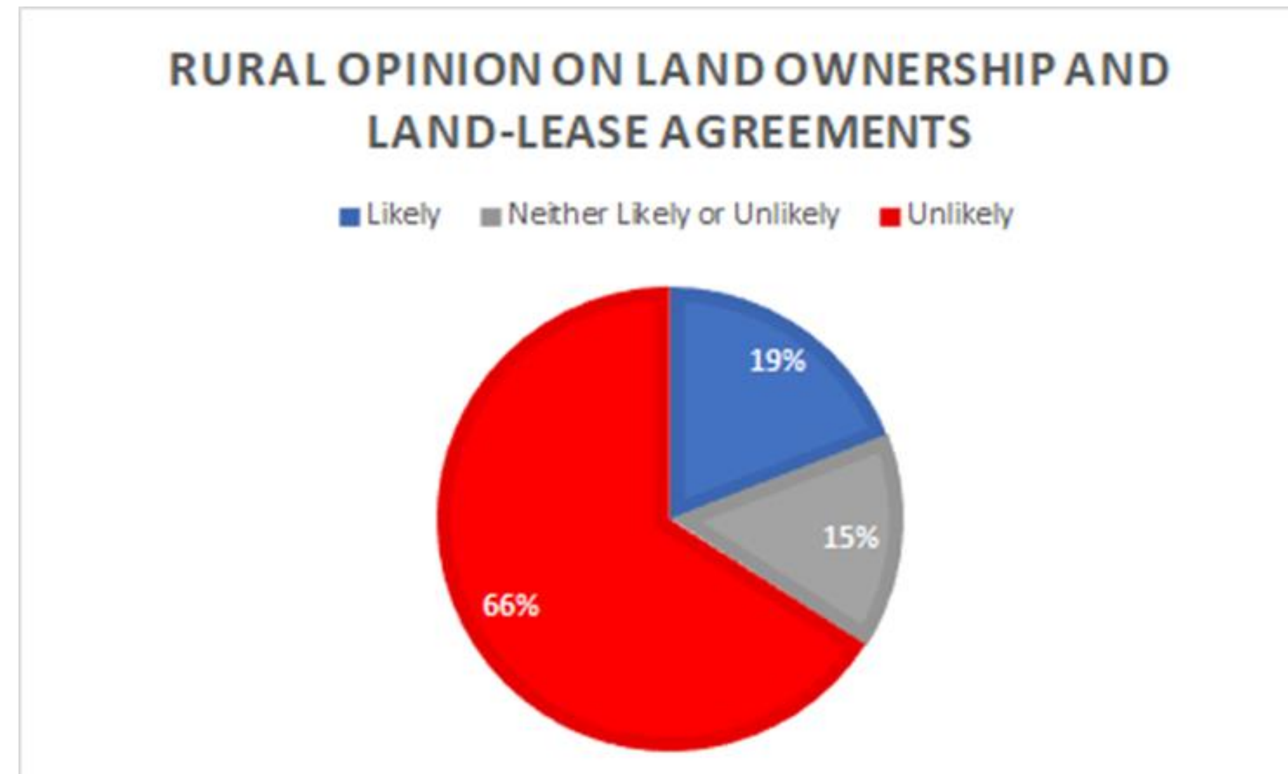



*Figure 45: Rural opinion on land ownership and land-lease agreements*

## Conclusions and Recommendations from Survey Findings

**Conclusions**

- People were favorable towards solar energy.
- People seem to be more uncertain about the externalities of wind energy.
- Developers will have to deal with heavy public opposition when applying for a conditional use permit for wind farm

**Recommendations**

- Use report and GIS model to guide staff report recommendations on conditional use permit.
- Encourage wind developers to host “Wind Power Hour” educational and information sessions to ease resident’s concerns.
- Ensure adequate time frames for public input to avoid lawsuits and problems after wind farm approval.

# 3.4 Policy Research

In the United States, local, state, and federal government policies regarding the siting and zoning of wind energy as well as best management practices share commonalities in terms of policy topics but differ in terms of specific regulations. As this is the case, it is difficult to recommend any specific regulations without first engaging in even more extensive policy research than what is already provided here and even more difficult to propose any finalized recommendations of regulatory specifics without having Linn County community stakeholders review the findings to determine their own comfort and tolerance with the range of possible regulations. The policy review presented here aims to provide Linn County decision makers with an initial introduction to the current set of wind energy practices that are recommended nationally and internationally. Linn county decision makers are encouraged to use the research as more of a reference guide in developing their own policies rather than a document of specific policy recommendations for immediate adoption. For general research on a wind energy topic, please consult the Appendix.

## General Application and Approval

**Policy Statements**
The Iowa Environmental Council recommends that Iowa counties follow the practices of Osceola and O'Brien Counties and include policy statements in their wind energy ordinances which explain the standards behind regulating wind energy developments (Baer, Kernek and Johannsen 2018). The Iowa Environmental Council also recommends that utility-scale wind energy applications generally follow a conditional use permit application process with clear and defined procedures and approval conditions (Baer, Kernek and Johannsen 2018).

**General Processes**
The National Regulatory Research Institute recommends seven best-practice procedures in siting utility-scale wind energy (Stanton 2012):

1. Establish and publish siting and zoning policies
2. Provide a single pre-application meeting to review procedures, permits, policies, and approvals
3. Identify and map exclusion, avoidance, and preferred wind energy development areas and make public such information
4. Prepare wind energy transmission plans in preferred wind energy development areas
5. Develop guidelines for public participation including public hearings
6. Gather technical documents, such as siting and zoning guidelines, checklists, and model ordinances, for local decision makers
7. Ensure the appropriate sequence of procedures are followed for any wind energy development

**Ordinances Checklist**
The American Planning Association (APA) provides a checklist of elements to be considered for ordinances (Rynne, et al. 2011):

- Definitions
  - Large wind, commercial systems should be defined in terms of capacity, such as over 1 MW.
- Allowed Uses
  - Utility-scale wind energy are normally permitted through conditional or special use, though some are permitted as-of-right and some through wind energy overlay districts
- Setbacks
  - Setbacks are usually in terms of the wind turbine height, though there are also absolute distances
  - Setbacks are normally required from structures, property lines, and public roads or right-of-ways
- Tower Height
  - Generally no height restrictions as wind turbine technology develops
- Electromagnetic Interference
  - In general, wind turbines must not cause interference with microwaves, television, radio, or navigation
  - They may be considered near military installations
- Visual Appearance
  - Usually wind turbines are to be painted in a neutral color and nonreflective, lighted by FAA guidelines, and limited signage
- Noise
  - Normally audible wind turbine noise to be below 40 dBA to 55 dBA at property lines
  - Possible waiver from signed consent of property owners
- Shadow Flicker
  - Some limit shadow flicker by setting a distance of more than 2,500 feet from wind turbines and some limit exposure to 30 hours per year
  - Possible waiver from signed consent of property owners
- Minimum Ground Clearance
  - Usually between 12 and 50 feet
- Safety
  - Measures to prevent unauthorized climbing and fencing around electrical substations and other utilities. Post emergency contact information may also be posted.
- Decommissioning
  - Decommissioning conditions may include when wind turbines will be decommissioned or the amount of restoration of the site and the roads
  - Financial assurance as decommissioning bonds, letters of credit, or other guaranties may be required

**Federal Agencies and Regulations**
In addition to local and state governments and policies, the following federal agencies and requirements may also be involved in wind energy development (Stanton 2012):

- The Federal Aviation Administration (FAA)

    - Determination of No Hazard to Air Navigation
    - Notice of Proposed Construction (Form FAA 7460-1)
    - Lighting plan
    - Post-construction Form (Form FAA 7460-2)
- U.S. Fish and Wildlife Services (USFWS)
    - Threatened Endangered Species Act
    - Section 7 Consultation and Migratory Bird Act
- U.S. Army Corps of Engineers (COE)
    - Clean Water Act Section 404 – Discharge of Fill Materials
    - Rivers and Harbors Act Section 10
- Federal Communications Commission (FCC)
    - Microwave studies
- U.S. Environmental Protection Agency (USEPA)
    - Spill Prevention, Control, and Countermeasures Plan (SPCC Plan, 40 CFR 112)
    - U.S. Military
        - Non-interference with flight operations and radar determination

**Application Documents**
The American Planning Association (APA) recommends the following documents to be included in permitting wind energy projects (Rynne, et al. 2011):

- A site map and plan of all wind turbine locations, including supporting infrastructure such as buildings, roads, utilities, tree cover, and other environmental features
- Landowner lease-agreements
- Environmental permits, including erosion and stormwater management from the appropriate authorities
- Utility interconnection agreements
- FAA approvals and lighting plans
- Highway access permits from the state departments of transportation
- Wildlife impact studies and monitoring agreements, with the U.S. Fish and Wildlife Service
- Road condition inventory and repair agreements
- Shadow flicker analyses
- Noise studies
- Visualizations or viewshed impact studies
- Decommissioning plans

Utility-scale wind energy applications are recommended to include stamped engineering documents from professional engineers who have designed the wind turbine equipment and facilities according to site-specific conditions (The Northwest Wind Resource & Action Center 2015).

To evaluate the visual impacts of a wind energy development, the Clean Energy States Alliance recommends the inclusion of several graphical documents and information as application materials. These include (Vissering, Sinclair and Margolis 2011):

- a project map
    - A project maps showing the locations of the wind turbines, access roads, clearing limits, meteorological towers, collector lines, substation locations, new transmission lines, laydown or temporary storage areas, and any buildings or structures
- a viewshed map, also known as a zone of visual influence map
    - A viewshed map, or a zone of visual influence map, combines data from Digital Elevation Models (DEMs) and GIS through viewshed mapping software to determine visibility within certain areas or distances
    - This document is used in initial evaluations to determine areas without visibility and other sight impacts, such as the visibility of FAA lights at various nacelle heights
    - There are two types of this document
        - Worst-case Scenario, which only accounts for topographic interference
        - Base Scenario, which accounts for visibility with topographic and vegetative interference
- the identification of natural and cultural resources and features
    - These include mountains, rivers, lakes and ponds, parks, natural areas, local, state, and federal highways, towns and historic sites
    - In general, these features should be publicly accessible and representative of areas with the most scenic quality and visibility
- photographs of existing visual character
    - Areas to photograph include public viewing areas, such as public parks, trails, recreational areas, water bodies, thoroughfares, overlooks, town centers, and historic sites
    - Photographs should be taken with GPS coordinates under good weather and visibility conditions
- simulations or visualizations
    - Professionals should prepare simulations or visualizations of the proposed wind turbines in photographs at various viewpoints using digital terrain modeling (DEM) and software
    - Viewpoints used should be the most visually sensitive areas, such of those of scenic or cultural value, areas of heavy public use, and other specified areas determined by local authorities and the public
    - Simulations or visualizations are helpful in depicting the wind energy project's visibility with respect to their surrounding landscape

**Public Consultation**
The European, non-government organization, Promotion of Renewable Energy and Development of Actions at a Community Level (PREDAC), recommends a maximum of 6 months for all permits to be obtained (Poussard, et al. n.d.). PREDAC also recommends a total of 2 public consultations over a period of 4 weeks (Poussard, et al. n.d.). Neighbors between 6,561.7 to 16,404.2 feet (2 to 5 kilometers) should be invited to the public consultation meetings (Poussard, et al. n.d.). During the public sessions, the project should be presented, and the planning process explained to the public (Poussard, et al. n.d.). A public official in the permit process should also attend the public sessions (Poussard, et al. n.d.).

The Rhode Island Department of Administration Division of Planning recommends notifying telecommunication operators before any wind energy proposals are approved (Rhode Island Department of Administration Division of Planning 2012).

**Approval Authority**

There are some differences in the final approval authorities among Iowa counties. In Kossuth County, commercial wind projects require a conditional use permit within a specified district to be ultimately approved by the County Board of Supervisors; whereas in Poweshiek County, the final approval authority rests with the Board of Adjustments (Baer, Kernek and Johannsen 2018).

## General Setbacks and Height

**Residential Properties and Occupied Structures**

In a review of Iowa wind energy ordinances, the Iowa Environmental Council found that most Iowa county ordinances have setbacks expressed in feet rather than in a percentage of total turbine height (Baer, Kernek and Johannsen 2018). The range of setbacks are between 1,000 feet to 1,250 feet: some Iowa counties have shorter setbacks, such as Boone County, and some counties have longer ones, such as Kossuth and Palo Alto Counties (Baer, Kernek and Johannsen 2018). The Iowa Environmental Council recommends a minimum setback of 1,000 feet from occupied structures (Baer, Kernek and Johannsen 2018). Wind energy developers report 1,500 feet as the maximum setback for viable utility-scale wind energy projects (Baer, Kernek and Johannsen 2018).

The State of Rhode Island Division of Planning recommends a setback of at least 2 times the turbine height from residential property boundaries (Rhode Island Department of Administration Division of Planning 2012).

PREDAC, a European, non-government organization, does not recommend any minimum setback distance to residential structures other than for noise, shadow flicker, and landscape considerations (Poussard, et al. n.d.).

**Property Lines**

The Iowa Environmental Council found that most Iowa counties have setbacks from property lines of 1.1 to 1.25 times the total turbine height (Baer, Kernek and Johannsen 2018). Clay County has setbacks from property lines of 110% or 1.1 times the total turbine height (Baer, Kernek and Johannsen 2018). Kossuth County, one of the few Iowa counties to express setback from property lines in feet, has setback of 600 feet from property lines (Baer, Kernek and Johannsen 2018).

**Unoccupied Structures and Right-of-Way**

The Iowa Environmental Council recommends similar setbacks for unoccupied structures and the right-of-way as for residential properties and occupied structures (Baer, Kernek and Johannsen 2018).

The Iowa Utilities Board does not have setback distances for wind turbines or other electric generation facilities from roads, farms, wetlands, or other towers under Section 199 of the Iowa Administrative Code, Chapter 24 (Iowa Utilities Board n.d.).

The State of Rhode Island Division of Planning recommends a setback of at least 1.5 times the turbine height from all other non-residential property boundaries and a setback of 1.25 to 1.5 times the turbine height from all public roads and right-of-way (Rhode Island Department of Administration Division of Planning 2012).

PREDAC, a European, non-government organization, recommends that wind turbines be sited at least the rotor radius away, with no overhang, from the edge of roads, railways, or waterways and at least the rotor diameter away from high voltage lines (Poussard, et al. n.d.).

**Natural Areas**

Setbacks from natural areas vary among Iowa counties. Kossuth County has a 600 feet setback from public conservation areas, Palo Alto County has a 1,500 feet setback from all public lands and public waterways, Boone County has a 1,320 feet setback from river bluffs, a 600 feet setback from public conservation areas, and a 600 feet setback from wetlands specified in the county zoning ordinance (Baer, Kernek and Johannsen 2018). A few Iowa counties require setbacks from natural areas on a project-by-project basis, such as Dickinson, Ida, and Palo Alto Counties which require wind energy developers to consult with the Iowa Department of Nature Resources (DNR) and then include the DNR's recommendations along with a site plan in addition to other application materials (Baer, Kernek and Johannsen 2018).

**Setback Waivers**

The Iowa Environmental Policy Council recommends that Iowa counties include setback waivers when appropriate (Baer, Kernek and Johannsen 2018). For example, Kossuth and Palo Alto Counties permit setbacks for any property type to be waived (Baer, Kernek and Johannsen 2018).
The State of Rhode Island Division of Planning notes that waivers for reduced setback may be permitted if a notarized letter confirming that the reduced setbacks would not have adverse effects and other written evidence, such operating protocols, safety programs, or recommendations from the manufacturer or a licensed engineer, are submitted in the wind energy development application (Rhode Island Department of Administration Division of Planning 2012).

**Height**

Unlike its recommendations for setbacks, the Iowa Environmental Council does not recommend Iowa counties to establish any height restrictions (Baer, Kernek and Johannsen 2018). Several Iowa counties require wind energy applicants to include a copy of a Federal Aviation Administration (FAA) permit or approval with their wind energy development application (Baer, Kernek and Johannsen 2018). The FAA determination, along with the recommended setbacks, should address concerns with utility-scale wind turbine heights (Baer, Kernek and Johannsen 2018).

Wind turbine rotors need to be placed higher than any surrounding structures to ensure that the rotor blades have unobstructed access to the wind flow and to reduce turbulence, which may later reduce wind quality and contribute to equipment wear and tear (The Northwest Wind Resource & Action Center 2015). Industry best practices note that the entirety of the wind turbine rotor should be at least 30 feet higher than any objects within 500 of the turbine tower (The Northwest Wind Resource & Action Center 2015). Even in flat and open terrain, the recommended minimum tower height is 60 feet (The Northwest Wind Resource & Action Center 2015). The imposition of height limits may limit the productivity and economic viability of a wind energy project (The Northwest Wind Resource & Action Center 2015).

## Meteorological Towers

**Markings**

In Iowa, the Iowa Agricultural Aviation Association advocates that meteorological towers should be marked according to FAA recommendations (Iowa Agricultural Aviation Association 2016).

For marking meteorological towers, the Iowa Environmental Council recommends adaptation of a requirement like Poweshiek County's installation of visible and reflective objects on guyed towers or installing plastic orange balls on guy-wires (Baer, Kernek and Johannsen 2018).

To assist aerial applications, the North Dakota Agricultural Aviation Association recommends that meteorological towers should be painted or brightly lit and any guy wires or supports should be marked and made visible (Gustafon 2009).

The FAA Extension, Safety, and Security Act of 2016 requires that towers, such as meteorological towers of at least 50 feet and no more than 200 feet above ground level, be marked according to FAA Advisory Circular 70/7460-1L and recorded in a FAA database with their location and height (114th Congress 2016, National Agricultural Aviation Association 2019). Following objections from the telecommunications industry, the FAA Reauthorization of 2018 permits telecommunication towers to be marked or logged but not both, while meteorological towers must be both marked and recorded in the FAA database (115th Congress 2018, National Agricultural Aviation Association 2019).

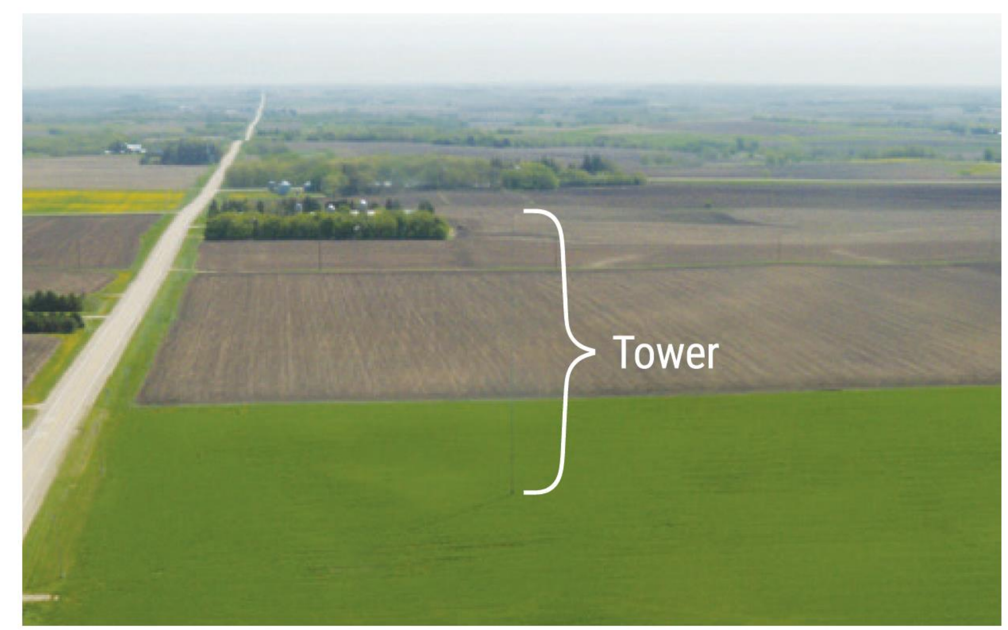



*Figure 46: An unmarked tower as sited in a field is nearly invisible Source: National Transportation Safety Board*

## Airports and Aerial Application/Crop Dusting

**Siting and Setbacks**

In Iowa, the Iowa Agricultural Aviation Association states that wind turbines should be sited in non-agricultural areas (Iowa Agricultural Aviation Association 2016).

The North Dakota Agricultural Aviation Association proposes a distance of at least 2,000 feet between wind turbine towers and fields that may be aerially sprayed and recommends a separation distance of 1 mile from an airport or runway (Gustafon 2009). Additionally, the North Dakota Agricultural Aviation Association recommends that wind turbines be placed linearly with enough room for aircraft to maneuver (Gustafon 2009).

The National Agricultural Aviation Association suggests operation procedures for pilots flying around meteorological towers and wind turbines, such as ferrying above 500 feet even in low population density areas and establishing a boxed work area (National Agricultural Aviation Association n.d.).

PREDAC, a European, non-government organization, recommends that wind turbines should not be sited in airport fly funnels and where they may interfere with aviation (Poussard, et al. n.d.). However, PREDAC also recommends that wind turbines may be sited in low fly and military zones (Poussard, et al. n.d.). Wind turbines sited closer than 12 kilometers (39,370.1 feet) from military and other defense installations should consult the appropriate authorities (Poussard, et al. n.d.).

**Mitigation**

There are several mitigation approaches between crop dusting and wind energy development. These include having wind turbines sited linearly, having wind energy developers notify surrounding businesses and landowners early and contribute to a centralized system of registered structures and location information, increasing markings for meteorological towers and wind turbines beyond any minimum legal requirements, and educating crop dusters on the risks and operations around wind turbines (Manjooran 2013). In Dekalb County, Florida Power and Light Energy Illinois Wind, a subsidiary of NextEra Energy, created a hotline for crop dusters so that wind turbines could be temporarily halted by the company for aerial applications and operations (Manjooran 2013). An additional proposal was made to non-participating landowners within half a mile of a wind turbine for some compensation in potentially losing some of their access to aerial application (Manjooran 2013).

In Wisconsin, state code directs wind energy developers to compensate famers on both participating and non-participating properties within half a mile of a wind turbine if there was an existing history of aerial spraying and that wind energy developments resulted in material reduction in production or material increase in application costs to growing potatoes, peas, snap beans, or sweet corn (Manjooran 2013).

## Wind Farm Transportation

**Mitigation**

In Poweshiek County, a pre-construction and post-construction survey of roads is completed so that the post-construction survey can be used to address any impacts or damages to roads (Baer, Kernek and Johannsen 2018).

In Minnesota, taxes may be collected from wind developers, but neither the Minnesota Public Utilities Commission (PUC) nor Minnesota legislation specifies how much of the collected taxes must be specifically reserved for road maintenance (Kronick 2011). Several Minnesotan county engineers, funded by the Minnesota Local Road Research Board and assisted by a Minnesota State University Mankato professor, developed a tool, “Best Practices: Managing Interaction Between Local Authorities and Major Traffic Generators, to provide engineers and other agency members with a guide to monitor and control roads during the construction of wind farms (Kronick 2011). The tool is a spreadsheet that calculates an assessment cost to a wind farm or any other project that places heavy loads on asphalt roads: the cost is an estimate of the road damage calculated by finding the difference in cost between a road designed with large traffic generation and a road designed without (Kronick 2011). The results of the calculation can then be used to estimate the cost per ESAL, or per installed turbine (Kronick 2011). This guide and tool may be beneficial for county secondary road departments to review before any wind energy developments.

## Wind Farm Construction

**Construction Inspections**

It is recommended that tower foundations and the poured concrete are inspected during the construction process to conform with manufacturer specifications (The Northwest Wind Resource & Action Center 2015).

## Visual and Aesthetic

**Federal Act**

The National Historic Preservation Act of 1966 contains Section 106, which directs federal agencies to consider the effects of their projects on historic properties (Advisory Council on Historic Preservation 2016). Historic properties are defined as a "prehistoric or historic district, site, building, structure, or object included in or eligible for inclusion in the National Register of Historic Places" and includes "artifacts, records, and remains" as well as "properties of traditional religious and cultural importance to an Indian tribe or Native Hawaiian organization" (Advisory Council on Historic Preservation 2016). The following includes potential adverse effects federal projects may have on historic properties (Advisory Council on Historic Preservation 2016):

- physical destruction or damage
- alterations inconsistent with the Secretary of the Interior's Standards for the Treatment of Historic Properties
- historic property relocation
- changes in the property's use or setting
- incompatible visual, atmospheric, or audible elements
- neglect and deterioration
- transfer, lease, or sale of a historic property out of federal control without preservation restrictions

The following questions help to determine whether a project requires Section 106 review (Advisory Council on Historic Preservation 2016):

1. Is the property federally owned or controlled?
2. Does the project receive federal funds, grants, or loans?
3. Does the project require federal permits, licenses, or other approval?

Most wind energy projects are from non-federal entities. Section 106 often concludes with a legally binding agreement on how the adverse effects of a federal project can be avoided, minimized, or mitigated (Advisory Council on Historic Preservation 2016). Specific regulations of Section 106 can be found in the Code of Federal Regulations at 36 CFR Part 800 "Protection of Historic Properties" (Advisory Council on Historic Preservation 2016).

**Visual Impact Evaluation**

The Clean Energy States Alliance recommends a two-step process for evaluating visual impacts of wind energy projects. The first step is to consider the visual impact of the project using four criteria (Vissering, Sinclair and Margolis 2011):

1. What are the project's visible elements?
2. What are the nature and distinctive features of the surrounding landscape?
3. What are the scenic elements and their sensitivity levels?
4. How will the project be seen or experienced from surrounding viewpoints?

Factors for consideration in the first step include: project scale and size, the proximity to the project, the duration of the view, the angle of the view, whether the view is panoramic or narrow, the number of visible turbines and the area of the view occupied, the presence of visual clutter, FAA lighting, and shadow flicker. (Vissering, Sinclair and Margolis 2011). The second step is to determine whether the visual impact of the project is "undue" or "unreasonable" using three criteria (Vissering, Sinclair and Margolis 2011):

1. Does the project violate any written, protective aesthetic standard?
2. Does the project dominate views from sensitive viewing areas or the region?
3. Has the developer failed to take measures to mitigate the project's visual impacts?

Factors for consideration in the second step include: the proximity of the view, the duration of the view, the direction of the view, viewer expectations for natural or intact landscapes, the uniqueness of the scenic resource, and whether a large number of wind turbines are visible in many of the views (Vissering, Sinclair and Margolis 2011). Furthermore, the Clean Energy States Alliance forwards three additional considerations in evaluating visual impacts (Vissering, Sinclair and Margolis 2011):

1. Statistically based and independently conducted surveys should be conducted pre and post construction to determine public perceptions regarding visibility concerns
2. Numerical or scoring systems should not be used for evaluation because of the difficulties behind quantifying visual resources
3. There are a variety of visual evaluation bodies employed by different states: a panel of experts, an aesthetic impact professional hired by wind energy developers, or an independent professional for visual evaluations

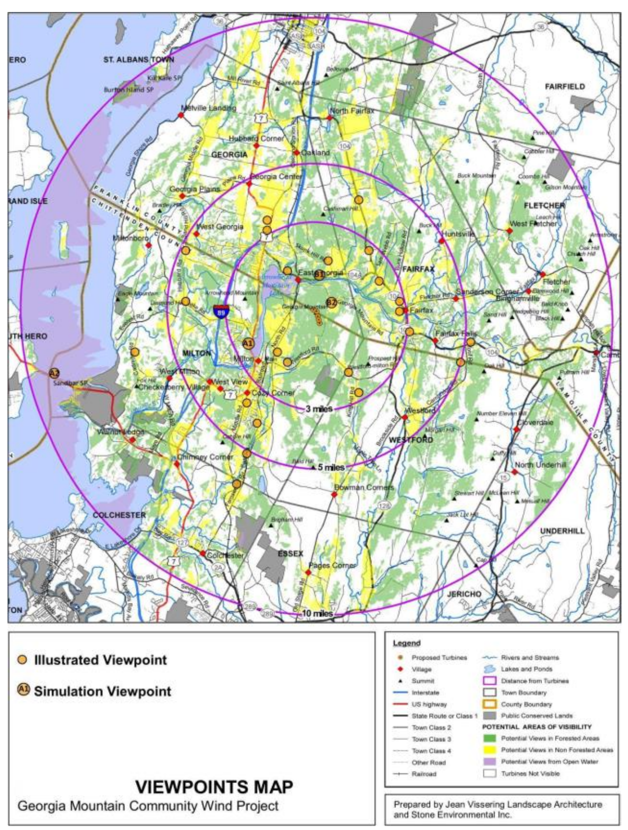



*Figure 47: An example of a viewshed analysis map with selected viewpoints Adapted from Vissering, Sinclair, and Morgolis, 20111*

**Visual Impact Mitigation**

The Rhode Island Department of Administration Division of Planning recommends municipalities require a view-shed impact study with photo simulations, with specific focus on various viewpoints during different seasons (Rhode Island Department of Administration Division of Planning 2012).

Other visual impact mitigation measures include appropriate siting, downsizing, relocating, lighting, turbine placement reconfiguration, project screening, turbine color, ensuring the same turbines for replacements, having a decommissioning plan, using non-reflective materials, minimizing the removal of vegetation, and burying or appropriately siting power lines (Vissering, Sinclair and Margolis 2011).

## Natural Environment and Wildlife

**Federal Acts**

Federally, there are three main wildlife acts of concern for wind energy developments. These are the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Endangered Species Act:

1. The Migratory Bird Treaty Act is composed of four international treaties that "[prohibit] the taking, killing, possession, transportation, import and export of migratory birds, their eggs, parts, and nests" unless authorized by the U.S. Department of the Interior (U.S. Fish & Wildlife Service 2012). The term "taking" is defined as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, wound, kill, trap, capture, or collect" (U.S. Fish & Wildlife Service 2012). Thousands of migratory birds, including eagles and other raptors, waterfowl, shorebirds, seabirds, wading birds, and passerines, are protected under the Act, but introduced species, such as the house (English) sparrow, European starling, rock dove (pigeon), Eurasian collared dove, and non-migratory upland game birds, are not protected (U.S. Fish & Wildlife Service 2012). The U.S. Fish and Wildlife Service maintains a list of protected migratory bird species available for future reference.
2. The Bald and Golden Eagle Protection Act "prohibits the take, sale, purchase, barter, offer of sale, purchase, or barter, transport, export or import, at any time or in any manner of any bald or golden eagle, alive or dead, or any part, nest, or egg" (U.S. Fish & Wildlife Service 2012). The term "taking" is defined as to "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb"; the term "disturb" is defined as "agitating or bothering an eagle to a degree that causes, or is likely to cause, injury, or either a decrease in productivity or nest abandonment by substantially interfering with normal breeding, feeding, or sheltering behavior" (U.S. Fish & Wildlife Service 2012).
3. Lastly, the Endangered Species Act instructs the U.S. Fish and Wildlife Service to identify, protect, and conserve any endangered and threatened species along with their habitats (U.S. Fish & Wildlife Service 2012). Candidate species may also receive similar treatment (U.S. Fish & Wildlife Service 2012). Terrestrial and freshwater species are managed by the U.S. Fish and Wildlife Service, while the National Marine Fisheries Service manages marine species (U.S. Fish & Wildlife Service 2012). The Act prohibits the "taking" of any listed species, defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage", but permits two forms of "incidental takings" (U.S. Fish & Wildlife Service 2012). The first is taking through lawful means when there is a federal agency, funding, or permit involved; the second is when an incidental taking permit is applied for in conjunction with the submission of a habitat conversation plan (HCP) (U.S. Fish & Wildlife Service 2012). Wind energy developers, operating without any federal funding or authorization, are advised to obtain an incidental taking permit if their activities may likely result in the taking of a listed species (U.S. Fish & Wildlife Service 2012).

**Mitigation**

Collision mitigation for birds and bats depend on wind energy siting and operations. Certain topographic features, such as ridge tops, upwind sides of slopes, and canyons should be avoided as large raptors rely on wind currents created by those features (American Wind Wildlife Institute 2017). Other landscape features to avoid include valleys, ridgelines, and riparian systems as they play a role in bat activities and migration routes (American Wind Wildlife Institute 2017). Operational practices may be altered to mitigate wildlife collisions. Wind energy developers may follow a tiered framework approach proposed by the U.S. Fish and Wildlife Service (American Wind Wildlife Institute 2017). Another technique is to halt wind turbine blades during low wind speeds (American Wind Wildlife Institute 2017). Stopping turbine blades or raising the cut-in speed to 5 to 6 meters/second during periods of migration have significantly reduced bat fatalities (Rhode Island Department of Administration Division of Planning 2012). Research indicates reductions in bat fatalities of 50% to 87% compared to normally operating turbine blades with this strategy (American Wind Wildlife Institute 2017). Shutting down wind turbines with high fatality rates may be effective at reducing certain raptor fatalities (American Wind Wildlife Institute 2017). Another strategy may be to use radar or acoustic devices. While research on whether radar and acoustic devices can predict collision risks are uncertain, ultrasonic transmitters may reduce bat fatalities by preventing them from approaching rotor swept areas (American Wind Wildlife Institute 2017). Attempts at coating wind turbine towers and blades with ultraviolet (UV) paint to make them more visible to birds and raptors to reduce collisions do not appear to be successful (American Wind Wildlife Institute 2017). Repowering older wind turbines between 40-330 kW that use a lattice support structure with newer wind turbines equal or more than 1 MW that use a tubular structure may reduce raptor collision fatalities by removing potential perching areas near the rotor swept area (American Wind Wildlife Institute 2017).

**General Framework of Tiered Approach**

**<u>TIER 1</u>**
A. Species of concern known to be present?
1. No ....................proceed to Tier 2
2. Unknown - Insufficient or inconclusive data ............proceed to Tier 2
3. Yes....................abandon site or proceed to Tier 2

**<u>TIER 2</u>**
A. Probability of significant adverse impacts?
1. Unknown - Insufficient or inconclusive data ............proceed to Tier 3
2. Low..............proceed to obtain state and local permit (if required), design, and construction following BMPs
3. Moderate ....................proceed to Tier 3 and mitigate
4. High, and:
a. can be adequately mitigated...modify project and proceed to Tier 3
b. cannot be adequately mitigated....................abandon project

**<u>TIER 3</u>**
A. Probability of significant adverse impacts?
1. Low ....................proceed to Tier 4
2. Moderate to high, and:
a. certainty regarding mitigation .................... proceed to Tier 4
b. uncertainty regarding mitigation ....................proceed to Tier 4
3. High, and:
a. can be adequately mitigated....................proceed to Tier 4
b. cannot be adequately mitigated .............modify or abandon project

**<u>TIER 4a (See Table 2, pg 39)</u>**
A. Tier 3 studies indicate <u>low</u> probability of significant adverse impacts
1. Documented fatalities are equal to or lower than predicted....................no further studies or mitigation needed
2. Documented fatalities are higher than predicted, but not significant, and:
a. comparable data are available that support findings of not significant....................no further studies needed
b. comparable data not available to support findings of not significant................additional year(s) of monitoring recommended
3. Documented fatalities are higher than predicted and are significant....................communicate with Service

B. Tier 3 studies indicate <u>moderate</u> probability of significant adverse impacts
1. Documented fatalities are lower than or no different predicted, and:
a. are not significant and no ESA or BGEPA species are affected ....................no further monitoring or mitigation needed
b. are significant *OR* ESA or BGEPA species are affected ....................communicate with Service
2. Documented fatalities are greater than predicted and are likely to be significant *OR* ESA or BGEPA species are affected....................communicate with Service

C. Tier 3 studies indicate <u>high</u> probability of significant adverse impacts
1. Documented fatalities are less than predicted and are not significant, and no ESA or BGEPA species are affected....................no further monitoring or mitigation needed
2. Documented fatalities are less than predicted but are still significant, and no ESA or BGEPA species are affected....................further monitoring or mitigation needed
3. Fatalities are equal to or greater than predicted and are significant OR ESA or BGEPA species are affected....................communicate with Service regarding additional mitigation

**<u>TIER 4b (See Table 3, pg. 42)</u>**
A. Species of habitat fragmentation concern potentially present?
1. No....................no further studies needed
2. Yes, and:
a. Tier 3 studies do not confirm presence...no further studies needed
b. Tier 3 studies confirm presence, but no significant adverse impacts predicted, and:
i. Tier 4b studies confirm Tier 3 predictions....................no further studies or mitigation needed
ii. Tier 4b studies indicate potentially significant adverse impacts ..................Tier 5 studies and mitigation may be needed
c. Tier 3 studies confirm presence, and significant adverse impacts predicted and mitigation plan is developed and implemented, and:
i. Tier 4b studies determine mitigation is effective ....................no further studies or mitigation needed
ii. Tier 4b studies determine mitigation not effective...........further mitigation and, where appropriate, Tier 5 studies needed

*Figure 48: A tiered approach to risk evaluation and siting and operations decision making*
*Source: U.S. Fish and Wildlife Service, 2012*

The U.S. Fish and Wildlife Service offers best management practices for wind energy projects in the domains of site construction and operation, retrofitting, repowering, and decommissioning. In collecting wind resource data, wind energy developers should rely on the minimal number of permanent meteorological towers (U.S. Fish & Wildlife Service 2012). Pre-construction activities should be confined to a minimal area and existing infrastructure, such as existing roads, should be used (U.S. Fish & Wildlife Service 2012). Non-disturbance areas could be established with input from state, local, tribal, and federal authorities to protect sensitive wildlife and environments (U.S. Fish & Wildlife Service 2012). Wind energy siting should avoid affecting existing hydrology, stream morphology, wetlands, and water resources and use the appropriate erosion controls (U.S. Fish & Wildlife Service 2012). Tubular towers or the best available technology should be selected to decrease perching and collisions (U.S. Fish & Wildlife Service 2012). If guyed wires are necessary, bird flight diverters or high visibility marking devices should be used (U.S. Fish & Wildlife Service 2012) . When placing wind energy facilities, the latest state and federal data showing sensitive locations should be utilized to appropriately place infrastructure to avoid risk to wildlife and the environment (U.S. Fish & Wildlife Service 2012). PREDAC, a European, non-government organization, has observed risks to bird populations at distances of about 656.2 to 984.3 feet (200 to 300 meters) (Poussard, et al. n.d.). During the construction process, the construction of infrastructure, such as new access roads or fences, should be kept to a minimum (U.S. Fish & Wildlife Service 2012). When fencing is necessary, they should be compatible with wildlife (U.S. Fish & Wildlife Service 2012). Low and medium voltage lines should be buried unless there is excessive cost or greater environmental impact (U.S. Fish & Wildlife Service 2012). Any above ground low and medium voltage lines, transformers, and conductors should follow the most recent guidelines from the Avian Power Line Interaction Committee (APLIC)'s "Suggested Practices for Avian Protection on Power Lines" (U.S. Fish & Wildlife Service 2012). Overhead lines may be used if they are away from heavy bird crossing areas and marked according to APLIC guidelines (U.S. Fish & Wildlife Service 2012). Additionally, overhead lines may parallel tree lines, use bird diverters, or be screened (U.S. Fish & Wildlife Service 2012). When project construction is completed, roads not needed for project operations and maintenance should be closed and roadbeds restored with native vegetation (U.S. Fish & Wildlife Service 2012). Wildlife and environmental mitigation techniques during the operations phase may first begin with general policy to avoid any wildlife disturbances, such as enforcing driving policies to avoid wildlife collisions (U.S. Fish & Wildlife Service 2012). Plans should also be in place to address wildfires and toxic substances (U.S. Fish & Wildlife Service 2012). Generally, there should not be any additions that may enhance existing wildlife habitats (U.S. Fish & Wildlife Service 2012). Native species should be restored according to state and federal agencies and invasive species should be prevented and controlled according to the relevant authorities (U.S. Fish & Wildlife Service 2012). Other maintenance activities include garbage and waste disposal, including any animal carcasses, to prevent wildlife from gathering in proximity to the facilities (U.S. Fish & Wildlife Service 2012). Lastly, lighting at any facilities within a half mile of the wind turbines should be kept minimal (U.S. Fish & Wildlife Service 2012). Lighting within the turbines and on the tower should only be on when occupied (U.S. Fish & Wildlife Service 2012). Lights should be activated by motion or heat sensor and have hoods that direct light downward to prevent horizontal and vertical dispersion (U.S. Fish & Wildlife Service 2012). High intensity, steady, or bright lights such as sodium vapor, quartz, halogen, or spotlights should be avoided (U.S. Fish & Wildlife Service 2012). FAA required red, or dual red and white strobe, strobe-like, or flashing lights should be used instead of steady lighting (U.S. Fish & Wildlife Service 2012).

Impacts on wildlife during wind energy repowering can be mitigated. Existing infrastructure should be utilized as much as possible, including existing roads, developed areas, turbine formations, substations, and other facilities (U.S. Fish & Wildlife Service 2012). Overhead lines may be reused if they parallel tree lines, use bird flight diverters, or are screened to avoid wildlife collisions or are not situated in bird crossings (U.S. Fish & Wildlife Service 2012). Standing low and medium voltage lines, transformers, conductors, and other facilities should comply with the Avian Power Line Interaction Committee (APLIC)'s "Suggested Practices for Avian Protection on Power Lines" (U.S. Fish & Wildlife Service 2012). When infrastructure is no longer used, sites should be restored with native plants and soil conditions where possible or with landowner requirements (U.S. Fish & Wildlife Service 2012). Repowered wind turbines should avoid guyed wiring; if their use is necessary then bird flight diverters or high visibility marking devices should be used (U.S. Fish & Wildlife Service 2012). Additionally, repowered wind turbines may relocate to areas with lower avian density (U.S. Fish & Wildlife Service 2012). Repowered wind turbines should continue to comply with FAA lighting standards and repowered substations and facilities should minimize lighting within a half mile of turbines (U.S. Fish & Wildlife Service 2012). The aforementioned lighting specifications by the U.S. Fish & Wildlife Service should also be followed during repowering.

Impacts on the natural environment and wildlife during the decommissioning of wind energy projects can also be mitigated. Wind turbine foundations should be removed to a minimum of 3 feet below the surrounding grade as 3 feet of removal is normal for agricultural sites (U.S. Fish & Wildlife Service 2012). The subterranean area should be filled with soil for native plants and not pose any disruptions to ground water flows (U.S. Fish & Wildlife Service 2012). Surface water should be restored to original conditions (U.S. Fish & Wildlife Service 2012). Surveys by professionals should be conducted to detect invasive species and measures taken to prevent and control any invasive species until their removal (U.S. Fish & Wildlife Service 2012). Any topsoil removed during decommissioning operations should be stored and reused as topsoil to restore native vegetation or to satisfy landowner specifications (U.S. Fish & Wildlife Service 2012). Decommissioning operations should also take care to minimize any new site disturbances and the removal of any native vegetation (U.S. Fish & Wildlife Service 2012). Soil at decommissioned sites should be stabilized and restored with the appropriate native vegetation or according to landowner specifications (U.S. Fish & Wildlife Service 2012). Erosion controls should be applied where necessary (U.S. Fish & Wildlife Service 2012). Petroleum leaks, chemical releases, or spills should be cleaned before the end of decommissioning (U.S. Fish & Wildlife Service 2012). Any infrastructure and supporting facilities, such as overhead pole lines or fencing, should be removed unless the landowner specifies otherwise (U.S. Fish & Wildlife Service 2012).

## Karst

**Mitigation**

Karst investigations may present a financial cost of $20,000 or more per wind turbine site for wind energy developers (Bangsund and Johnson 2013). Karst evaluations should be conducted in a stepwise manner, so early detections can be known at lower costs to the developer while more expensive actions can be completed as the project progresses and has more funding available (Bangsund and Johnson 2013). Karst investigations may be divided into two forms, desktop studies or field studies. Each investigation method is listed in approximately increasing costs (Bangsund and Johnson 2013):

- Desktop studies include:
  - Literature search
  - Aerial-photo and map review, lineament analysis
  - Existing well and boring logs search
  - Survey of local experts
- Field studies include:
  - Site reconnaissance
  - Pit tests
  - Geophysics
  - Drilling (may include downhole camera and downhole mapping methods)

Karst risk may be mitigated through one of five strategies (Bangsund and Johnson 2013):

1. First, a more detailed investigation can be conducted before exploring whether the wind turbine should be moved to reduce risk.
2. Second, the wind turbines at risk may be moved.
3. Third, thick soil unrelated to the bedrock, such as glacial till or wind-blown deposits, may provide a bridge over bedrock karst features to mitigate subsidence risk. This method may be performed relatively cost-free during normal geotechnical investigations for foundation design, such as borings.
4. Fourth, alternative construction methods may be implemented, such as placing the foundation on piles supported by rock below the karst zone, grouting the potential voids to prevent collapse, or constructing a foundation that bridges the risk zone. These construction mitigation measures may add significant financial costs of hundreds of thousands to each wind turbine.
5. Lastly, karst risk may be avoided entirely by not proceeding with projects with significant karst risk.

## Electromagnetic and Telecommunications Interference

**Near-field Interference and Mitigation**

Telecommunication antennas have near-field zones in which objects that can interfere with radio waves should be avoided, such as 65.6 feet (20 meters) for High Band Ultra-High Frequency (UHF) signals of cellular phone services between 800 MHz to 1,900 MHz, 2,362.2 feet (720 meters) for point-to-point microwave links, and 13.1 feet (4 meters) for low-band VHF paging systems (Environment Protection and Heritage Council (EPHC) 2010). A conservative recommendation to mitigate near-field impacts is to site wind turbines 0.6 mile (1 kilometer) away from any telecommunicate site (Environment Protection and Heritage Council (EPHC) 2010).

**Radar Interference and Mitigation**

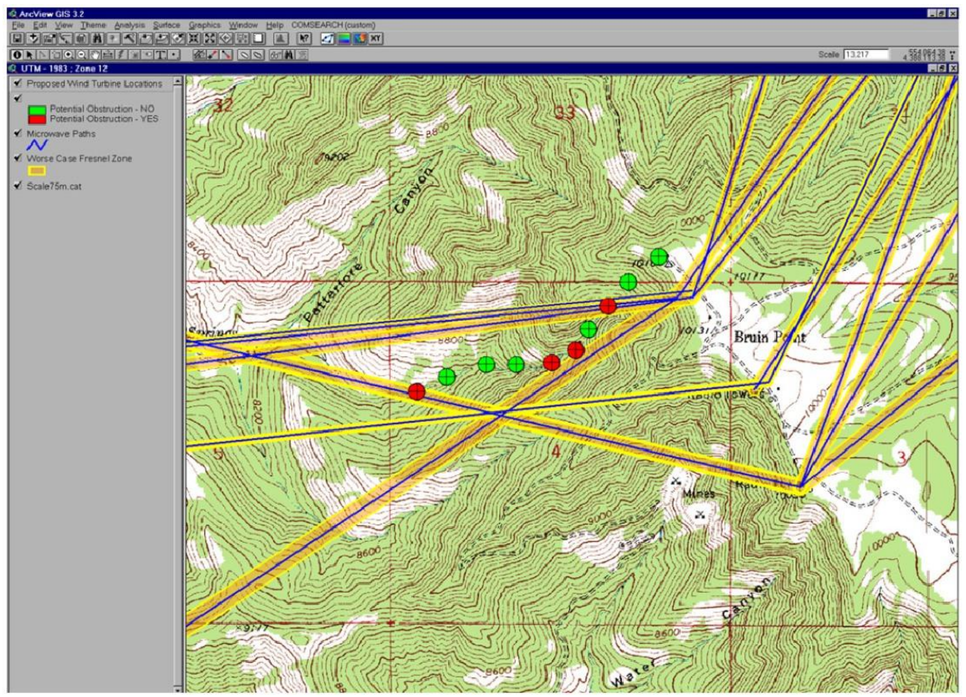
Concerning radars in general, wind turbines may obstruct weaker signals from smaller targets and may also cause detection of a Doppler shift (Angulo, et al. 2014). For weather radars, wind turbines may cause misidentification as thunderstorms and other meteorological events (Angulo, et al. 2014). For air traffic control radars, a similar effect occurs and may lead to false target reports (Angulo, et al. 2014). For shipborne and shore-based marine radars, wind turbines may return multiple interfering echoes (Angulo, et al. 2014). To mitigate wind turbine interference effects on radars, wind turbines should be located away from the line-of-sight of radar antenna (Angulo, et al. 2014). For weather radars, the wind turbine blade tip should be located below the lowest elevation angle of the radar beam, which can be achieved by reducing the mast height or the blade length (Angulo, et al. 2014). When siting wind turbines away from the line-of-sight is not feasible, wind turbines should be sited in line with radar to minimize cross section interference with the radar beam (Angulo, et al. 2014). Current research on weather radars is exploring the automatic detection of wind turbine returns and mitigation through adaptative scanning and radar data analysis (Angulo, et al. 2014). Advanced signal processing can also be used to mitigate effects of wind turbines on air traffic control radars (Angulo, et al. 2014). Gap infill radar may also be applied (Angulo, et al. 2014).

**Aircraft Interference and Mitigation**

Wind turbines may interfere with VOR, VHF Omnidirectional Radio, used for aircraft approach and departure and navigation, and ILS, Instrument Landing System, used to guide aircraft landings especially during low visibility (Angulo, et al. 2014). VOR receivers on aircraft may experience some azimuth direction shifts and if the total bearing exceeds 3 degrees, then the service may be completely disrupted (Angulo, et al. 2014). ILS systems may experience poor flight calibration results (Angulo, et al. 2014). As of 2014, researchers are not aware of available mitigation measures for wind turbine effects on VOR and ILS (Angulo, et al. 2014).

**Radio Interference and Mitigation**

A radio link, also known as microwave link, is a telecommunication facility between two fixed points that facilitates the transmission of radio waves between the two points (Angulo, et al. 2014, Polisky 2005). Wind turbines may obstruct radio wave transmission by causing fades in the signal received by one link or scatter, by creating interference with reflected signals (Angulo, et al. 2014). A wide frequency range of 900 MHz to 40 GHz may be affected (Polisky 2005). Before the siting of any wind turbines, the location of individual turbines and their dimensions can be reviewed by the telecommunications provider and the wind energy developer to ensure that transmissions are not impacted (Angulo, et al. 2014). Software can be utilized to identify microwave paths (Polisky 2005). If transmission between the two points are impacted by wind turbines, an intermediate radio link station, or a repeater, may be employed (Angulo, et al. 2014). The Rhode Island Department of Administration Division of Planning recommends that wind energy not be sited within line-of-sight to existing microwave communication links where interference may occur (Rhode Island Department of Administration Division of Planning 2012).



Microwave Paths Fresnel Zones and Affected Wind Turbines

*Figure 49: Microwave Paths Fresnel Zones and Affected Wind Turbines*
*Source: Polisky, 2005*

**Broadcasting Interference and Mitigation**

With respect to broadcasting, wind turbines may cause secondary or ghost images with loss of color, buzz on sound, loss of detail, brightness flicker, and teletext pages issues for television transmissions (Angulo, et al. 2014, Polisky 2005). When wind turbines are sited between the television station and the point of reception, a loss of up to 8 dB or an 84.2% decrease in signal strength may be observed (Polisky 2005). Electromagnetic interference would be more prominent at lower VHF channels, such as channels 2 through 6 than channels 7 and above (Polisky 2005). And at distances greater than 0.5 miles from a wind turbine, interference effects are minimal (Polisky 2005). New digital systems, such as the ATSC system in the U.S., are technologically advanced enough to avoid wind turbine interference up to a certain operational signal level (Angulo, et al. 2014). For receivers, one of the mitigation measures is to improve the directivity of the receiving antenna; for broadcasters, a new television transmitter in a site with good coverage away from wind turbines may be required (Angulo, et al. 2014). The installation of satellite or cable may also be utilized (Angulo, et al. 2014). Direct broadband satellite (DBS) television is cost effective but may not have local content for rural areas (Polisky 2005). Wireless or cable television distribution systems to rebroadcast television channels may also be considered in more rural areas (Polisky 2005).

**Telecommunication Interference and Mitigation**

Wind turbine interference with wired telephone and cellphone services is not an issue because those services operate at a higher frequency of 800 to 900 MHz (Proceedings of the NWCC Siting Technical Meeting 2006). Audio mediums, such as wireless telephone, land mobile radio (LMR) and AM and FM radio, are less likely to be affected by wind turbines than video mediums (Proceedings of the NWCC Siting Technical Meeting 2006). If wind turbines do interfere with the transmission cell antennas, additional antennas may be installed on the wind turbine, cell, or utility towers (Proceedings of the NWCC Siting Technical Meeting 2006).

# Shadow Flicker

**Mitigation**

Some metrics that should be reported when evaluating shadow flicker include (Priestly, Allen and Lampeter 2011):

- distance of property or structure to the wind turbine causing shadow flicker
- the days per year shadow flickers occurs
- the total annual hours of shadow flicker
- days per year of shadow flicker adjusted for cloud cover
- annual hours of shadow flicker adjusted for cloud cover
- duration of the longest daily shadow flicker
- average daily shadow flicker
- the times or seasons with the greatest shadow flicker exposure
- environmental conditions such as landscape or structures

In Kossuth and Palo Alto Counties, wind energy developers are required to submit computer modeling as evidence that shadow flicker would be below a limit (Baer, Kernek and Johannsen 2018). The Iowa Environmental Council recommends that Iowa counties do not adopt a shadow flicker requirement, but if one were to be adopted then the shadow flicker conditions should be clear achievable by wind energy developers (Baer, Kernek and Johannsen 2018).

The Rhode Island Department of Administration Division of Planning recommends 3 hours as the base minimum for shadow flicker exposure and a maximum of 30 hours annually for wind energy developers who can shut off wind turbines during periods of shadow flicker (Rhode Island Department of Administration Division of Planning 2012). The Rhode Island Department of Administration Division of Planning also proposes that the annual shadow flicker exposure limit can be raised in commercial or industrial areas where shadow flicker may not be considered as impactful (Rhode Island Department of Administration Division of Planning 2012).

PREDAC, a European, non-government organization, recommends a maximum of 30 hours per year or 30 minutes a day of shadow flicker under normal wind directions and a clear sky, following industry practice in Germany (Parsons Brinckerhoff 2011). However, there is variation among European limits (Parsons Brinckerhoff 2011). British industry professionals have expressed concern over setting a specific limit on shadow flicker due to potential variations from site-specific latitudinal differences and effectiveness of mitigation strategies; British local planning officials have expressed favor of specific shadow flicker limits, though they acknowledge difficulties in determining sensitivities to shadow flicker (Parsons Brinckerhoff 2011).

Shadow flicker mitigation measures, such as shutting down turbines, have proved successful (Parsons Brinckerhoff 2011). Mitigation strategies for shadow flicker ordered from most preferable to least preferable are (Parsons Brinckerhoff 2011):

- appropriate site design
- turbine shut down
- installation of blinds on affected properties
- and landscaping or vegetative screening

Most shadow flicker assessments occur pre-construction with modeling, and measurements post-construction are limited (Priestly, Allen and Lampeter 2011). It is recommended that communities first determine their own tolerance for shadow flicker, such as whether 30 hours of shadow flicker per year is appropriate, and then consider individual tolerances, for both participating and non-participating property owners, on morning and evening shadow flicker (Priestly, Allen and Lampeter 2011).

Summary of mitigation measures in International guidance.

| | Careful site design | Turbine shut-down | Installation of blinds | Landscaping / vegetation screening |
|---|---|---|---|---|
| United Kingdom guidance | | | | |
| England | Yes | | | |
| Northern Ireland | Yes | Yes | | |
| Wales | Yes | Yes | Yes | Yes |
| International guidance | | | | |
| Ireland | Yes | Yes | | Yes |
| Germany | | Yes | | |
| United States | Yes | | | Yes |
| Canada | | Yes | | |
| Non-governmental organisation guidance | | | | |
| International Finance Corporation | Yes | | | |

*Figure 50: A summary of international practices in mitigating shadow flicker.*

## Lighting and Marking

For lighting and marking of meteorological towers and wind turbines, please refer to the latest version of the FAA's Advisory Circular No. 70-7460-IL. As of the time of this writing, FAA Advisory Circular 70/7460-1L is on Change 2 effective September 6, 2018. Wind energy developers may choose to install an Aircraft Detection Lighting System (ADLS) from a FAA approved vendor to reduce aircraft collisions and to minimize nighttime lighting (Federal Aviation Administration 2018).

In general, wind turbines and their blades are recommended to be coated with low reflective material to address blade glint (Australian Government National Health and Medical Research Council 2010).

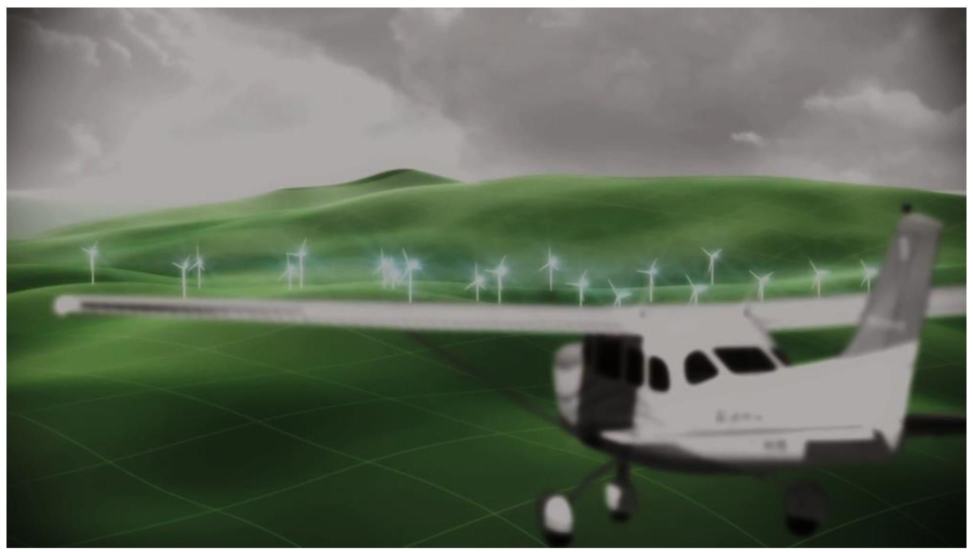


*Figure 51: An illustration of an Aircraft Detection Lighting System (ADLS)*
*Adapted from Vestas*

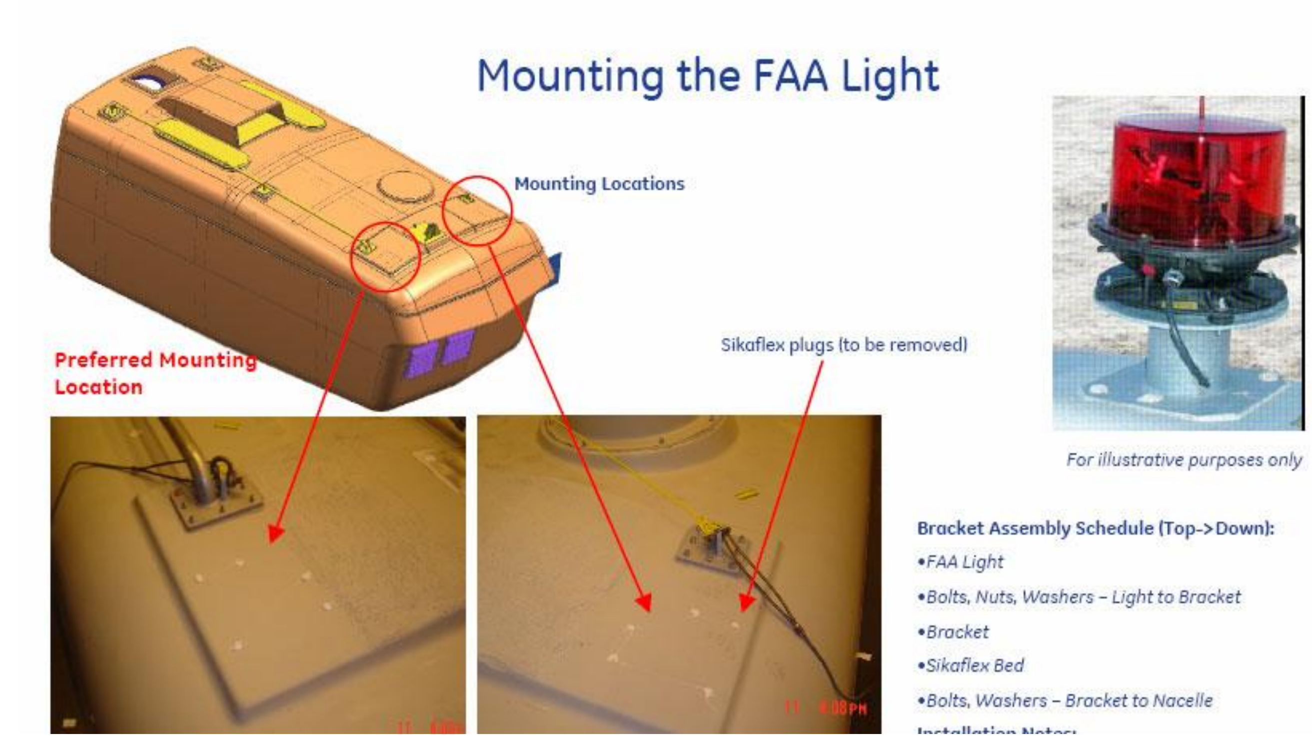



*Figure 52: Mounting FAA Lights*
*Source: Taylor and Parsons, 2009*

## Icing and Ice Throw

**Detection**

For ice detection, multiple anemometry and relative humidity measurements can be used during assessments and ice sensors and the power curve method can be used during operations (Ilinca 2011).

A recommended process to assess the risk for ice throw and ice fall is to (Bredesen, Cattin, et al. 2017):

1. conduct a site-specific ice assessment
2. apply the general ice throw and ice fall calculation equations
3. perform ice throw and ice fall simulations to determine the spatial distribution of strikes per year per meter squared
4. determine an acceptable risk level despite no established international standard
5. apply ice throw and ice fall mitigation strategies

International recommendations for ice fall and ice throw risk assessments are available from IEA Wind (Krenn, Weber, et al. 2018).

**Mitigation**

Ice mitigation strategies can be classified as either anti-icing or de-icing (Ilinca 2011). Anti-icing prevents ice from accumulating, while de-icing removes accumulated ice (Ilinca 2011). Both classes have passive and active components (Ilinca 2011). Passive methods rely on the properties of the wind turbine blades to remove and prevent ice, while active methods require either additional thermal, chemical, or pneumatic actions (Ilinca 2011). Examples of passive treatments include coating or spraying to reduce icing and to increase heat absorption; examples of active treatments include electric foils, heated air, or other thermal devices (Froese 2017). Heating wind turbine blades is a validated method of preventing icing and can even lower wind turbine energy consumption when used with passive hydrophobic coating (Ilinca 2011).

Additional ice mitigation strategies include:

- setting automatic shutdowns (Krenn, Jordaens, et al. 2016, Rhode Island Department of Administration Division of Planning 2012, Tammelin, et al. 2000)
  - if shutdown mechanisms and icing operational procedures are not adequate, adjust setbacks to a minimum of 1.5 times the sum of the hub height and the wind turbine diameter and a maximum of 1.75 times the total wind turbine height (Rhode Island Department of Administration Division of Planning 2012)
  - PREDAC, a European, non-government organization, recommends that during icing conditions, wind turbines that are sited closer than their total height from infrastructure, such as the edge of roads, railways, or waterways, be automatically stopped (Poussard, et al. n.d.)
- training operators to identify icing conditions, the risk of ice throw, and areas of ice throw risk (Tammelin, et al. 2000)
- installing warning systems such as warning signs, lights, sirens, or SMS warnings (Krenn, Jordaens, et al. 2016)
- installing anti-icing (Tammelin, et al. 2000) or ice-protection (Krenn, Jordaens, et al. 2016)
- erecting physical barriers such as fences (Rhode Island Department of Administration Division of Planning 2012), reinforced roofs over vehicles and over wind turbine access doors (Krenn, Jordaens, et al. 2016), or mobile protective roofs (Krenn, Jordaens, et al. 2016)
- preparing winter access vehicles such as snow mobiles, special tracked vehicles, tracks fitted to trucks, and regular snow removal service vehicles (Krenn, Jordaens, et al. 2016)
- re-examining setbacks
  - setbacks of 656.2 to 1,640.4 feet (200 to 500 meters) minimize risk of injury from ice throw and structural failure (Chief Medical Officer of Health (CMOH) of Ontario 2010)
  - setbacks of the wind turbine height from property lines and occupied buildings to minimize the risk of ice shedding (The Northwest Wind Resource & Action Center 2015).
- re-siting wind turbines entirely (Tammelin, et al. 2000)

Comparison of ice mitigation techniques.

| Techniques | Protection type | Retrofitting | Lightning protection | Control issues | Stage | Effectiveness | Roughness increase | Cost | Energy Consumption |
|---|---|---|---|---|---|---|---|---|---|
| Hydrophobic coatings | Anti-icing | Yes | No | N/A | Prototype | Limited | Medium | Low | N/A |
| Icephobic coatings | Anti-icing | Yes | No | N/A | Prototype | Limited | Medium | Low | N/A |
| Biscous coatings (non-water soluble) | Anti-icing | Yes | No | N/A | Prototype | Momentaneous and degrading | Medium | Low | N/A |
| Biochemicals | Anti-icing | Yes | No | N/A | Experimental | Momentaneous and degrading | Medium | Low | Medium |
| Black paint | Anti-icing | Yes | No | N/A | Prototype | Very limited | Very Low | Very Low | N/A |
| Pneumatic | De-icing | No | No | Medium | Operational(1) | Very effective | Very High | High | Very Low |
| Expulsive | De-icing | No | No | Medium | Operational(1) | Effective | High | High | Very Low |
| Hot air | Both | No | No | High | Operational | Effective | N/A | Very High | Medium-High |
| Outside resistive heaters | Both | Yes | Yes | Medium | Operational | Effective | Medium | Very high(3) | Low-Medium |
| Inside resistive heaters – In the resin | Both | No | Yes | Medium | Experimental | Very effective | N/A | High | Low-Medium |
| Inside resistive heaters – Outside the resin | Both | No | Yes | Medium | Experimental | Effective | N/A | Medium | Low-Medium |
| Microwave | De-icing | Yes | Yes | Very High | Experimental | (2) | N/A | Medium | Low |
| Infared | De-icing | Yes | Yes | Very High | Experimental | – | N/A | Medium | – |
| Ultrasonic waves | De-icing | Yes | No | Low | Experimental | Very effective | Very low | Medium | Low |
| Active pitch control | None | Yes | No | High | Experimental | Effective | N/A | N/A | Low |
| Operational stop | Anti-icing | Yes | No | High | Prototype | Limited | N/A | N/A | N/A |

*Figure 53: Ice mitigation techniques*
*Adapted from Fakorede, et al. 2016*

## Structural Failures and Blade Throw

**Detection**
Common causes of wind turbine structural failures include (Ciang, Lee and Bang 2008):

- moisture absorption
- fatigue
- wind gusts
- thermal stress
- corrosion
- fire
- lightning strikes
- poor quality control
- and improper installation or component failure

Structural damage can be detected by sensors and data analysis algorithms (Ciang, Lee and Bang 2008). Predictive models, active and passive systems, and other inspection methods, such as acoustic emission, thermal imaging, ultrasound, modal-based approaches, fiber optics, laser doppler, electrical resistance, strain memory alloy, x-radioscopy, and eddy currents, can also be used to detect structural damages (Ciang, Lee and Bang 2008, Shohag, et al. 2017).

**Mitigation**
Injuries and fatalities are most commonly reported during construction and maintenance activities (Chief Medical Officer of Health (CMOH) of Ontario 2010). The risk of injury from wind turbine structural failure is minimized by a setback of 656.2 to 1,640.4 feet (200 to 500 meters) (Chief Medical Officer of Health (CMOH) of Ontario 2010). Reports indicate that the throw distance for the entire blade is 492.1 feet (150 meters) and for blade pieces is 1,640.4 feet (500 meters) (Chief Medical Officer of Health (CMOH) of Ontario 2010). The Northwest Wind Resource & Action Center recommends a setback of the wind turbine height from property lines and occupied buildings to minimize the risk of tower collapse (The Northwest Wind Resource & Action Center 2015).

The Iowa Environmental Council recommends the following safety precautions (Baer, Kernek and Johannsen 2018):

- posting emergency contact information throughout the project site
- posting warning signs
- locking wind turbine doors to prevent unauthorized access
    - locking wind turbine doors would also prevent unauthorized access to the climbing ladders within the wind turbine towers (The Northwest Wind Resource & Action Center 2015)
- avoiding siting other structures near wind turbines that would allow people to climb

The Iowa Environmental Council recommends that Iowa counties reference Story County's safety provisions and Kossuth County's practice of requiring an emergency plan as part of the ancillary agreements for conditional project approval (Baer, Kernek and Johannsen 2018). The American Planning Association (APA) recommends preparing a written emergency plan to account for all plausible scenarios (Baer, Kernek and Johannsen 2018).

## Sound and Noise

**Mitigation**

Local authorities can regulate wind turbine noise through absolute standards, relative standards, or a mix of both absolute and relative standards. Absolute standards refer to a fixed limit regardless of existing noise levels, for example 50 dB(A) regardless of wind speed, or at different limits at various wind speeds (Colby, et al. 2009). Relative standards refer to fixed limits in increases over the existing levels and may consist of an absolute floor or ceiling (Colby, et al. 2009). For example, a level of 55 dB(A) would not be allowed after a relative increase of 10 dB(A) from an existing level of 45 dB(A) if the ceiling was 50 dB(A) (Colby, et al. 2009). The Iowa Environmental Council recommends a decibel standard of no lower than 50 dB(A), in line with other Iowa counties' sound pressure level range of 50 dB(A) to 60 dB(A) (Baer, Kernek and Johannsen 2018). The American Planning Association (APA) recommends that the U.S. Environmental Protection Agency standard on sound for jurisdictions without any sounds standards (Rynne, et al. 2011). One report recommended a planning guideline of 40 dB(A) as an ideal design goal and 45 dB(A) as an appropriate regulatory limit (Stanton 2012). In developing wind turbine noise standards, local authorities should consider standards from the International Electrotechnical Commission (IEC) in making noise measurements, and the International Standards Organization (ISO), World Health Organization (WHO), and local community values in setting the standards (Rhode Island Department of Administration Division of Planning 2012, Ellenbogen, et al. 2012). Turbine manufacturers' sound level data and best available sound modeling practices should also be considered (Rhode Island Department of Administration Division of Planning 2012, Baer, Kernek and Johannsen 2018, Stanton 2012). PREDAC, a European, non-government organization, recommends noise standards be scaled with wind speed (Poussard, et al. n.d.).

Another regulatory option is through fixed distance setbacks, though this method has been criticized as it ignores the number and size of wind turbines and other potential sources of noise (Colby, et al. 2009). The Iowa Environmental Council recommends a setback range of 1,000 feet to 1,250 feet for Iowa counties (Baer, Kernek and Johannsen 2018). The American Planning Association (APA) has noted that typical setback against sound for homes has been 1,000 feet (Rynne, et al. 2011). The State of Rhode Island recommends against universal setbacks for wind turbine noise, unlike Massachusetts, Michigan, and New Hampshire with setback guidelines of 1.5 times the wind turbine height and a noise limit of no more than 10 dB above the ambient in Massachusetts (Rhode Island Department of Administration Division of Planning 2012). Instead, Rhode Island proposes that a noise study be performed for every wind energy project rather than using a universal numeric setback (Rhode Island Department of Administration Division of Planning 2012). Similarly, a study also goes against universal fixed setbacks, such as concluding that a 1 mile setback was unwarranted (Colby, et al. 2009) and another study recommended not regulating setback distance but sound instead (Stanton 2012). Internationally, the Province of Ontario, Canada has a minimum setback of 1,804.5 feet (550 meters) for wind turbines from a receptor and setback increases with the number of turbines and the sound level rating of the selected turbines (Chief Medical Officer of Health (CMOH) of Ontario 2010). The setbacks are based on modeling of sound from the wind turbines and are intended to limit sound at the nearest residence to no more than 40 dB, consistent with World Health Organization (WHO) Europe's 40 dB nighttime noise guideline (Chief Medical Officer of Health (CMOH) of Ontario 2010).

Community engagement during the initialization of wind energy projects may reduce potential health concerns about the projects (Chief Medical Officer of Health (CMOH) of Ontario 2010). In the Canadian province of Ontario, the Ministry of the Environment requires wind energy applicants provide written notice to all tax-assessed land owners within 393.7 feet (120 meters) of a wind energy project during the project planning phase (Chief Medical Officer of Health (CMOH) of Ontario 2010). Wind energy applicants must also post a notice in the local newspaper on at least two separate days (Chief Medical Officer of Health (CMOH) of Ontario 2010). Before an application is submitted, applicants of wind energy projects more than 50 kW must also hold a minimum of two community meetings to discuss their project and its potential local impacts and make publicly available any required studies for 60 days prior to the community meeting (Chief Medical Officer of Health (CMOH) of Ontario 2010). After the meetings, applicants are required to submit a "Consultation Report" with their application that describes the comments received from the public and how those comments were addressed in their proposal (Chief Medical Officer of Health (CMOH) of Ontario 2010). Additionally, the wind energy applicants must also consult directly with any local municipalities regarding municipal lands, infrastructure, and services (Chief Medical Officer of Health (CMOH) of Ontario 2010).

Other recommendations in regulating sound and noise from wind turbines include varying noise standards depending on an area's existing and expected land uses, allowing participating land owners to waive noise standards, establishing procedures to manage complaints, and identifying the triggers and techniques for mandatory sound monitoring, arbitration, and mitigation (Stanton 2012).

## Property Values

**Mitigation**
Local authorities are recommended to encourage wind energy developers to conduct community engagement and possibly prepare financial mechanisms as a means against property reductions. Public meetings at the county or community level are recommended for developers to present information and research and address local concerns (Center for Rural Affairs 2018). Local authorities can attend, as necessary, to ensure balanced and factual presentations (Rhode Island Department of Administration Division of Planning 2012). Developers should meet with host landowners and neighbors to discuss the avoidance of subjective impacts on property values and the creation of dis-amenities, such as a new access road if one already exists (Center for Rural Affairs 2018). Additionally, discussions should address any loss of property value from any post-construction property damages and develop a process for managing damages (Center for Rural Affairs 2018). County authorities may seek the opportunity to work with wind energy developers to improve local amenities, such as road improvements during wind energy construction and then benefit from the improvement post-construction (Center for Rural Affairs 2018). In terms of potential impacts on property values from disruptions to visual amenities, appearances, and senses of place and community, local authorities may create an escrow account for such purposes (Stanton 2012). Groups with general resistance to wind energy developments propose local authorities codify a "Property Value Guarantee" (PVG) for wind energy, citing various counties and municipalities around the U.S. (Droz, Do Wind Projects Adversely Affect Proximate Residential Property Values? 2019). A group has even advanced the notion of having developers choose between a 2 mile setback or a 1 mile setback with a PVG (Droz, Writing An Effective Regulatory Wind Ordinance 2018).

PVG measures have been demonstrated in Linn County, such as the agreements between the Martin Marietta Materials, Inc. and their surrounding property owners in 2002.

Some states offer property tax incentives for wind energy which helps to reduce high capital costs for wind energy developers, attract wind energy development to areas of lower wind resources, and serve as a negotiation item for local authorities (Costani, et al. 2006). However, these property tax incentives do little to impact the value of the project's tax revenue to the local community (Costani, et al. 2006). If local authorities were to consider property tax incentives, the incentives should be limited in duration and phased in, considerate of surrounding jurisdiction's incentives, and may also take the alternative form of payment-in-lieu-of-taxes (PILT) if local authorities do not have taxing authority for wind energy projects under state law (Costani, et al. 2006).

## Legality

Windustry provides the following recommendations for wind energy easements and leases (Windustry's Wind Easement Work Group 2005):

- Option periods are recommended to be limited to 5 years
- Easement periods are recommended to be limited to 30 years and not automatically renewed for longer
- Wind rights are recommended not to be separated from surface rights
- Liability insurance for the wind energy developer is recommended as well as having the developer indemnify the landowner against liabilities for injuries or claims

## Decommissioning and Repowering

**Decommissioning**

Decommissioning is the process of removing wind turbines at the end of their operation life (American Wind Energy Association n.d.). In 2017, 46 MW of wind capacity were decommissioned, mainly from 1980s wind projects (American Wind Energy Association n.d.). The majority of the wind turbines in the US, three-quarters of them, are still under 10 years old (American Wind Energy Association n.d.). Generally, wind turbine decommissioning includes the deconstruction of the blades then the nacelle and then the tower, the on-site separation of components, and the transportation of components to a recovery facility (Ortegon, Nies and Sutherland 2013). Transportation of the disassembled components face similar challenges with construction transportation, namely the availability of truck trailers and rail cars with the ability to transport wind turbine components, differences in oversized restrictions among states, driver shortages and training, non-optimized loads, and hours-of-service constraints (Ortegon, Nies and Sutherland 2013). Since turbine components are disassembled on-site, the number of trucks used to haul components during decommissioning may be more than the number used during the construction phase (Ortegon, Nies and Sutherland 2013).

Laws regarding wind turbine decommissioning are varied and undeveloped (Stripling 2016). Currently, there is not a standard process for decommissioning wind turbine (Stripling 2016). However, there are three prevailing decommissioning policy stances among states. First, there are states without any decommissioning regulations; these states are Texas, Iowa, Kansas, Massachusetts, Michigan, Montana, and New Mexico (Stripling 2016). Second, there are states with "naked decommissioning" or states that require decommissioning but without any financially secured decommissioning; these states are California, North Dakota, and Ohio (Stripling 2016). Third, there are states that require operators to contribute to a fund or post a bond to cover decommissioning costs; these states are Oklahoma, Oregon, and Indiana (Stripling 2016). The states that do have decommissioning provisions generally set 12 to 24 months of inactivity per turbine as the condition for decommissioning (Conaway 2017).

Differences in turbine models, siting locations, and decommissioning timelines, in addition to the limited availability of public data make it difficult to calculate a per-turbine decommissioning cost (Stripling 2016). From the current data that is available, estimates for decommissioning costs are in the tens of thousands of dollars per installed turbine (Stripling 2016).

As Texas experienced with its oil and gas industry, states without decommissioning policies or with inadequate decommissioning policies are susceptible to abandonment (Stripling 2016). Though wind leases may contain decommissioning clauses, there is no decommissioning security against any operator who may declare bankruptcy or insolvency before complete decommissioning (Stripling 2016). To ensure against such events, the following are recommended decommissioning policies (Stripling 2016):

- Statutes should place the burden of decommissioning on operators, not landowners, and require operators to post financial surety to cover decommissioning costs
- At a minimum, decommissioning security should be in place on or before a project's payout date (Stripling 2016)
- Clearly define specific events that trigger the decommissioning process
- Any decommissioning policy is best legislated and administrated at the state level

There are two financial implementation strategies for decommissioning provisions (Stripling 2016):

1. Operators deposit money into a sinking fund for the project life
   a. Deposits are made according to a schedule within the lease.
   b. Landowners are permitted to withdraw money from the fund if the operator fails to remove wind turbines or to restore the site.
2. Operators post a performance bond, letter of credit, or guarantee from an entity with a specified credit rating to ensure decommissioning

As mentioned above, Oklahoma, Oregon, and Indiana have decommissioning provisions with financial surety:

- Oklahoma: Oklahoma Energy Development Act
  - The term "abandonment" is defined as failure to generate electricity for 24 consecutive months and complete decommissioning within 12 months of abandonment or at the end of useful life is required (Stripling 2016).
  - Wind energy facilities, generating on or after December 31, 2016 are required to provide evidence to the Oklahoma Commission by the 5th year of operation in the form of "a surety bond, collateral bond, parent guaranty, cash, cashier's check, certificate of deposit, bank joint custody receipt or other approved negotiable instrument" allowed by the Commission. For installations generating on or after December 31, 2016, security must be 125% of the estimated total cost of decommissioning minus the salvage value of the equipment as estimated by a licensed engineer. Failure to submit evidence of financial security is subject to penalty not to exceed $1,500 per day (Conaway 2017).
- Oregon: Oregon Energy Facility Siting Council (OEFSC)
  - The Council requires that the land can be adequately restored, and that the applicant has a "reasonable likelihood of obtaining a bond or letter of credit in a form and amount satisfactory...to restore the site." (Conaway 2017)
- Indiana: Indian Public Utility Regulatory Commission
  - Operators are required to establish a decommissioning plan that "include[s] an independent financial instrument in an amount equal to the demolition and removal cost estimate." (Conaway 2017).

In Iowa, the early wind energy projects have life-spans of 20 to 25 years while current wind energy projects now have life-spans of 40 years (Baer, Kernek and Johannsen 2018). Decommissioning is similar across most Iowa counties, but Poweshiek County's decommissioning can serve as an example (Baer, Kernek and Johannsen 2018).

**Repowering**

Repowering is the process of replacing or upgrading existing wind turbines. A full repowering occurs when all the turbine equipment and infrastructure, including the tower and foundation, are removed and then replaced (Lantz, Leventhal and Baring-Gould 2013). Older equipment may be recycled or resold (Lantz, Leventhal and Baring-Gould 2013). In a partial repowering, new drivetrains (gearbox and generator) and rotors are installed on existing towers and foundations (Lantz, Leventhal and Baring-Gould 2013). Accessory electrical components, such as power converters, may also be replaced (Lantz, Leventhal and Baring-Gould 2013). In an analysis performed by the National Renewable Energy Laboratory, a partial repowering by replacing only the turbine drivetrain and rotor was found to have reduced the cost of repowering by 10% but only retain 50% of the energy production improvements that would have occurred with a full repowering (Lantz, Leventhal and Baring-Gould 2013). These results indicate a partial repowering are not as economical as a full repowering under the tested conditions, though there are other partial repowering alternatives that may still be financially viable (Lantz, Leventhal and Baring-Gould 2013). General Electrics (GE) reports that repowering wind turbines can increase fleet output by 25% and can add 20 more years to the operational life of wind turbines from the time of the repowering (Suparna 2017).

In 2015, the Production Tax Credit (PTC) was extended until the end of 2019. The four-year extension is expected to provide 10 more years of tax credits to repower wind facilities (Suparna 2017). A wind facility may qualify for the PTC if 80% of the property's value is new, allowing owners and developers the option of a partial repowering instead of full repowering (Suparna 2017).

A wind generating facility becomes financially feasible to repower, when compared to new development on surrounding greenfield sites, after 20 to 25 years of operation (Lantz, Leventhal and Baring-Gould 2013). Before 20 years, turbines are still able to generate revenues for a few more years.

Several factors affect repowering considerations (Lantz, Leventhal and Baring-Gould 2013):

- Technological advancements
  - Rapid advances in technology encourage repowering
  - Slower advances discourage repowering
- Availability of Alternative Wind Resources
  - Unavailability of alternative high wind resources encourages repowering
  - Availability of alternative high wind resources encourages greenfield development
- Electricity Wholesale Market Prices
  - Higher prices for future repowered turbines and lower Power Purchase Agreements (PPA) prices for existing turbines encourage earlier repowering
- Operations Expenditure: Durability and Reliability of Equipment
  - Rate of cost escalations with aging facilities encourage earlier repowering
- Repowering Cost Savings: Reusing Existing Infrastructure
  - Capturing more than 5% in cost savings from a potential repowering encourages repowering
  - Higher costs for repowering discourage repowering

## Case Study: DeKalb County, Illinois

Paul Miller, AICP, Director of Planning, Zoning, and Building for DeKalb County, Illinois presented at the American Planning Association's "Tuesdays at APA" event on DeKalb County's first utility-scale wind farm. DeKalb County, Illinois contains 14 municipalities and covers approximately 636 square miles in area, about 88% of which was devoted to agriculture in 2010 (P. R. Miller 2010). Florida Power and Light, now NextEra Energy, proposed a wind farm consisting of 151 wind turbines across 22,000 acres in DeKalb County and neighboring Lee County, including four townships and two municipalities in DeKalb County (P. R. Miller 2010). The proposed wind turbines were 1.5 MW GE turbines, each 263 feet tall to the nacelle or 399 feet tall to the tip of the blade (P. R. Miller 2010). Florida Power and Light anticipated the construction of a new substation and miles of access drives and underground transmission lines (P. R. Miller 2010). In 2010, the project was estimated at $400 million and tax revenues were projected to be $41 million over 30 years (P. R. Miller 2010).

In 2010, the DeKalb County Zoning Ordinance had no wind farm provisions because the growth in wind energy technologies was too rapid and not commensurate for the work required for frequent ordinance amendments (P. R. Miller 2010). However, the Zoning Ordinance did contain Special Uses that included "essential service structures", such as "telephone exchange or repeater buildings and towers, electrical station and substation buildings…as well as other structures and buildings related to essential or public services" (P. R. Miller 2010). The wind energy developers filed their project application under Special Uses and carried the burden to prove that their usage was classified as "essential service structures" (P. R. Miller 2010). The properties to be developed were all zoned A-1 Agricultural (P. R. Miller 2010).

A total of three separate public hearings were held in DeKalb County during the application review process. The wind energy developer's completed application to DeKalb County was received on January 6, 2009 and the first public hearing was held on February 19, 2009 (P. R. Miller 2010). Underestimating the capacity of the public hearing revenue, DeKalb County canceled their first public hearing when over 400 people attended a venue meant to accommodate only 250 people (P. R. Miller 2010). The second public hearing was held on March 21, 2009 in a venue that could accommodate 1,500 people (P. R. Miller 2010). With approximately 800 attendees, the public hearing began at 9 a.m. Saturday morning and finished on 3:30 a.m. Sunday morning (P. R. Miller 2010). After the public hearing, the County Hearing Officer recommended denial and wind energy developers filed additional exhibits as a response (P. R. Miller 2010). Under recommendations from the State Attorney, the public hearing was re-opened to allow for the re-examination of the new exhibits (P. R. Miller 2010). The third public hearing was held on May 11, 2009 in a revenue that could accommodate up to 1,000 people but only 200 people attended (P. R. Miller 2010). Learning from experience, DeKalb County held the public hearing over the course of two days, with hearings on the first day from 9 a.m. to 4 p.m. and then 7 p.m. to 10 p.m. and on the second day from 9 a.m. to 12 p.m. (P. R. Miller 2010). After the third public hearing, the Hearing Officer completed a supplemental report and recommended approval because the initial pubic concerns that were raised had been addressed by the additional exhibits (P. R. Miller 2010). On June 17, 2009, the DeKalb County Board approved the wind energy developer's Special Use permit with 36 conditions (P. R. Miller 2010). The first Building Permit for the wind farm was received on July 13, 2009 and several days later on July 22, 2009 the first lawsuit against the wind energy developer and the County Board was filed (P. R. Miller 2010). By the end of December 2009, the wind farm was operational (P. R. Miller 2010).

There were at least 8 different categories of public objections that were raised. The first and most common was the issue of noise (P. R. Miller 2010). Second, was the perceived negative appearance of the wind farm that caused a sudden and drastic change to the rural landscape (P. R. Miller 2010). Third, was concern for property value loss (P. R. Miller 2010). While there may be a loss of potential buyers who do not want to live in proximity to a wind farm, the eventual buyer of a property, with no concerns over the wind farm, may still end up paying the appropriate property price (P. R. Miller 2010). Fourth, was the compliant of shadow flicker (P. R. Miller 2010). Fifth, was potential negative health effects (P. R. Miller 2010). Sixth, was interference with telecommunications such as radio, TV, and internet (P. R. Miller 2010). There was one instance of interference in DeKalb County in which a HAM Radio operator reported interference from the wind turbines, but further investigations by the wind energy developer revealed the source of interference to be the fluorescent lights inside the wind turbines and not the wind turbines themselves (P. R. Miller 2010). Seventh, was environmental concerns over bird and bat kills (P. R. Miller 2010). Lastly, there were concerns over interference with crop dusting (P. R. Miller 2010). Additional conflicts arose between participating landowners and nonparticipating landowners (P. R. Miller 2010).

Several factors contributed to the project's approval. The first was the anticipated tax revenue, which appealed to the DeKalb County Board (P. R. Miller 2010). The wind energy developers agreed to pay DeKalb County under the existing tax scheme and pay more than the existing tax if the tax scheme were to change and call for more taxes but not less than the existing tax if the tax scheme were to change and call for fewer taxes (P. R. Miller 2010). Second, was that an independent noise pollution standard from the Illinois Pollution Control Board was applied to control for noise pollution (P. R. Miller 2010). The wind energy developer was also required to complete an acoustic study after the wind farm was operational to determine compliance with those standards (P. R. Miller 2010). Third, to mitigate telecommunication interference, the wind energy developer offered Dish TV to residents who experienced television interference or internet boosters to those with satellite internet (P. R. Miller 2010). Lastly, the wind energy developer entered into property value guarantees with property owners such that if a property owner accepted a lowered sales price than a previously agreed upon appraised price, the wind energy developer would make up any differences (P. R. Miller 2010).

The experiences of DeKalb County with its first wind farm offer some insights for other counties with respect to wind energy siting details, public sentiments, and the public hearing process. Paul Miller offers a recommendation for other counties to conduct a viewshed assessment prior to any wind energy projects (P. R. Miller 2010). Additionally, Miller reports that DeKalb County used a setback of 1,400 feet from nonparticipating properties in 2010 (P. R. Miller 2010). In terms of public sentiments, Miller warns that the non-participating property owners would be the most likely to object any wind energy developments (P. R. Miller 2010). Lastly, Miller presents some advice based on his experiences with DeKalb County's public hearings: the public should be given more than ample public notice for public hearings; the entire application should be made publicly available online; a larger venue than expected should be arranged; public hearings should be held during both the day and night and even on weekends for several days with reasonable start and stop times; the public should be allowed to give their input until they are satisfied during public hearings; any speakers during the public hearing should first identify their name and address, which will then be compiled into a list used to call each speaker one at a time; professional or expert witnesses at public hearings should be allowed to cross-examine each other but not individual residents (P. R. Miller 2010).

While in 2010, Paul Miller believes that counties do not necessarily have to possess any wind farm regulations, just the appropriate land use within their zoning ordinance (P. R. Miller 2010). The DeKalb County Board approved a wind ordinance in 2018 after nearly nine months of considerations and a moratorium on wind energy projects extended since 2017 (Finlone 2018, Stephens 2018). The new ordinance seeks to eliminate shadow flicker, introduce low maximum noise levels, and issue a 3,000 feet setback from neighboring properties (Finlone 2018, Stephens 2018).

# 4 Conclusions

# Conclusions

Wind energy has steadily moved east as turbine technology advances and the low hanging fruit of wind resource is captured in northwestern Iowa. MidAmerican has a goal of 100% renewable energy and has begun or completed projects in Mahaska and Poweshiek Counties (MidAmerican Energy Company n.d.). Alliant Energy is also making moves to increase their wind energy capacity with a 1,000 MW proposed installation (Alliant Energy n.d.). These are the primary utility providers of electricity in Linn County and industry trends point towards Linn County receiving applications for wind farms within the near future.

The primary goals of this project were to analyze the feasibility of a large-scale wind farm within Linn County and provide staff with the resources to make recommendations regarding the suitability and compatibility of future wind farm applications.

## Primary Conclusions

Data from NREL and Openwind software showed that wind energy present in Linn County was strong enough for large-scale wind farms.

- Areas with viable wind resource and were allowed-use with a conditional permit were present.
- Areas exist with the viable suitability and compatibility conditions as defined by this report.
- A survey captured public attitudes towards renewable energy and large-scale wind farms.

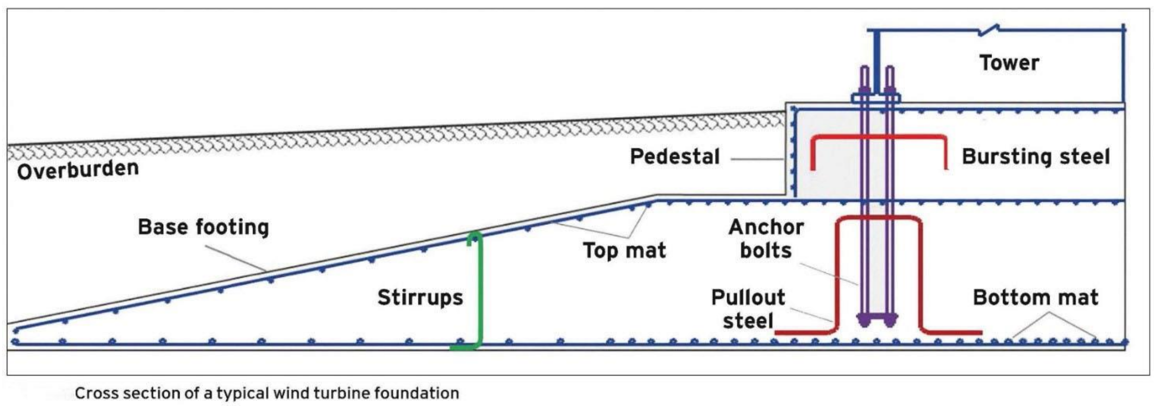
## Final Recommendations

- **Integrate these suitability and compatibility findings into the Conditional Use Permit application review process.** Compatibility and suitability concerns are already integrated into Linn County's CUP permitting process. By consulting the maps generated using the compatibility and suitability factors, staff will be aware of which specific factors might be of concern to individual utility-scale wind energy developments based on their location (Is the development within a potential karst formation? Is it within an area anticipated for future urban growth? Etc.). The answers to these questions will inform any conditions placed on potential approvals.
- **Utilize the GIS model to ensure regulatory, suitability, and compatibility maps are current and up-to-date.** The GIS model can recreate all three of these maps in ArcMap. Input new data as Future Land Use classifications change, residential structures are built, and any of the dynamic variables that need updating.
- **Use the extensive policy research included in this report as a reference guide when future questions arise.** Consult the section pertaining to whichever topic is in question to gain a baseline understanding of the issue and follow sources cited if a more in-depth understanding is necessary.
- **Use survey responses and public sentiment towards wind energy to guide the conditional-use permit process.** Developers will find it easier to hold public outreach and educational events to ease concerns over wind farm externalities and effects.

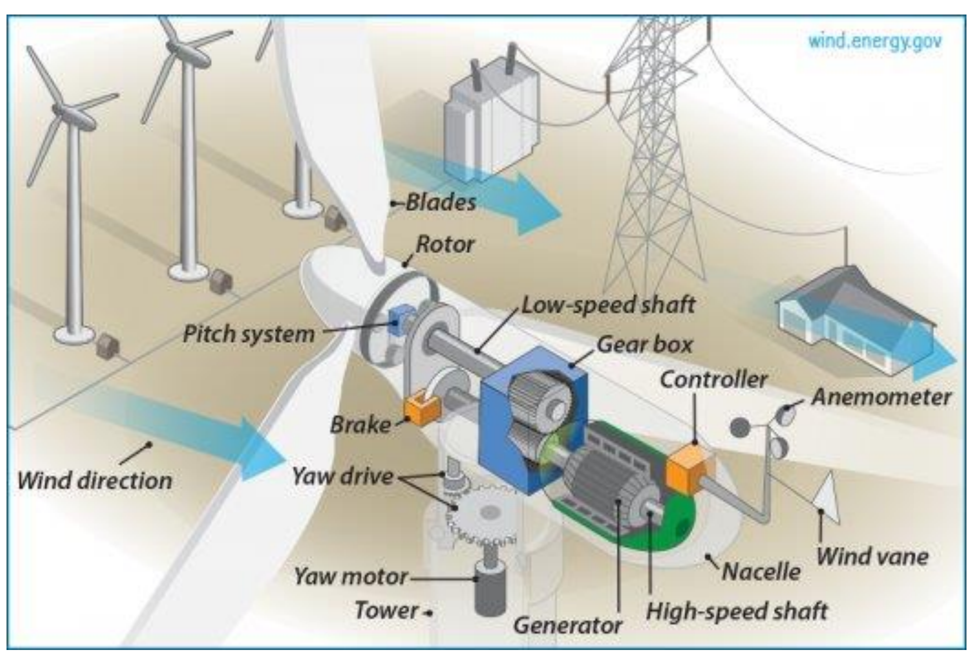
# Appendix

# Wind Turbine Anatomy

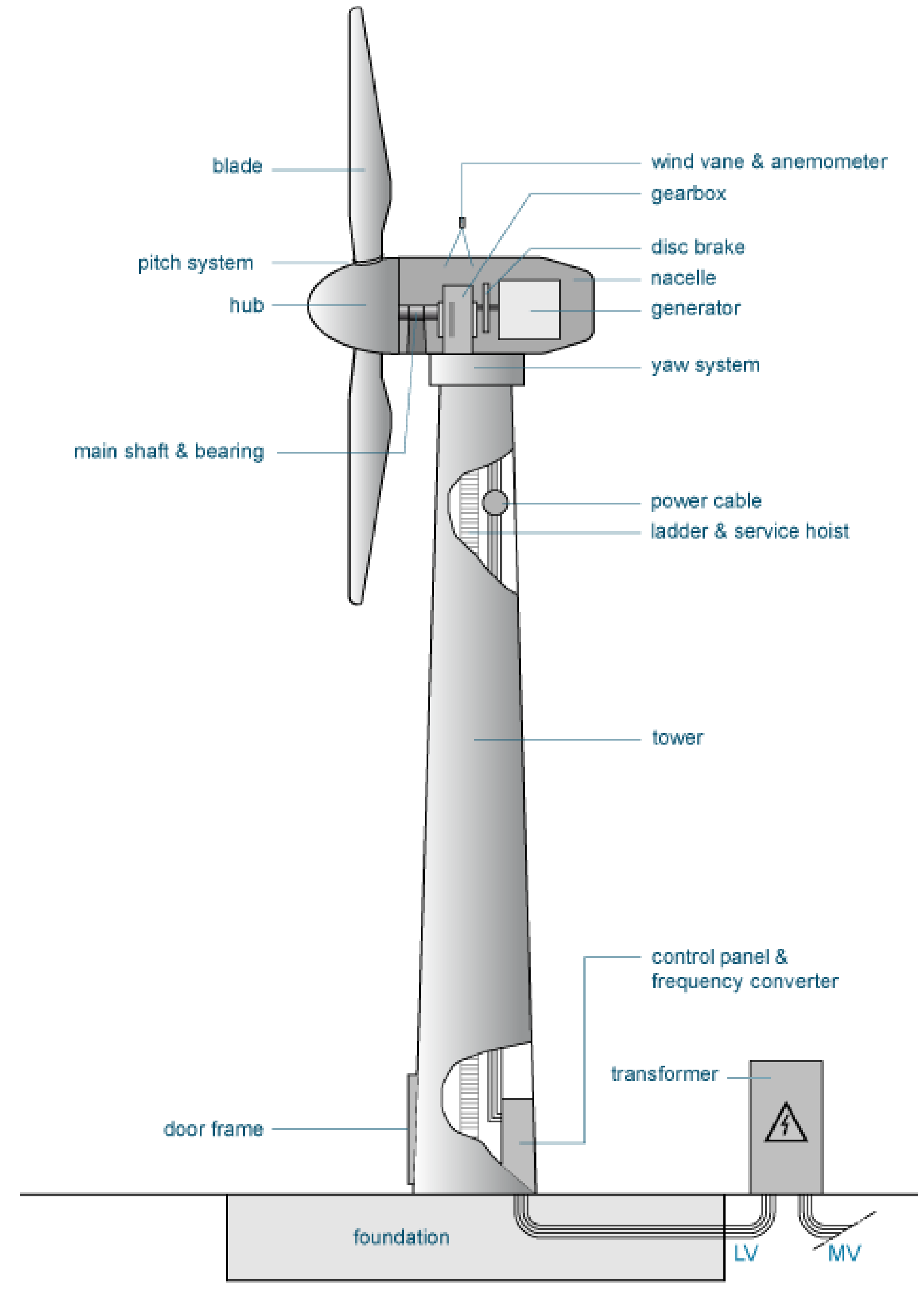
Modern conventional wind turbines are steel towers with a hub, three attached blades, and a nacelle, which encloses the shaft, gearbox, generator, and controls (American Wind Energy Association n.d.). The tower sections are hollow and include a ladder along the inside of the sections to allow access to the nacelle for maintenance and repair (WE Energies n.d.). Eighty-one percent of the total wind turbine weight comes from the tower, gearbox, and blades (Ortegon, Nies and Sutherland 2013, 196). These components are constructed of steel and fiberglass, whereas the foundation is constructed from concrete (Ortegon, Nies and Sutherland 2013, 196).




*Cross section of a wind turbine foundation.*
*Source: Wind Power Monthly*



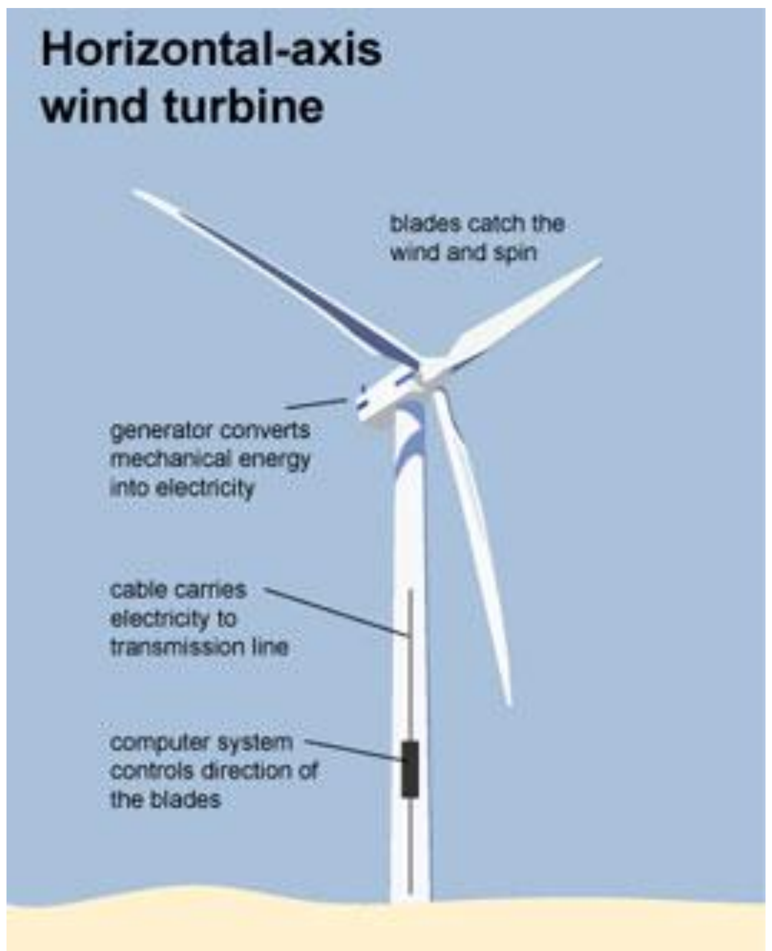

*The internal components of the nacelle.*
*Source: Office of Energy Efficiency & Renewable Energy*




*Cross section of a wind turbine.*
*Source: NewEn Canada*

## Wind Turbine Electric Generation and Distribution

To generate electricity, wind turbines capture kinetic energy from the wind. The movement of wind causes the wind turbine blades to rotate, capturing the wind's kinetic energy and converting it to mechanical energy (American Wind Energy Association n.d.). The rotation of the blades turns an internal shaft connected to a gearbox that increases the speed of the rotation, which in turn spins a generator to produce electricity (American Wind Energy Association n.d.). The cut-in speed, of 6 to 9 miles per hour, is the minimum for electricity generation; but cut-out wind speeds at 55 miles per hour may cause turbines to shut down to prevent equipment damage (American Wind Energy Association n.d.). Newer wind turbines generally rotate more slowly and quietly than older, smaller turbines: turning at 10 to 20 revolutions per minute (rpm) compared to 40 to 60 rpm (Suparna 2017). Slower wind turbine rotations help to mitigate some issues, such as bird mortality and shadow flicker (Suparna 2017).




*Electricity generation in a horizontal-axis wind turbine.*
*Source: U.S. Energy Information Administration (EIA)*

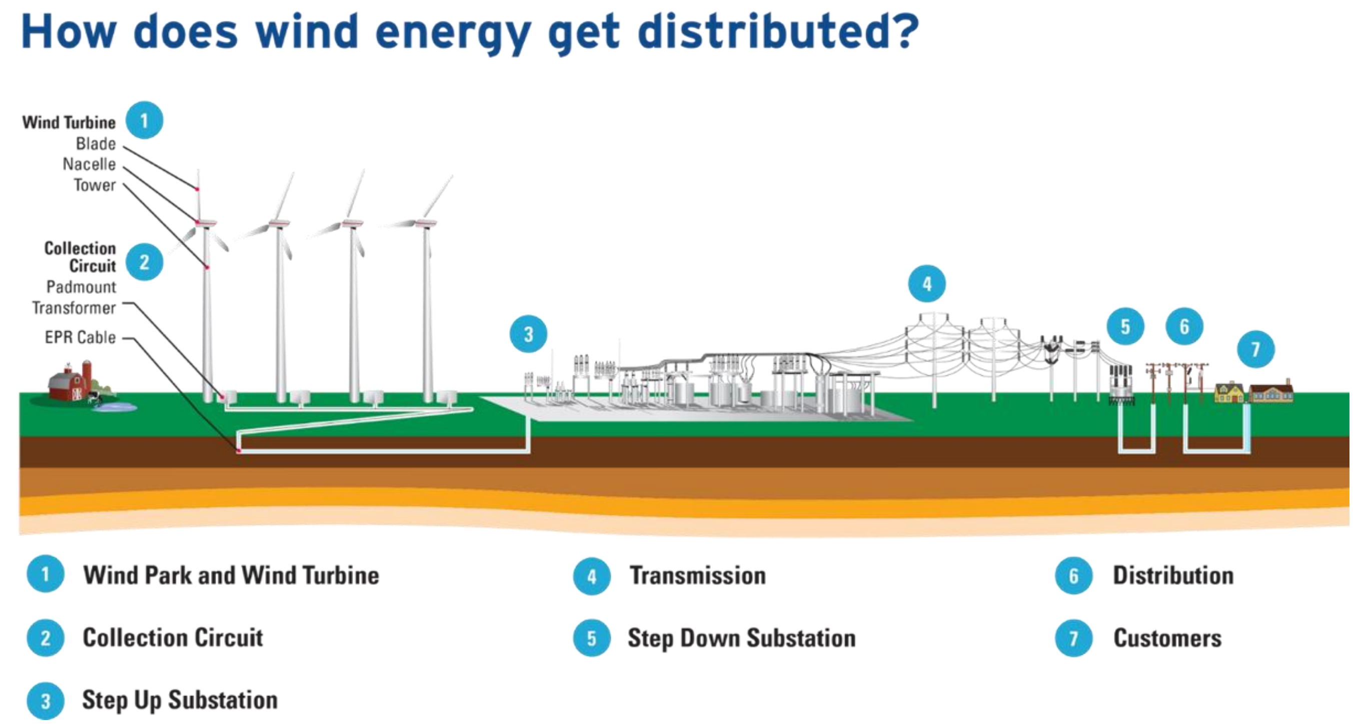
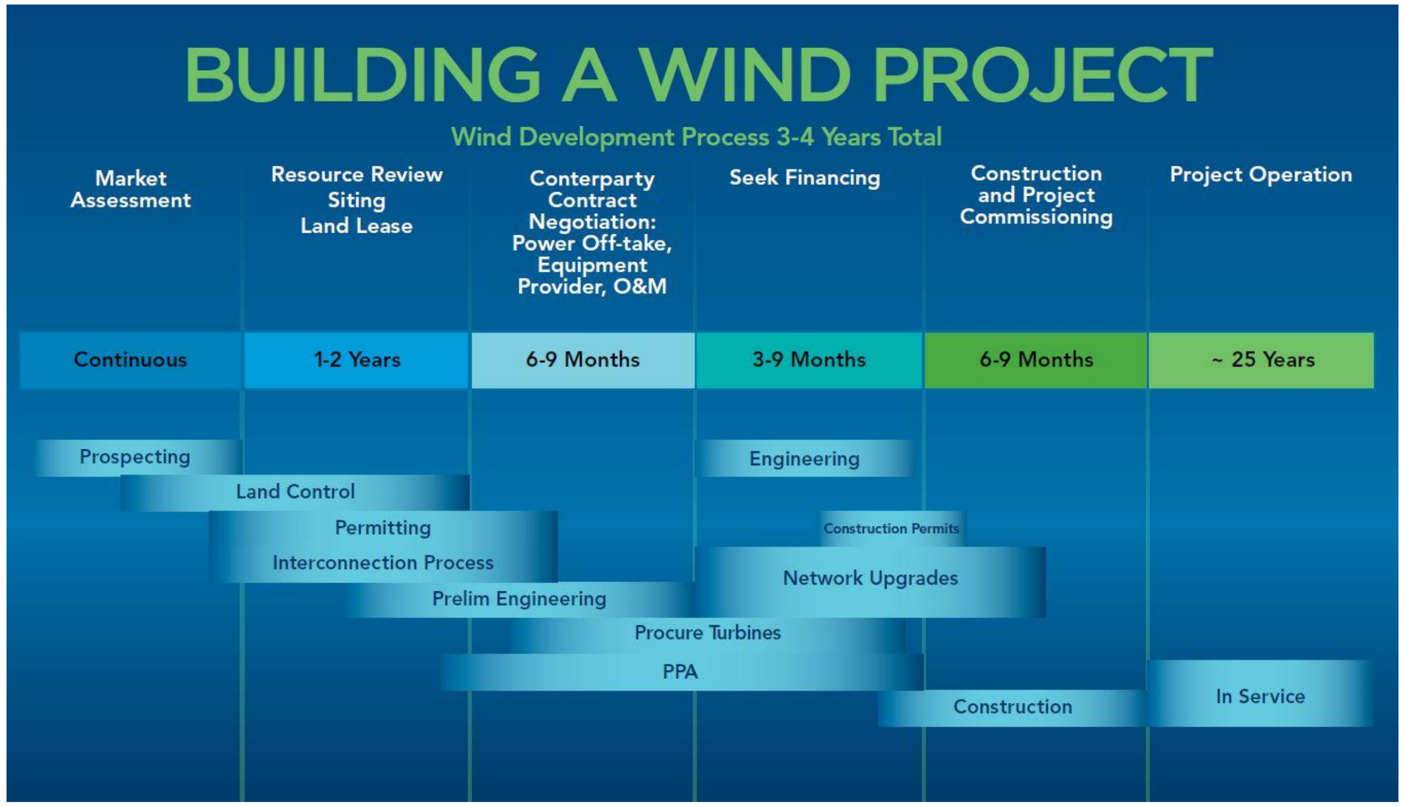


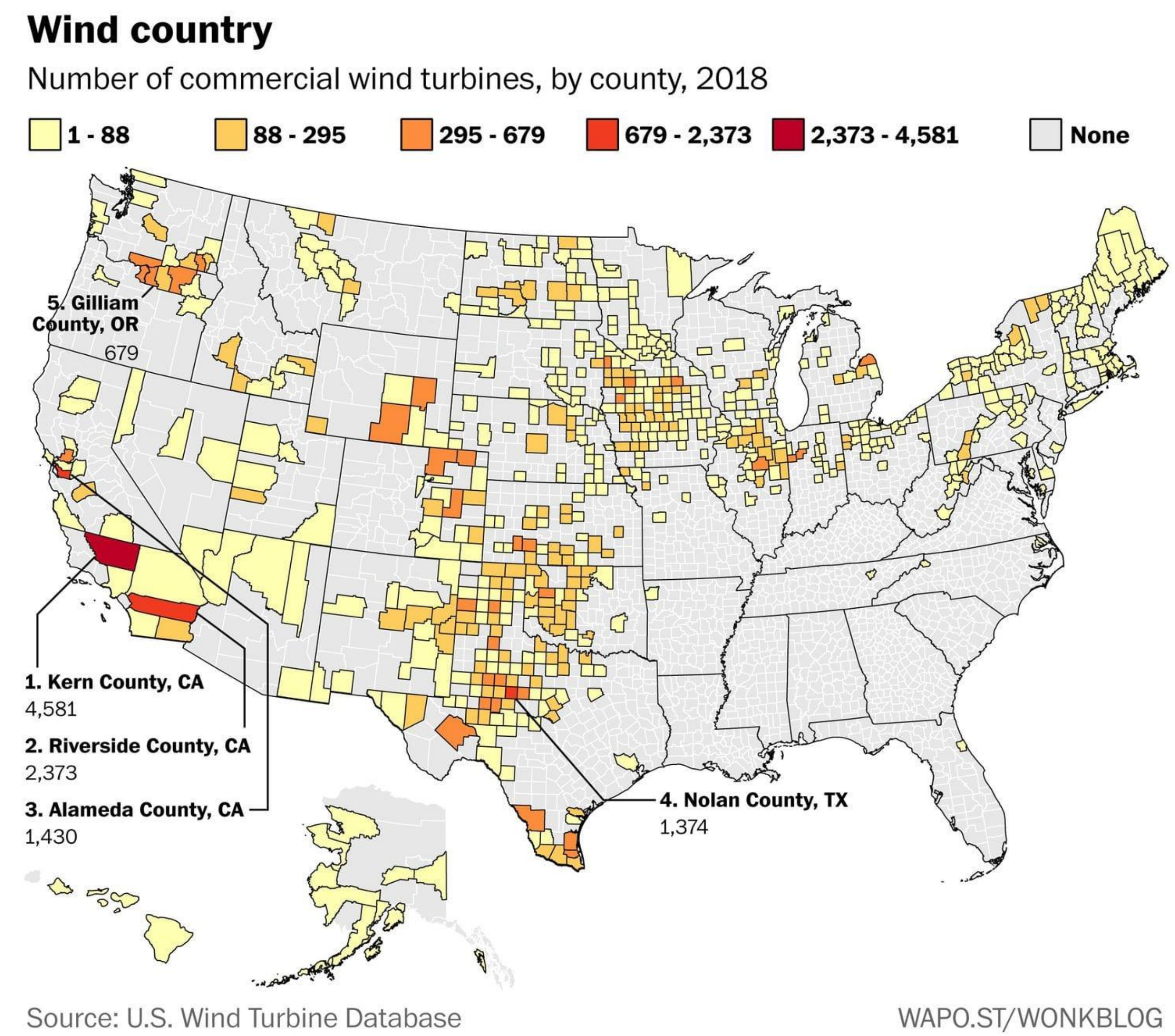

*Illustration of electricity distribution from wind energy.*
*Source: DTE Energy*

## Wind Development Process



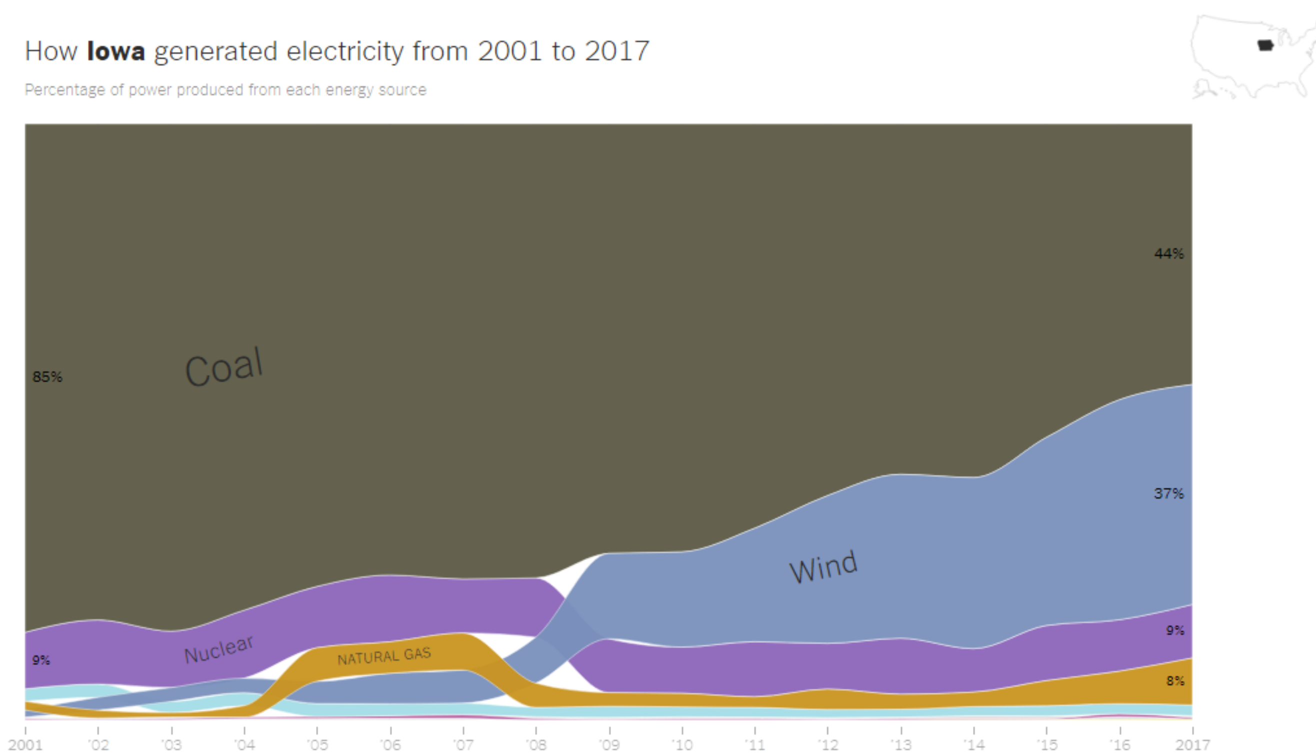

*A timeline for a wind energy project from initialization to operations.*
*Source: American Wind Energy Association*

## Distribution of Commercial Wind in the U.S.



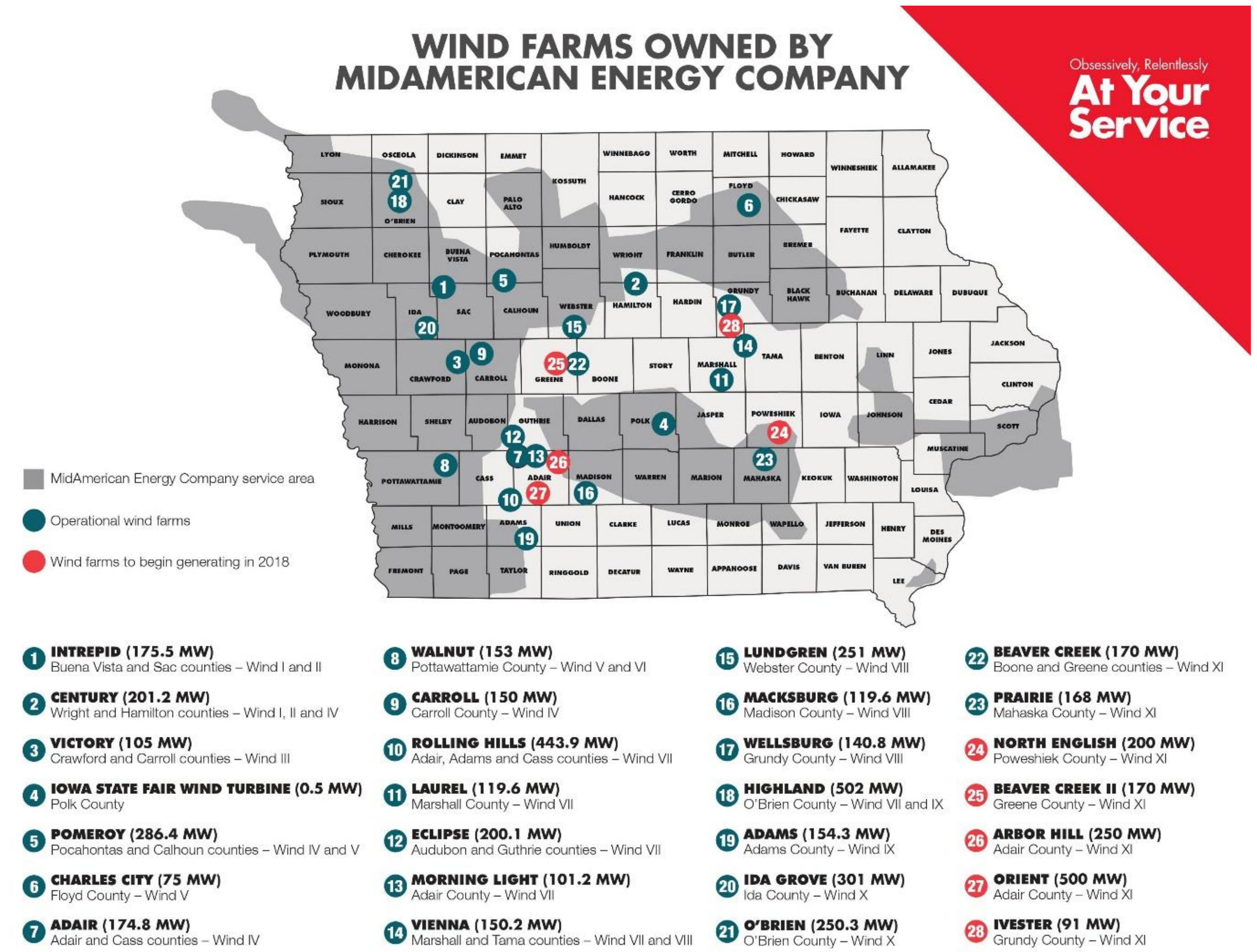

*Source: The Washington Post*

## Sources of Electricity Production in Iowa

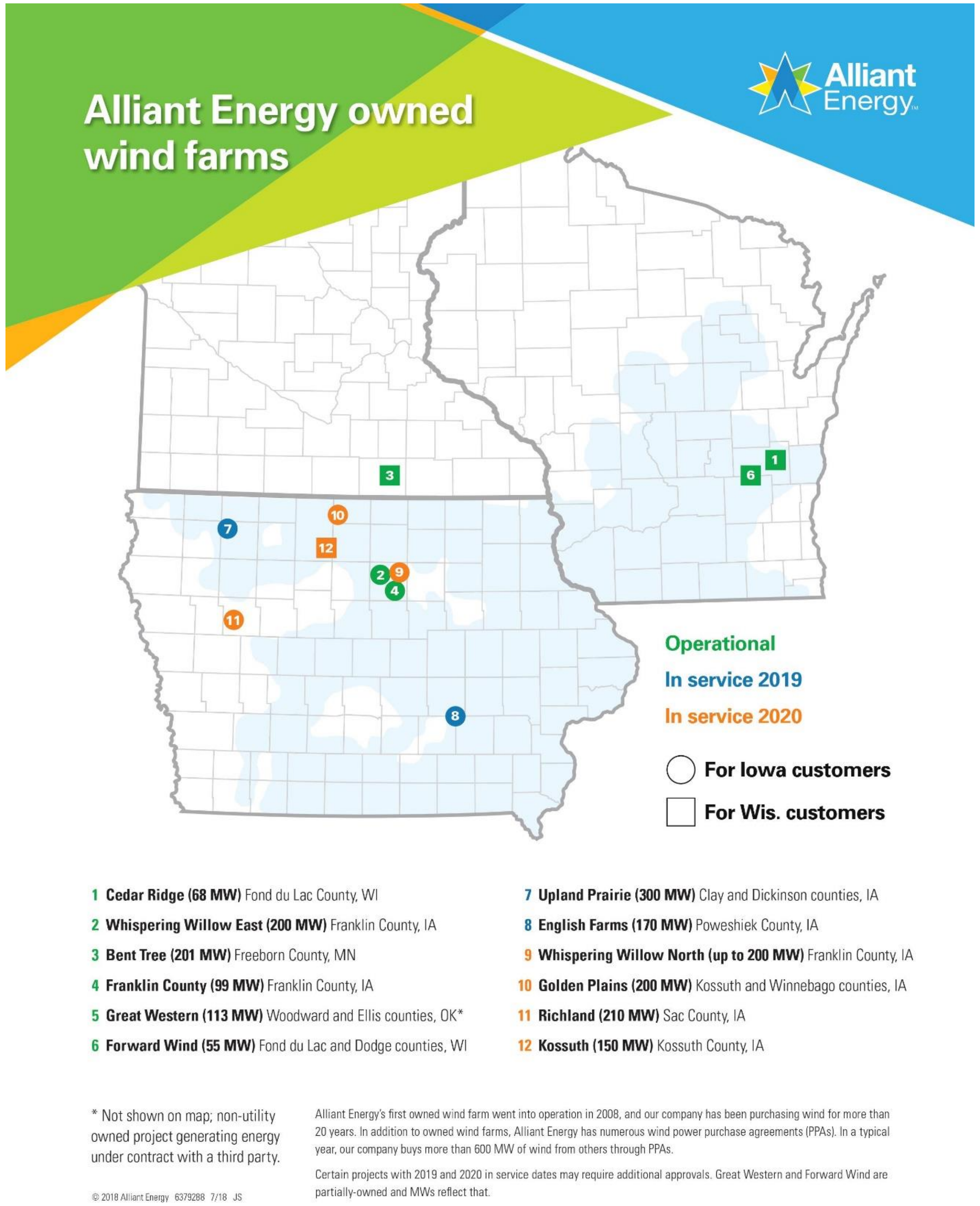



*Source: The New York Times*

## Wind Farms in Iowa Owned by MidAmerican Energy and Alliant Energy



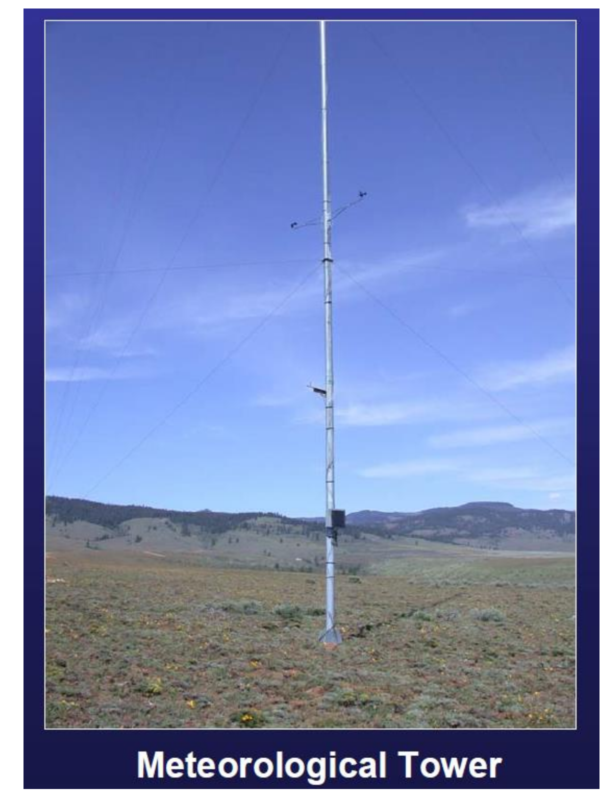

*Source: MidAmerican Energy*




*Source: Alliant Energy*

## Meteorological Towers

Wind energy developers first collect meteorological data with meteorological towers (met towers) to determine the appropriate wind turbines to construct for a wind energy development project (U.S. Department of the Interior Bureau of Land Management 2005). Meteorological towers, mainly metal, lattice-structures installed with weather data collection equipment, are around 165 feet (50 meters) in height (U.S. Department of the Interior Bureau of Land Management 2005). They can be transported by pickup trucks and medium-duty trucks and installed typically within one day (U.S. Department of the Interior Bureau of Land Management 2005). Meteorological weather data that would be collected by meteorological towers include wind speed and direction, wind shear, temperature, and humidity over the course of one to three years installed with weather data collection equipment.

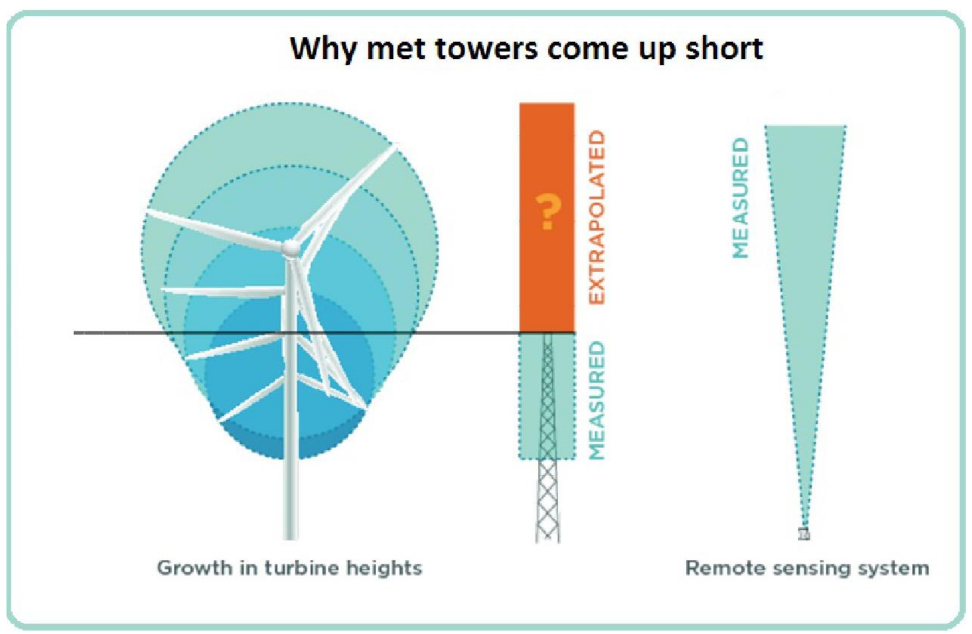



*A photograph of a meteorological tower.*
*Source: (Walker 2008)*

**Alternative: SoDAR**

As an alternative to meteorological towers for collecting wind measurement data, wind developers may utilize Triton SoDAR, a ground based remote sensing device (Dvorak 2016). The validity and reliability of measurements obtained from Triton SoDAR have been confirmed by Ecofys, a wind energy consultancy, (Dvorak 2016) and by studies conducted by the National Renewable Energy Laboratory (Yi, et al. 2012, Scott, Elliott and Schwartz 2010). SoDAR may be used for micro-siting, wind farm layout, turbine selection, and optimizing energy production for existing wind farms (Dodd 2018).

*A picture of the Triton SoDAR device at the Ecofys Testing Site in Lelystad, Netherlands. Source: (Dvorak 2016)*




*Illustrative comparison between meteorological towers and remote sensing. Adapted from Wind Power Engineering and Development*

A Comparison Between Meteorological Towers and Remote Sensing Devices

| | **Meteorological Towers** | **Remote Sensing Devices** |
|---|---|---|
| **Advantages** | • Industry familiarity and acceptance | • Portable and convenient<br>• Typically, does not require a permit<br>• Can be installed in a day<br>• Better than meteorological towers at providing full rotor sweep data in addition to wind speed and shear over various heights<br>• Currently used by some wind energy developers for competitive advantage |
| **Disadvantages** | • Mechanical failures<br>• Over-speeding in gusty conditions<br>• May stop in severe ice<br>• Lightning strikes<br>• Visibility to competitors<br>• Impacted by wind turbine tower shadow<br>• Requires reliable power supply<br>• Cannot measure hub height temperature, pressure, or humidity | • May be buried in deep snow<br>• Susceptible to geographic placement and atmospheric conditions<br>• Mechanical or electrical failure<br>• Requires reliable power supply<br>• Cannot measure hub height temperature, pressure, or humidity<br>• Currently lacks acceptance from financiers |
| **Costs** | • Time and financial costs with obtaining siting permits<br>• For a 100-meter tower, around $80,000 to $130,000 without permit fees<br>• For a 60-meter tower, around $25,000 to $40,000<br>• Insurance claims around $12,000 to $140,000 for icing and snow damage to tower collapse from high winds or construction error. Possible accidents from working at height or vandalism | • For a 200-meter profiling device, around $175,000<br>• For a 120-meter profiling device, around $60,000 to $70,000<br>• Vulnerable to theft and damage under extreme weather |

*Source: (Dodd 2018)*

## Wind Farm Transportation

**Nacelles**

Nacelles, that may exceed 165,000 pounds (74.8 metric tons) (Dvorak, Challenges in moving huge and heavy components 2011), are often transported by 19-axle trailers (Gosman 2010). Nacelles for 3 MW and 5 MW turbines are approximately 86.0 tons and 143.3 tons (78 metric tons and 130 metric tons) without the gearbox and generator, respectively (114.6 tons and 190.7 tons or 104 metric tons and 173 metric tons with both installed, respectively) (Cotrell, et al. 2014). Others estimate nacelles for 2.5 MW turbines to weigh up to 88.5 metric tons (Gosman 2010).

A 19-axle trailer carrying a nacelle.
Source: TrailKing Industries

**Tower Sections**

Tower sections are often transported by Schnabel trailers (Gosman 2010). Schnabel trailers are trailer sections that attach to opposite ends of the wind turbine tower sections (Dvorak, Challenges in moving huge and heavy components 2011). Tower sections for 1.5 MW turbines may require 1.5 Schnabel trailer units, while tower sections for 2.5 MW turbines may require 2.5 Schnabel units (Gosman 2010). As tower sections are produced with larger diameters, Schnabel trailers are needed to lower the overall height during transportation (Dvorak, Challenges in moving huge and heavy components 2011). Tower sections that exceed 15 feet in height pose difficulties, especially going under bridges (Dvorak, Challenges in moving huge and heavy components 2011).

A Schnabel trailer holding a wind turbine tower section.
Source: WindPower Engineering

**Blades**

Wind turbine blades pose some specific transportation difficulties. Some research indicates that the breakpoints in the length of wind turbine blades for transportation on roads are between 173.9 feet (53 meters) and 203.4 feet (62 meters) (Cotrell, et al. 2014). One of the longest trailers on the market currently is the TrailKing TK85EFX, which is 155 feet (47.2 meters) in length (Patel 2014). Federal law permits a 30-foot (9.1 meters) overhang; so, the maximum total length of a wind turbine blade that can be transported on current trailers without beam inserts, or trailer extensions, is 183.7 feet (56 meters) (Patel 2014). Vehicles that transport wind turbine blades with an overhang of 30 feet (9.1 meters) are vulnerable to top swing with signage and poles (Patel 2014). If a blade is longer than 183.7 feet (56 meters), then either beam inserts could be added to expand the length of the trailer or new legislation can be implemented to increase the maximum allowable rear overhang (Patel 2014). Blades over 190.3 feet (58 meters) will have an overhang of at least 30 feet (9.1 meters) (Patel 2014).


*Companies that supply blade lengths over 56 meters may face transportation challenges in the U.S.*
*Source: (Patel 2014)*

There are also extendable trailers that can accommodate two wind turbine blades simultaneously (Rudolfs 2012).

| **Selected Examples of Major Specialized Stretch Blade Trailer Manufacturers** (Patel 2014) |
|---|
| • TrailKing (predominant in North America)<br>• Temikso<br>• K Line<br>• Cometto (mostly in South America)<br>• Faymoville (mostly in South America)<br>• XL<br>• IST Trailers<br>• Heil Trailer<br>• Goldhofer (mostly in Europe) |

**Transportation Breakpoints**[a]

| | Component Breakpoint | Hub Height/ MW Affected | Notes |
|---|---|---|---|
| **Tower Components** | Width: 4.3 or 4.6 m in diameter [A,C]<br>Length: 52 or 63m [D]<br>Weight: ~ < 80,000 lbs. (truck) [B] | Width: 80-m–160-m turbines and any turbine larger than ~1.9 MW [C] | [A] Rolled steel can be used to overcome this breakpoint, though it greatly increases capital costs.<br>[B] Weight is likely not going to play a large role in transportation of a tower component in the future due to rolled steel and tower segmentation.<br>[C] Most turbines today are influenced by this transportation breakpoint.<br>[D] The length breakpoint accommodates for turning radiuses. Segmentation of tower sections is how this breakpoint is achieved. |
| **Blades** | Length: 52 m–63 m [A, C]<br>Width: (aka blade root) 4.3 m–4.6 m [A]<br>Weight: ~ < 80,000 lbs. (truck) [D] | Length: Potentially affects 2.2-MW–3.8-MW turbines [C]<br>Width: 4.3–7.3 MW. [B] | [A] New technologies in blade design could allow for longer blades despite the transport breakpoint.<br>[B] This is based on future turbines with longer blades. The length breakpoint potentially affects future turbine installations with lengths up to 80 m and 4.3 MW–7.3 MW.<br>[C] This potentially affects 2.2-MW–3.8-MW turbines; however, there appears to be no absolute limit on length, yet longer lengths increase turning radius and this seems to be the accepted breakpoint in order to accommodate turning radius (~120 ft). At the same time, longer lengths mean longer trailer overhangs, and most states limit these overhangs.<br>[D] The weight breakpoint does not appear to affect blade transportation because blades are the lightest component. |
| **Nacelle** | Length: 11.7 m [A]<br>Height: 4.3 m–4.6 m [B]<br>Weight: ~< 80,000 lbs. (truck); ~< 102 tonnes, ~225,000 lbs (rail) [C,D] | Weight: 3–5 MW [E] | [A] Limited to the 19-axle trailer load deck.<br>[B] Designed to fit under overpasses and traffic controls.<br>[C] 225,000 lbs. is approximately the weight limit of rail transport (~260,000).<br>[D] Trucks and nacelles (total load) need to be less than 80,000 lbs. in order to comply with U.S. interstate restrictions. In some states, special permits can be purchased to increase the weight by a fixed amount. In order to keep nacelles under this weight, the nacelle components are separated as much as possible.<br>[E] Unless future technology can significantly reduce nacelle weight, any future turbines of 3 MW–5 MW will be affected by this breakpoint, and nacelles will be too heavy to transport on the road even with internal components shipped separately. This will lead to a stronger reliance on rail for the majority of the transportation, and any trucking to the site will need special and costly permits. |

*Adapted from (Mooney and Maclaurin 2016)*

**Vehicular Weights**

The weights of vehicles involved in the transportation of wind turbine components are commensurate with their loads. Common weights of wind turbine transportation vehicles are roughly 218,000 pounds (98.9 metric tons) for the gross weight of a truck carrying a nacelle for a 300 feet (91.4 meters) wind turbine and around 134,000 pounds to 232,000 pounds (60.8 metric tons to 105.2 metric tons) for the gross weight of a truck that carrying tower sections (Kronick 2011).

**Number of Vehicular Trips**

According to the American Wind Association, transporting one wind turbine could require as many as 8 trips: one for the nacelle, one for the hub, one for each of the three blades, and one for each of the three tower sections (Ortegon, Nies and Sutherland 2013). Others have presented similar estimations: one study predicts up to 8 oversized loads for a wind turbine: one for the nacelle, three for the blades, and four for the tower sections (Mooney and Maclaurin 2016); another study estimates 12 over-dimensional loads and 2-3 legal loads for three blades, one hub, one to two nacelle and side panels, four to five tower sections, and two to three legal loads for the foundation (Patel 2014); yet another estimates 9 to 10 trucks, of specialized trailers, such as three for the three blades, one specialized trailer for the nacelle, and up to four specialized trailers for tower sections (Dvorak, Challenges in moving huge and heavy components 2011). Generalizing to the entire wind farm, 689 truckloads, 140 railcars, and 8 shops may be required to transport a 150 MW wind project (Mooney and Maclaurin 2016). To deliver 6 turbines a week, 6 or more trailers and rigs, 18 or more blade trailers, 54 drivers, and support equipment such as escorts and pilot cars may be necessary (Dvorak, Challenges in moving huge and heavy components 2011).

**Transportation Challenges**

General challenges during the transportation of wind turbines to the construction site include (Ortegon, Nies and Sutherland 2013):

- the availability of truck trailers and rail cars capable of wind turbine transportation
- differences in state-to-state oversized loads restrictions
- driver shortages and training
- non-optimized loads
- hours-of-service constraints

More specific transportation challenges include:

- the large turning radius for the turbine blades; the weight turning radius and road curvatures (Mooney and Maclaurin 2016)
  - Wind turbine blade transport vehicles need a wider turning radius than present at rural intersections, so corners may need to be widened (Kronick 2011)
- vertical and horizontal clearances for the tower sections (Mooney and Maclaurin 2016)
  - vertical clearance may be difficult with overhead passages, so tower sections are generally limited to 14.1 feet to 15.1 feet (4.3 meters to 4.6 meters) in diameter (Cotrell, et al. 2014)
  - travel on bridges and tunnels with height restrictions (Mooney and Maclaurin 2016)
- large transportation vehicles with heavy wind turbine components may exceed rural road capabilities and damage gravel roads (Kronick 2011)
  - wind project construction usually begins early spring when roads are the weakest (Kronick 2011)

**Factors Influencing Route Choice and Transportation Costs**

| Mode | Influencing Factors |
|---|---|
| All modes | • Component being transported—size and weight configurations<br>• Fuel costs<br>• Distance traveled<br>• Proximity of manufacturing facilities and wind sites<br>• Labor costs<br>• Storage facilities (*if applicable*)<br>• Number of needed mode changes<br>• Transportation company used |
| Rail | • Tracking rights and rail ownership<br>• Rail-line partnerships or agreements<br>• Age and dimensions of railways, tunnels, and bridges<br>• Track radius/ track curvature |
| Truck | • Permitting uniformity<br>• Regional permitting associations, multi-state or multi-jurisdiction permits<br>• Number of required permits—number of pass-through regulatory jurisdictions<br>• Requirements for each permit (e.g., overhang limitations, daylight hour restrictions, road restrictions, bonding requirements, escort requirements)<br>• Available information and permitting process<br>• Road type<br>• Road and bridge clearances and weight limits<br>• Number of exits/ turns and road curvature<br>• Weather, time of day, and season of travel<br>• Number and roadway condition of pass-through places (e.g., urban areas, cities, towns) |
| Ship/barge | • Port fees<br>• Port clearances<br>• Weather and season of travel<br>• Channel depth |

*Adapted from (Mooney and Maclaurin 2016)*

While challenges in the transportation of wind turbines exist, researchers are optimistic that overcoming transportation and logistics barriers generally may encourage wind energy development in low and moderate wind speed regions (Cotrell, et al. 2014).

**Transportation Costs**

Estimates for the proportion of transportation costs to the total capital costs for land-based wind energy projects are between 3% and 8% (Mooney and Maclaurin 2016). Other studies estimate that transportation account for an average of 10% of the upfront capital costs of a wind project (Gosman 2010).

# Wind Farm Construction

**General Construction Process**

Wind farms contain four components to be constructed. The first is the construction of project facilities (Taylor and Parsons 2009). These facilities include gravel access roads, electrical cables, project substation, and an operations and maintenance building (Taylor and Parsons 2009). The second is road construction (Taylor and Parsons 2009). Roads are graded to 16 to 20 feet (4.9 to 6.1 meters) in width, compacted, have drainage installed in the form of culverts or fords, laid with a base of either geo-fabric or geo-grid, and then overlaid with 6 to 8 inches (15.2 to 20.3 centimeters) of gravel (Taylor and Parsons 2009). The completed road profile has a 2% crown in the center for drainage and a shoulder with a maximum of 2% slope for cranes to transverse (Taylor and Parsons 2009). After construction is completed, shoulders are normally restored (Taylor and Parsons 2009). It is estimated for every megawatt of wind project capacity to be installed, 0.46 acres of land would be converted for roads (Conaway 2017). Wind developers may construct their own roads and field drives but doing so raises safety issues with the placement and number of entrances, disruption with drainage ditches or culverts, and potential effects on drainage tiles under heavy loads (Kronick 2011). The third is the wind turbine tower foundations (Taylor and Parsons 2009). The tower has a pier foundation consisting of the footing between 50 to 80 feet (15.2 to 24.4 meters) in diameter and 4 feet (1.2 meters) in depth with taper, pier between 16 to 30 feet (4.9 to 9.1 meters) in diameter and 3 feet (0.9 meters) in height, and an apron which is a compacted area over the diameter of the footing and has 6 inches (15 centimeters) of rock surface (Taylor and Parsons 2009). During construction, the area is excavated to a depth of 8 to 50 feet (2.4 to 15.2 meters), a lean concrete mud mat of 2 to 4 inches (5.1 to 10.1 centimeters) is placed, a rebar cage and anchor bolts cage erected, concreted is poured, and the cavity refilled with native soil (Taylor and Parsons 2009). The fourth is the installation of the wind turbine tower (Taylor and Parsons 2009).

**Construction Equipment**

Lifting the nacelle requires the largest crane capacity because of the height and mass involved with the lift (Cotrell, et al. 2014). Large cranes, such as the 1,250 metric tons and 1,600 metric tons crawler cranes, may be needed; however, cranes above the 600 metric tons class may have limited availability (Cotrell, et al. 2014). Other commonly used cranes in wind farm construction are the rough-terrain cranes, which are two-axle vehicles that weigh around 100,000 pounds (45,359.2 kilograms) (Kronick 2011). These large cranes pose transportation and maneuvering challenges: for example, the 1,600 metric ton crane has a width of 41 feet (13 meters), which is wider than a two-lane interstate with shoulders and would require around 100 semi-tractor trailers to transport (Cotrell, et al. 2014)

*A rough-terrain crane.*
*Source: Norman Spencer*

*A crawler crane.*
*Source: Norman Spencer*

*A crawler crane hoisting a wind turbine blade.*
*Source: Liebherr*

**Case Study: MidAmerican Energy**

MidAmerican Energy provides the public with a video on the construction process of a wind turbine (MidAmerican Energy Company 2015). First, the wind turbine site is cleared and then around 40 to 100 geopiers are added for soil stability (MidAmerican Energy Company 2015).

Second, the site is excavated to a depth of 10 feet and diameter of 100 feet (MidAmerican Energy Company 2015). Excavation can be performed in one day (MidAmerican Energy Company 2015).

*Excavation for the wind turbine foundation.*
*Source: MidAmerican Energy*

Third, a layer of concrete is poured and set within a day before the rebar, of about 96,000 pounds of reinforcing steel, for the wind turbine foundation is erected (MidAmerican Energy Company 2015). The concrete for the foundation requires 53 concrete trucks and cures in two days (MidAmerican Energy Company 2015).


*The rebar for the wind turbine foundation.*
*Source: MidAmerican Energy*

Fourth, soil is backfilled over the concrete wind turbine foundation and the site is leveled (MidAmerican Energy Company 2015).

Fifth, the wind turbine components are transported to the site in 8 truckloads: 3 for the blades, 3 for the tower sections, 1 for the nacelle, and 1 for the rotor (MidAmerican Energy Company 2015). In this construction, the wind turbine blade is 173 feet (52.7 meters) long and weighs 27,000 pounds (12,247.0 kilograms) (MidAmerican Energy Company 2015). The base tower has a height of 53 feet and 11 inches (16.4 meters) and weigh 97,459 pounds (44,206.7 kilograms) (MidAmerican Energy Company 2015). The mid-tower height is 84 feet and 6 inches (25.8 meters) and weighs 115,587 pounds (52,429.4 kilograms) (MidAmerican Energy Company 2015).The top tower height is 119 feet (36.3 meters) and weighs 104,167 pounds (47,249.4 kilograms) (MidAmerican Energy Company 2015). The nacelle weighs 181,000 pounds (82,100.2 kilograms) (MidAmerican Energy Company 2015).

*The delivery of the wind turbine components to the construction site.*
*Source: MidAmerican Energy*

Sixth, the base and the mid-section of the wind turbine tower are constructed within an average of 5 hours (MidAmerican Energy Company 2015).

*The hoisting of the mid-tower section to be installed.*
*Source: MidAmerican Energy*

Seventh, the rotor is assembled in an average of 4 hours by using cranes to attach the three wind turbines blades to the nacelle (MidAmerican Energy Company 2015).


*The assembly of the wind turbine rotor and blades with cranes.*
*Source: MidAmerican Energy*

Eighth, the nacelle is hoisted to the top of the erected wind turbine tower and installed within an average of 4 hours (MidAmerican Energy Company 2015).

*Hoisting the nacelle to the top of the wind turbine tower for installation.*
*Source: MidAmerican Energy*

Ninth, the rotor with the attached three blades is hoisted to be installed to the nacelle (MidAmerican Energy Company 2015). For this wind turbine model, the rotor diameter is 354 feet (107.9 meters) (MidAmerican Energy Company 2015). The completed wind turbine height from the base to the blade tip is 442 feet (134.7 meters) (MidAmerican Energy Company 2015).

*Installation of the rotor with attached blades to the nacelle.*
*Source: MidAmerican Energy*

An average time for trained technicians to climb to the top of the wind turbine tower is 10 minutes (MidAmerican Energy Company 2015). The total time from the initial site excavation to the operations of the completed wind turbine is 3 weeks (MidAmerican Energy Company 2015).

*A newly constructed wind turbine.*
*Source: MidAmerican Energy*

# Case Study: WE Energies Blue Sky Green Field Wind Farm Construction Process

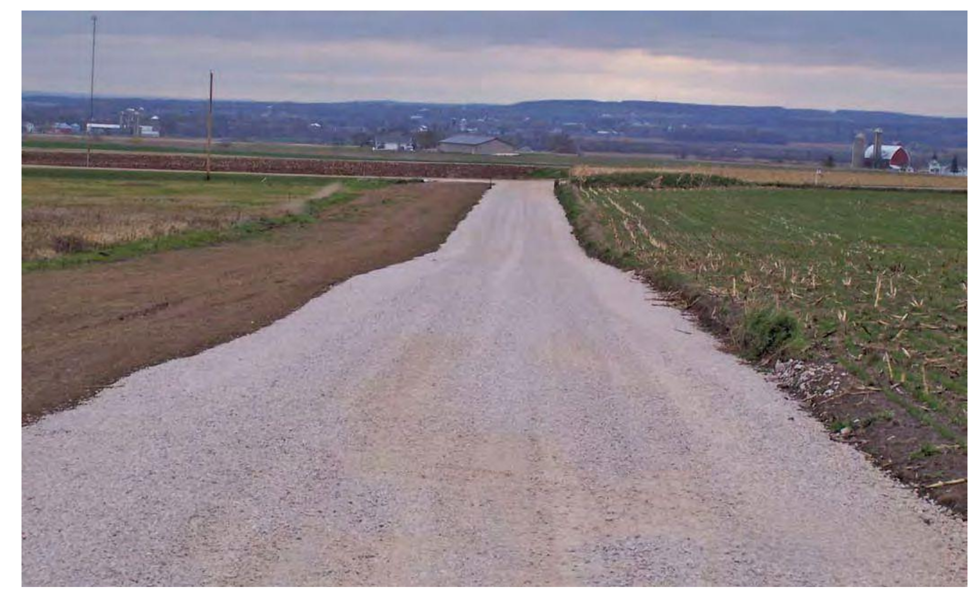
WE Energies, an electric service provider in Wisconsin and Michigan's Upper Peninsula, provides the public with an online presentation of their construction process for their Blue Sky Green Field wind farm located in the towns of Calumet and Marshfield in northeastern Fond du Lac County, Wisconsin (WE Energies 2012). The project began service in 2008 with 88 1.65 MW Vestas V82 horizontal-axis wind turbines, generating a total of 145 MW (WE Energies 2012). The initial cost for the project was reported as approximately $300 million (WE Energies 2012).

The construction process for the Blue Sky Green Field wind project can be divided into five steps. The first step is site preparation. During site preparation, the site is first cleared of debris and vegetation before gravel access roads are constructed. Temporary access roads approximately 40 feet wide are constructed from the existing public roadway to each wind turbine site (WE Energies n.d.).

*Initial site clearance and temporary road access.*
*Source: (WE Energies 2012)*

During the construction of the access roads, topsoil is removed and reserved, subsoil compacted, and a geotextile matting placed before the gravel is laid (WE Energies n.d.). Afterwards, the temporary access roads are converted to smaller, permanent roads approximately 16 feet wide (WE Energies n.d.). Although the primary travel path of the road is 16 feet, some portions may be up to 40 feet wide to accommodate large construction vehicles; but once wind turbine construction is completed, access roads are restored to 16 feet in width (WE Energies n.d.). The area of the road sections that were not converted are removed of the gravel and fabric, de-compacted, and layered with topsoil (WE Energies n.d.).

*Laying out the geotextile matting.*
*Source: (WE Energies 2012)*



*A completed gravel access road.*
*Source: (WE Energies 2012)*

Following the construction of access roads, culverts, from 150 feet to 175 feet in length, are installed for drainage and the delivery of large components (WE Energies n.d.).

*Laying out the culverts alongside the access road.*
*Source: (WE Energies 2012)*

Next, a crane path is constructed for the two different cranes used to erect wind turbines. A smaller crane is used to install the wind turbine's control system, base, rotor, and lower mid-tower sections; while a larger crane is used to install the upper mid-tower and top-tower sections, nacelle, and rotor (WE Energies n.d.). The size, weight, and slow speed of the two cranes prohibit them from operating on public roads, so they are transported by constructing cross-country paths that are determined by the shortest distance between turbines, participating properties, changes in grade, and the avoidance of woods, wetlands, and waterways (WE Energies n.d.). The construction of the crane path is similar to the construction of the access roads in which the topsoil is removed and reserved, the subsoil is compacted, and the area restored after wind turbine construction (WE Energies n.d.). Landowners are compensated for their lost crops due to the crane path but not for the access roads (WE Energies n.d.).

*A completed crane path.*
*Source: (WE Energies 2012)*

The second step is the installation of the collector system. The collector system is a network of underground cables that connect the wind turbines to the electrical substation (WE Energies n.d.). Wind turbines may be connected as a circuit instead of directly to the substation (WE Energies n.d.). A single circuit is installed in a two-feet wide and minimum four-feet deep trench (WE Energies n.d.). When multiple circuits are installed, a five-foot separation is required (WE Energies n.d.).

*Burying the electric cables.*
*Source: (WE Energies 2012)*

The third step is the construction of the wind turbine foundation. First, the topsoil and subsoil are removed and stockpiled separately and then they are returned according to their strata when the foundation is completed (WE Energies n.d.).


*A prepared site for the wind turbine foundation.*
*Source: (WE Energies 2012)*

Second, a hole is excavated for the foundation and then the foundation is formed by poured concrete over a reinforced steel structure (WE Energies n.d.). Foundations may be 55 feet wide and 8 feet deep in the center (WE Energies n.d.). When the foundation is completed, the topsoil and subsoil are returned around the foundation, but the center of the foundation remains exposed above the soil surface (WE Energies n.d.).


*The concrete wind turbine foundation being constructed.*
*Source: (WE Energies 2012)*


*Covering over the completed wind turbine foundation.*
*Source: (WE Energies 2012)*

Afterwards, a crane pad, approximately 55 feet by 80 feet, is then constructed near the foundation for cranes to erect the wind turbine tower but also for later maintenance activities (WE Energies n.d.).


*A crane pad near a wind turbine foundation.*
*Source: (WE Energies 2012)*

The fourth step is the construction of the wind turbine itself. Trucks carrying the wind turbine components and the necessary cranes are assembled near the wind tower foundation to first erect the base and mid-section of the wind turbine tower (WE Energies n.d.). Once the nacelle is lifted and installed, the three wind turbine blades are hoisted and assembled to the nacelle (WE Energies n.d.).

*Transporting a wind turbine tower section to the construction site.*
*Source: (WE Energies 2012)*

*Erecting the other wind turbine tower sections.*
*Source: (WE Energies 2012)*


*Erecting the base wind turbine tower section.*
*Source: (WE Energies 2012)*

*Lifting the nacelle onto the wind turbine tower.*
*Source: (WE Energies 2012)*

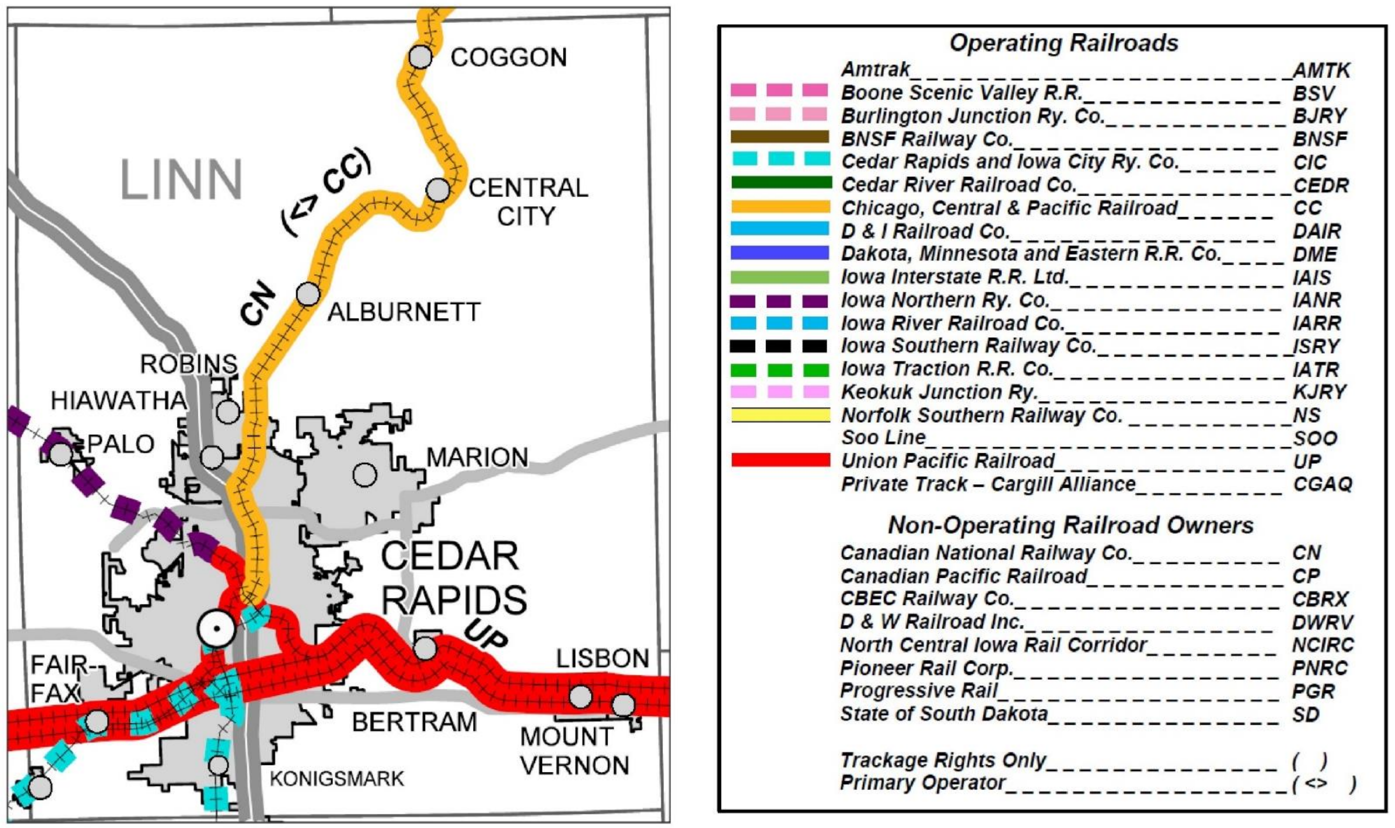
*Installing the wind turbine blades onto the hub.*
*Source: (WE Energies 2012)*

*Assembling the hub with three wind turbine blades to the nacelle.*
*Source: (WE Energies 2012)*

The final step is site restoration. After the construction of a wind turbine, a 15 feet radius around the wind turbine tower is reserved for equipment and the remaining area is restored to its original use (WE Energies n.d.). Since infrastructure for the wind turbine, like the concrete foundation and grounding cables, are only 18 inches to 24 inches below the surface of the concrete foundation, gravel is commonly placed in the area around the wind turbine as a reminder of the infrastructure underground (WE Energies n.d.).

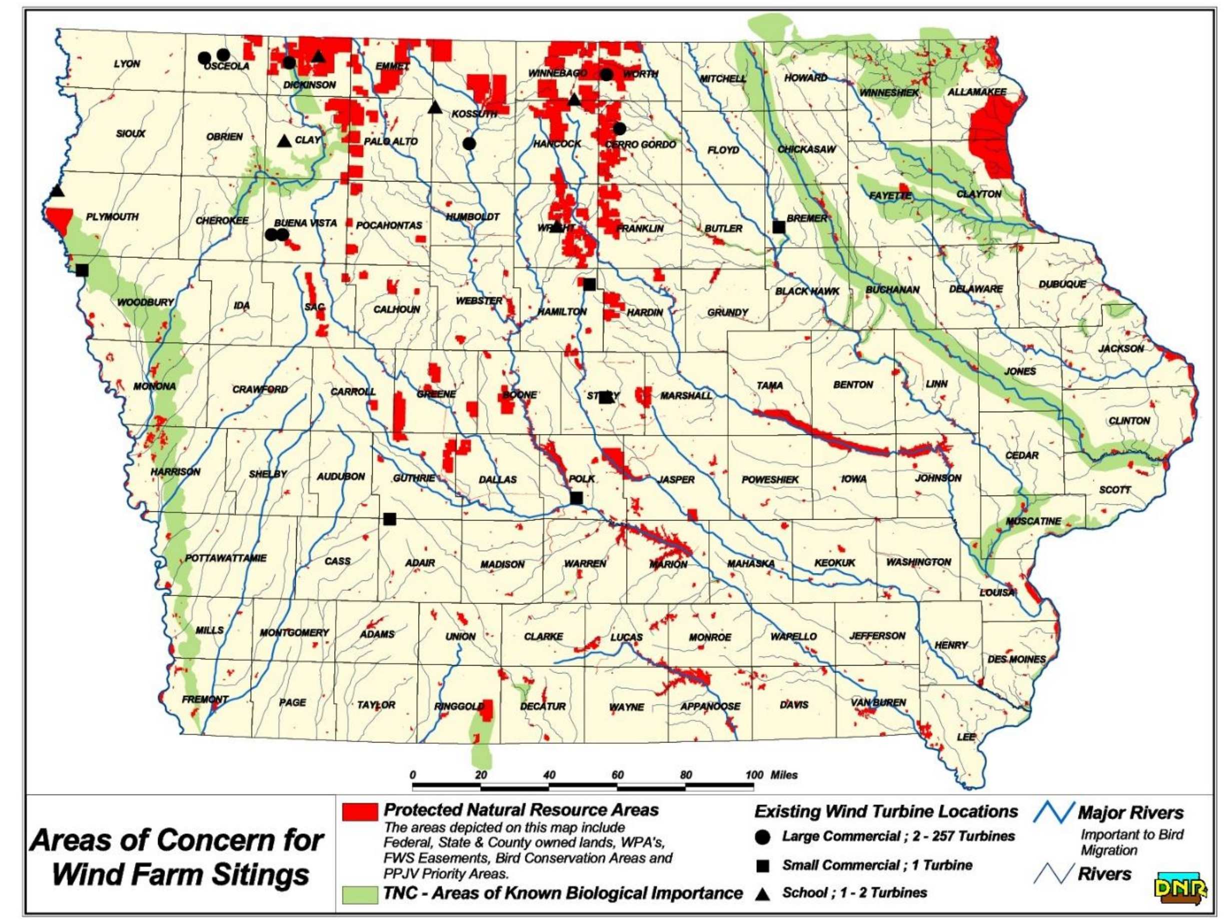
*The base around a completed wind turbine.*
*Source: (WE Energies 2012)*

## Railroads in Linn County

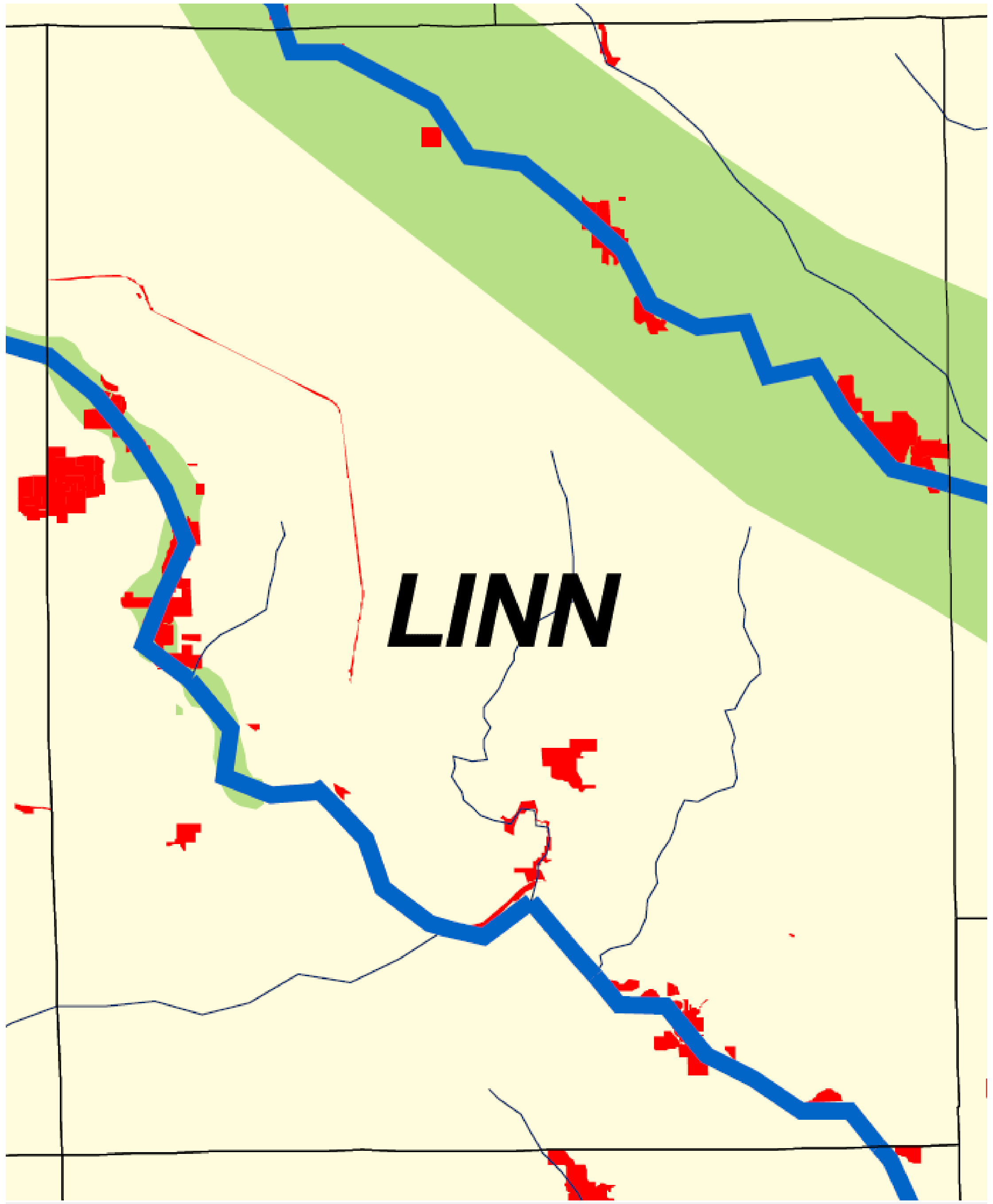



*A map of the operational railroads in Linn County.*
*Source: (Iowa Department of Transportation 2017)*

## Natural Environmental Areas of Concern for Siting Wind Energy




*A map of natural environmental areas of concern in Iowa for siting wind farms.*
*Source: Iowa DNR from MidAmerican Energy*




*A map of natural environmental areas of concern in Linn County for siting wind farms. Source: Iowa DNR from MidAmerican Energy*

# Impacts on Wildlife

**Impacts on Wildlife**

There are differences in regional wildlife fatalities. Wind energy sites in the Great Plains experience lower fatalities than the rest of the U.S., while sites in the Pacific experience higher fatalities (American Wind Wildlife Institute 2017). In the upper Midwest and eastern forests, bat fatality rates may be higher than bird fatality rates (American Wind Wildlife Institute 2017). Agricultural or forested areas, or areas with a mix of the two, experience equally high fatality rates (American Wind Wildlife Institute 2017).

Other general research finds that the lighting requirements currently recommended by the Federal Aviation Administration (FAA) do not increase the risk of wildlife collisions (American Wind Wildlife Institute 2017). More research is needed on the effects of wind turbine height and rotor swept area on wildlife fatalities and whether collision risk at individual turbines is comparable to individual turbines in a wind farm setting (American Wind Wildlife Institute 2017).

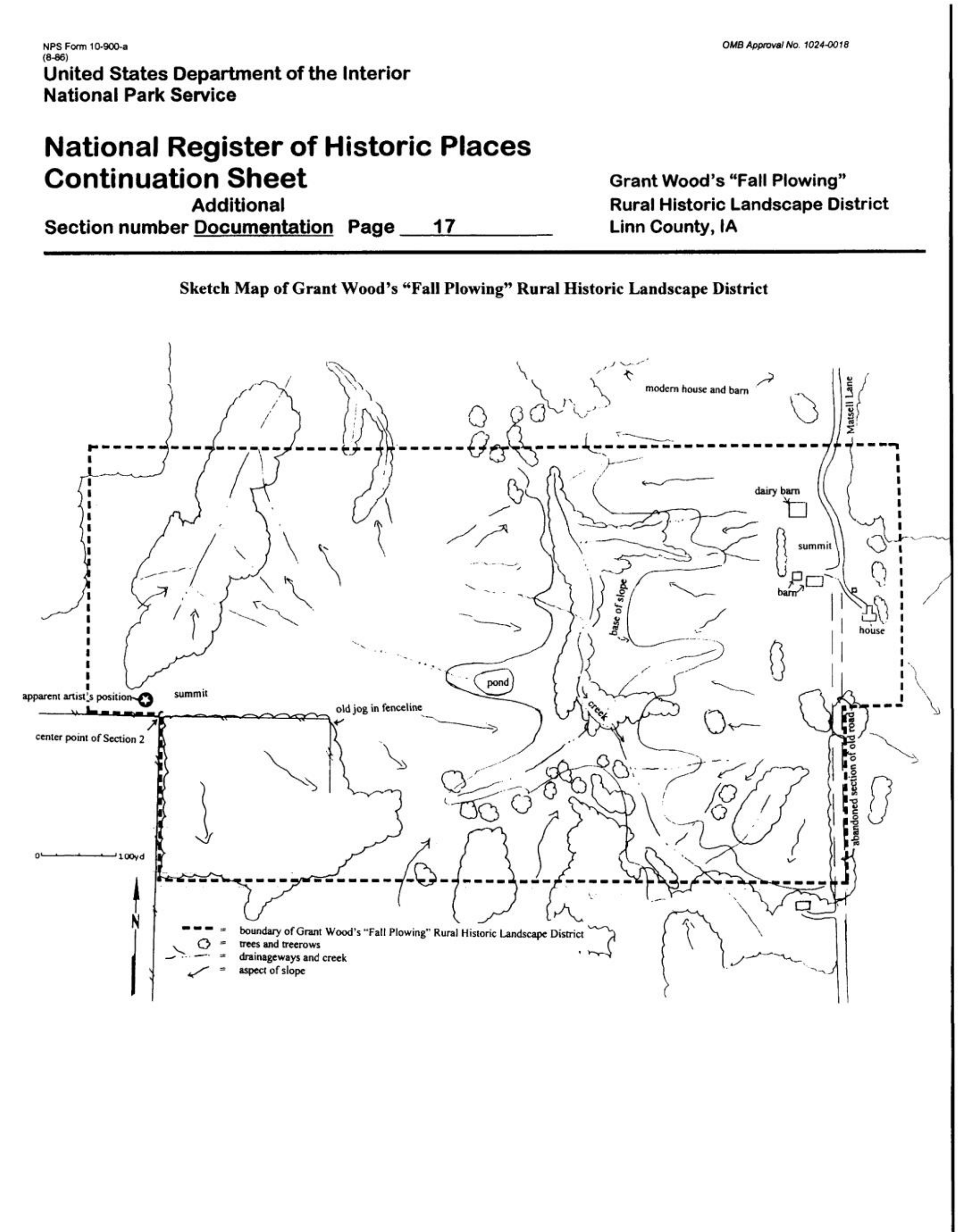
Wind energy projects have both direct and indirect impacts on wildlife. Direct impacts refer to wildlife collisions with wind turbine blades or towers, while indirect impacts refer to the effects on wildlife habitats from wind energy construction and operation, such as displacement (American Wind Wildlife Institute 2017).

Current research speaks to wildlife direct mortality and wildlife population effects. Wildlife direct mortality assumes birds and bats collide with rotating turbine blades, though it is also possible that their collisions are with the turbine towers instead (American Wind Wildlife Institute 2017). Publicly available studies indicate that mortality for all bird species range from 3 to 6 birds per MW per year and no more than 15 per MW per year (American Wind Wildlife Institute 2017). Avian fatalities from collisions with wind energy facilities are two to four orders of magnitude lower than other human causes of bird fatalities (American Wind Wildlife Institute 2017). Current estimated fatality rates do not suggest that the bird populations would decline (American Wind Wildlife Institute 2017). The impacts on the bat population are still not well studied (American Wind Wildlife Institute 2017). The effects of wind energy facilities on the movements of big game and other large terrestrial vertebrate populations are also uncertain (American Wind Wildlife Institute 2017).

Research on bird mortality covers passerines, raptors, and game birds. The majority of bird fatalities at wind energy developments have been small passerines: public data report approximately 250 bird species as fatalities at U.S. wind energy sites, but small passerines represent 60% of those fatalities though they also compose of more than 90% of all land-birds (American Wind Wildlife Institute 2017). As passerines are migratory, their fatalities are highest in the spring and fall (American Wind Wildlife Institute 2017). Fatalities of diurnal raptors, those which hunt during the day, are more frequent in the western U.S. where they are more prevalent; their relatively high fatality rates, which correspond to high collision vulnerability, may be of concern (American Wind Wildlife Institute 2017). Prairie chicken and greater sage grouse may avoid wind energy facilities because they perceive turbine towers as perches for predators (American Wind Wildlife Institute 2017). Roads, utility poles or lines, trees, oil and gas platforms, and human habitats have also been shown to displace prairie chickens and sage grouse (American Wind Wildlife Institute 2017). Additional research is needed on native game bird collisions, such as sage, grouse, and prairie chicken, though pheasants are a large portion of fatalities in the western U.S. (American Wind Wildlife Institute 2017). Water-birds and waterfowl, such as ducks, gulls and terns, shorebirds, loons, and grebes, are not frequently reported for land-based wind energy (American Wind Wildlife Institute 2017). The relationship between bird behaviors and bird collision risk in proximity to the rotor swept area requires more clarification from research: species that hunt prey close to wind turbines, such as red-tailed hawks and golden eagles, have higher fatality rates than those that just fly around wind turbines, such as the common raven (American Wind Wildlife Institute 2017).

Bat collision fatalities are their highest during the late summer and early fall migration sessions in the northern U.S. (American Wind Wildlife Institute 2017). Specifically, in the Midwest, cave dwelling bats have been reported as higher causalities than in the rest of the U.S. (American Wind Wildlife Institute 2017). Periods of high bat fatalities coincide with mating readiness in male hoary, eastern red, and silver-haired bats (American Wind Wildlife Institute 2017). At least twenty-four species of bats have been reported as collision fatalities: though three migratory tree-roosting bats, namely the hoary bat, the eastern red bat, and the silver-haired bat, comprise the majority, 70%-80%, of reported fatalities at North American wind energy facilities (American Wind Wildlife Institute 2017). Wind turbines may attract migratory tree bats either through the sounds produced by the wind turbines or by the insects that gather near the turbines (American Wind Wildlife Institute 2017). Weather may also affect bat collision fatalities: research indicates that bat fatalities occur on nights with low wind speed (American Wind Wildlife Institute 2017). Additional weather factors may include temperature, wind direction, or changing barometric pressure (American Wind Wildlife Institute 2017). Barotrauma, or injury from rapidly changing air pressure produced by moving wind turbine blades, does not appear to be a major source of fatalities, though more research is needed (American Wind Wildlife Institute 2017). Further research is also needed on whether the collision risk is higher for male migratory tree bats than for female tree bats (American Wind Wildlife Institute 2017).

# Grant Wood's "Fall Plowing" Rural Historic Landscape District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OMB Approval No. 1024-0018
United States Department of the Interior
National Park Service

National Register of Historic Places
Continuation Sheet
Additional
Section number Documentation Page 17

Grant Wood's "Fall Plowing"
Rural Historic Landscape District
Linn County, IA

Sketch Map of Grant Wood's "Fall Plowing" Rural Historic Landscape District



Source: (Rogers and Nash 2002)

NPS Form 10-900-a
(8-86)
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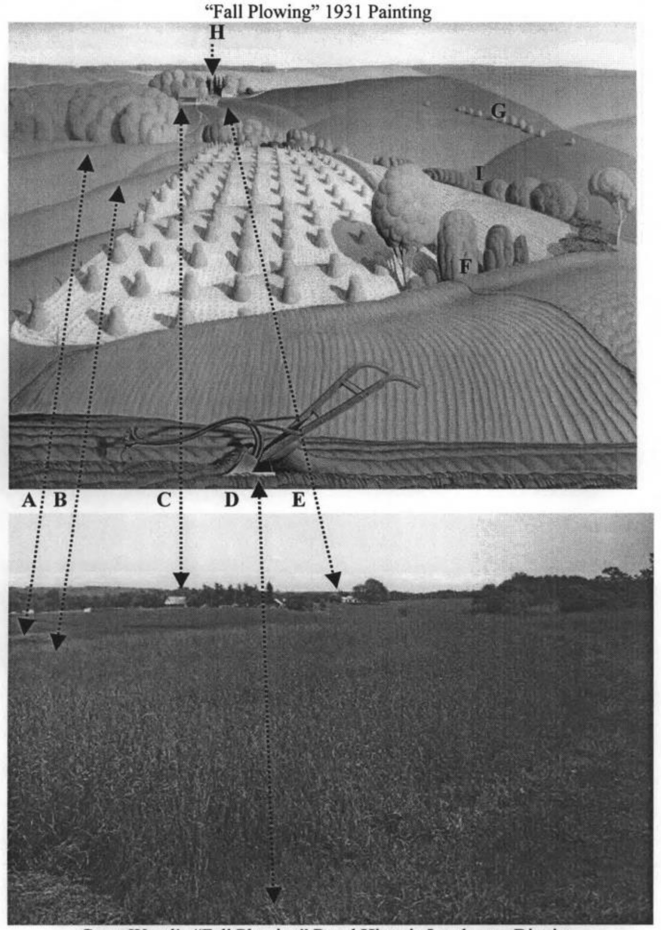
## National Register of Historic Places Continuation Sheet

Section number Additional Documentation Page 19

Grant Wood's "Fall Plowing"
Rural Historic Landscape District
Linn County, IA

"Fall Plowing" 1931 Painting




Grant Wood's "Fall Plowing" Rural Historic Landscape District,
View to the East from Near Apparent Artist's Position

**A** = rolling hillslopes match

**B** = rolling hillslopes match

**C** = dairy barn

**D** = apparent position of plow and artist's vantage point

**E** = house

**F** = jog in fence and fence line are still extant in actual landscape

**G** = tree row/fence line still extant in actual landscape

**H** = foundation for windmill still extant

**I** = fork in creek valley evident in actual landscape

Source: (Rogers and Nash 2002)

NPS Form 10-900-a
(8-86)
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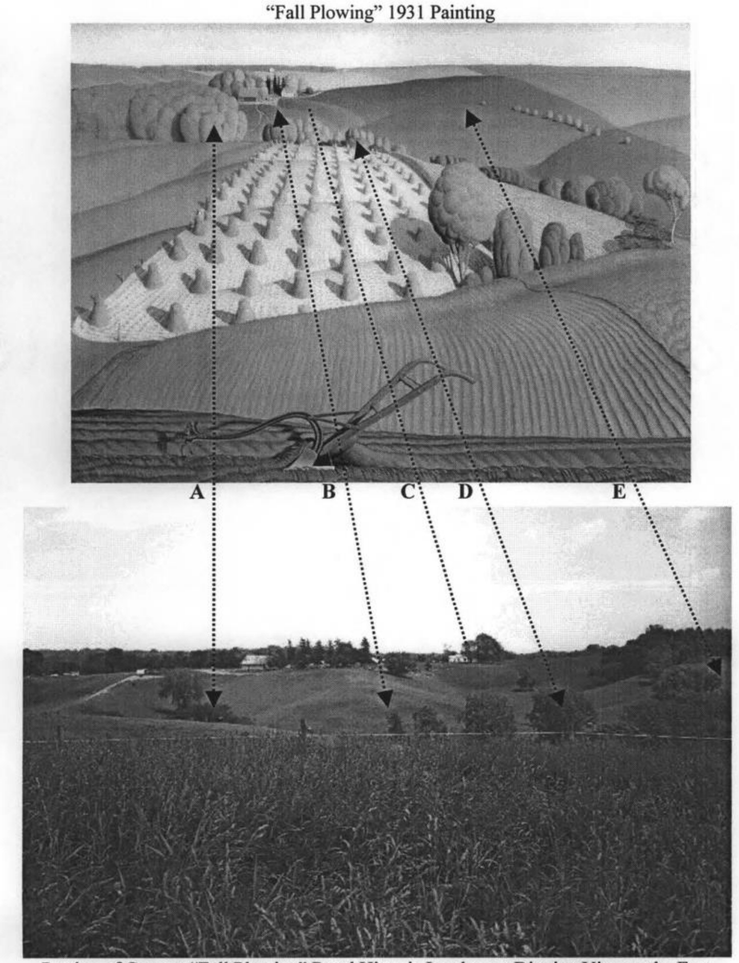
United States Department of the Interior
National Park Service

## National Register of Historic Places Continuation Sheet

Section number Additional Documentation Page 20

Grant Wood's "Fall Plowing"
Rural Historic Landscape District
Linn County, IA

"Fall Plowing" 1931 Painting




Portion of Current "Fall Plowing" Rural Historic Landscape District, View to the East

**A** = tree row in creek valley still evident in actual landscape

**B** = hillslope matches

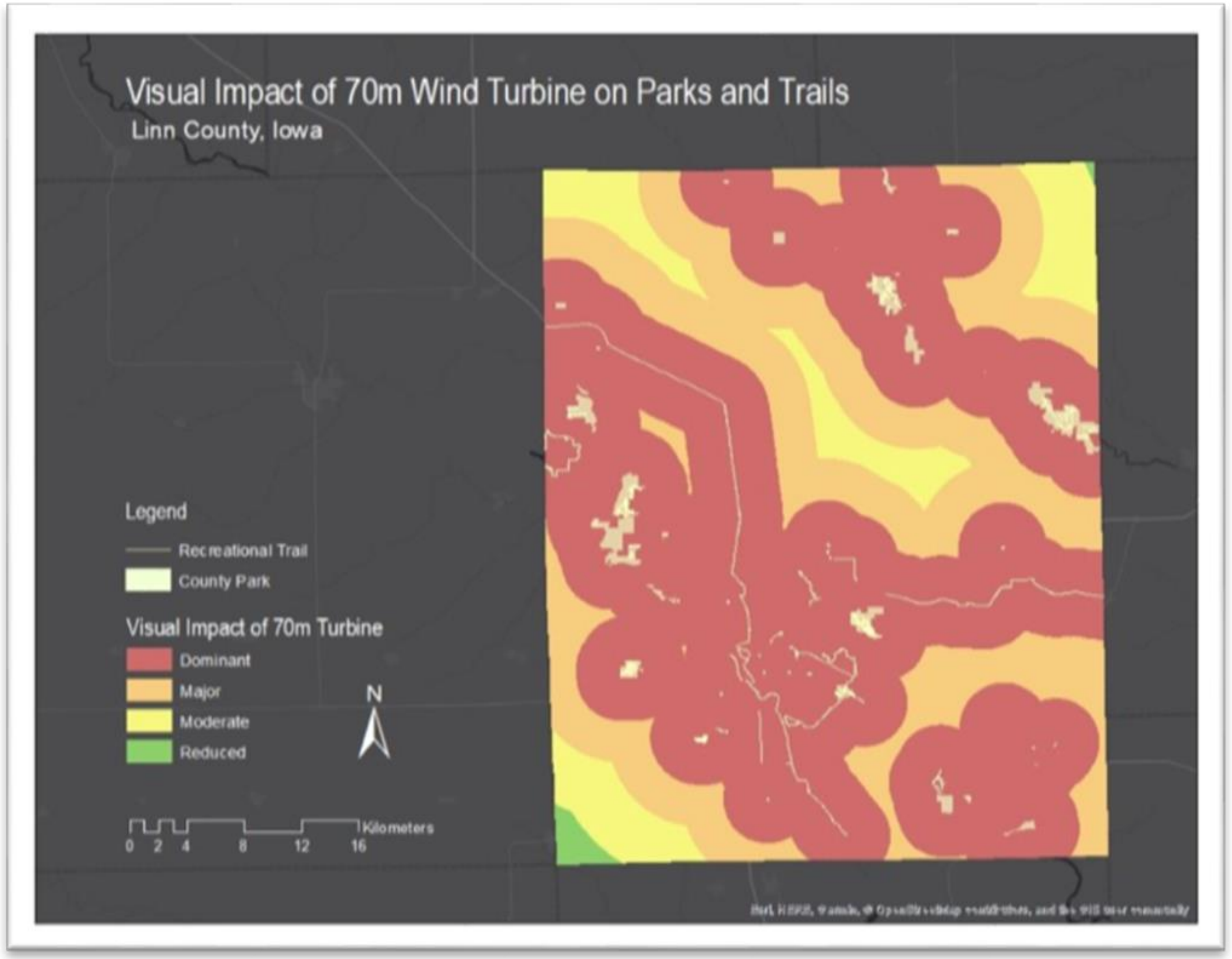
**C** = road cut in front of house still extant

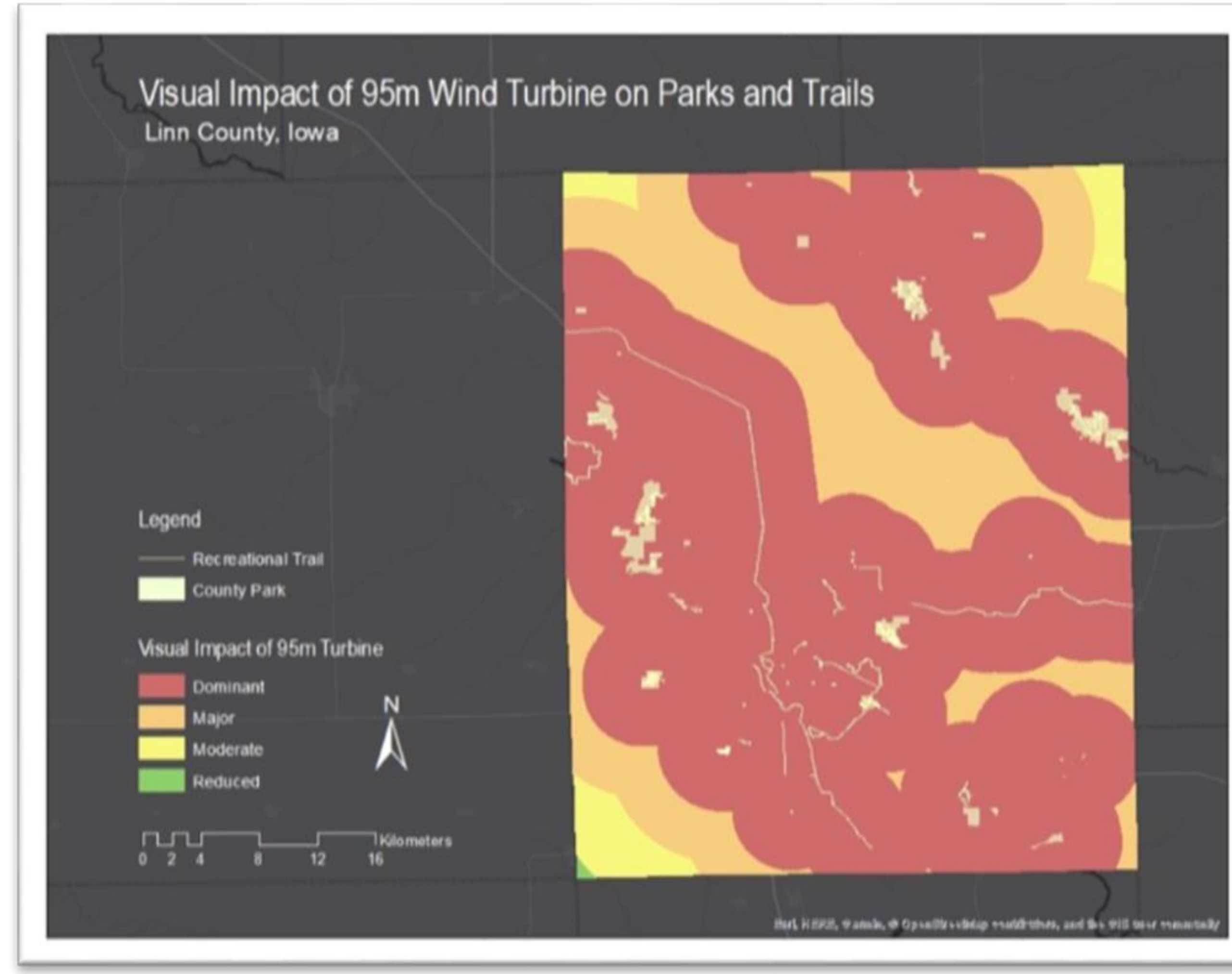
**D** = trees in valley match

**E** = hillslope matches

Source: (Rogers and Nash 2002)

## Visual Impact on Parks and Trails



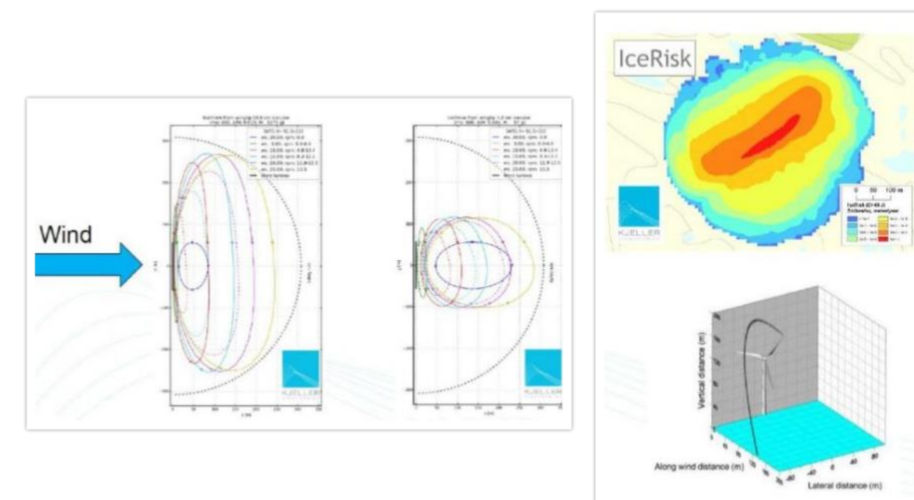
## Electromagnetic and Telecommunications Interference

Wind turbines may interfere with electromagnetic and telecommunication signals because of their rotating blades or their electric transmission lines, but the time and frequency of the interference may vary depending on fixed factors, such as distance to the source or material composition of the wind turbine, and variable factors, such as wind turbine orientation or rotation speed (Angulo, et al. 2014, Tetra Tech EC, Nixon Peabody 2008, Rhode Island Department of Administration Division of Planning 2012, Australian Government National Health and Medical Research Council 2010). Electricity production from wind turbines generate electromagnetic forces, though they pose no threat to public health because of the insulation of the electrical cables (Australian Government National Health and Medical Research Council 2010). Weather, air traffic control, and maritime radars, aeronautical navigation systems, radio links, and analog and digital terrestrial broadcasting services may all be impacted by wind turbines, but there are mitigation measures (Angulo, et al. 2014). Additional systems that may be affected include microwave systems, off-air TV broadcast signals, land mobile radio (LMR) operations, and mobile telephone services (Tetra Tech EC, Nixon Peabody 2008). The Rhode Island Department of Administration Division of Planning recommends that wind energy systems not be sited in proximity to existing fixed broadcast, retransmission, or reception antennae for radio, television, or wireless phone, medical, police, or fire, or other personal communication systems where signal transmission or interference might occur unless a replacement signal is provided (Rhode Island Department of Administration Division of Planning 2012). PREDAC, a European, non-government organization, recommends telecommunications receive compensation if experiencing any nuisance from wind turbines (Poussard, et al. n.d.).

## Icing and Ice Throw

In colder climates, such as Maine, Minnesota, Wisconsin, and Michigan, weather conditions may cause ice to accumulate on wind turbine blades (Rhode Island Department of Administration Division of Planning 2012). Accumulated ice may be susceptible to (Rhode Island Department of Administration Division of Planning 2012):

- ice carry, in which falling ice from a wind turbine is blown by wind
- ice shed or ice fall, in which ice drops from a turbine
- and ice throw, in which ice is flung from a moving wind turbine blade




*Left: Calculations for ice throw distances. Large ice pieces are thrown to the sides (left) and small pieces are carried by the wind (right).*
*Right: IceRisk spatial risk distribution.*
*Source: (Bredesen 2017)*

The general equation to determine the maximum distance for ice throw is (Krenn, Jordaens, et al. 2016)

- $1.5 * (\text{Hub Height} + \text{Rotor Diameter})$

and for ice fall is (Krenn, Jordaens, et al. 2016)

- $wind\ speed\ at\ the\ hub\ height * \frac{(\frac{Rotor\ Diameter}{2} + Hub\ Height)}{15}$

However, the general equations are not site-specific and ballistic computer models should be used to model specific site conditions (Krenn, Jordaens, et al. 2016). Reports indicate that ice fragments have been found within 328.1 feet (100 meters) of wind turbines (Chief Medical Officer of Health (CMOH) of Ontario 2010).

| Solution | Advantage | Disadvantage | References |
|---|---|---|---|
| **Empirical formulas** | + Fast, long history<br>+ Easy to understand<br>+ Widely used by authorities | - Does not provide the actual risk level<br>- simplistic and inaccurate<br>- Site-specific conditions cannot be considered | Paper: [221] [225] [226] [227] [228] |
| **Ballistic models** | + Results can be used as a basis for risk assessments compared to accepted risk levels<br>+ Site specific conditions can be considered<br>+ precise | - Mathematical model required (e.g. Monte Carlo Simulation)<br>- No established standards- not validated | Paper: [224] [229] |

*Solutions for assessing ice fall and ice throw from wind turbine blades*

Source: (Krenn, Jordaens, et al. 2016)

In a survey conducted by the International Energy Agency Wind, several wind turbine manufacturers reported having solutions for cold climates, including (Krenn, Jordaens, et al. 2016):

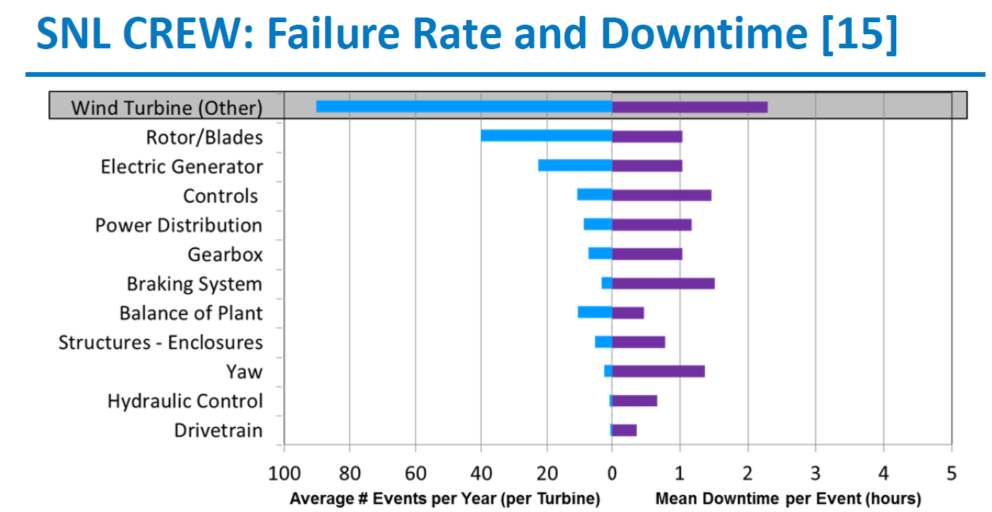
- Dongfang
- Enercon
- Lagerwey
- Nordex
- Northern Power Systems
- Senvion
- Siemens
- and Vestas

Acciona, Alstom, GE, Gamesa, ENO Energy, Goldwind, Mervento, Sinovel, and Vensys did not respond to the survey (Krenn, Jordaens, et al. 2016). Third-party providers known to also have cold climate solutions include Green Wind Global (EcoTEMP), Kelly Aerospace, Adios, and Wicetec (Krenn, Jordaens, et al. 2016).

According to one Canadian project manager, it is possible that wind farms may experience up to 20% in annual energy production losses from icing (Froese 2017). Additional icing and cold climate effects include measurement errors, power loss, overproduction, mechanical failures, electrical failures, and safety hazards (Ilinca 2011).

## Structural Failures and Blade Throw

The most common areas on wind turbines for damage are the rotor, the blade, and the tower (Ciang, Lee and Bang 2008, Shohag, et al. 2017). Sandia National Laboratories compiles the Continuous Reliability Enhancement for Wind (CREW) database to collect Supervisory Control and Data Acquisition (SCADA) data, downtime and reserve event records, and daily summaries of operation times for U.S. wind turbines (Sheng 2013). According to the CREW database, the top four most common issues with wind turbines are the rotor and blades, electric generators, the balance of plant, and controls and the top four most common reasons for wind turbine downtime are the braking systems, controls, yaw, and power distribution (Sheng 2013).




*Source: (Sheng 2013)*

Type 1: Damage formation and growth in the adhesive layer joining skin and main spar flanges *(skin/adhesive debonding* and/or *main spar/adhesive layer debonding)*;

Type 2: Damage formation and growth in the adhesive layer joining the up- and downwind skins along leading and/or trailing edges *(adhesive joint failure between skins)*;

Type 3: Damage formation and growth at the interface between face and core in sandwich panels in skins and main spar web *(sandwich panel face/core debonding)*;

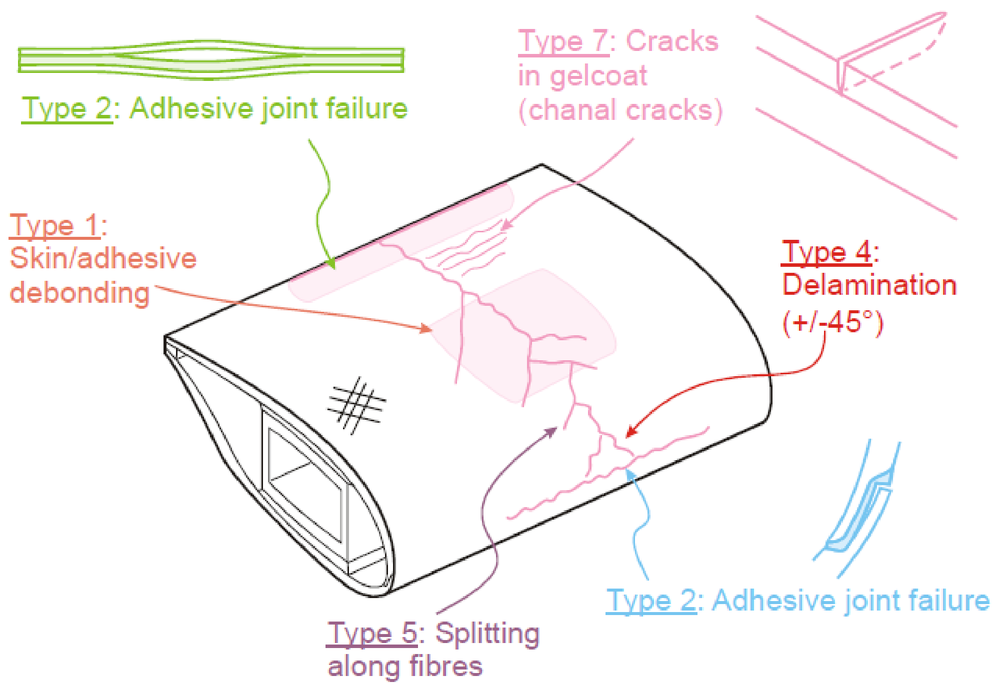
Type 4: Internal damage formation and growth in laminates in skin and/or main spar flanges, under a tensile or compression load *(delamination driven by a tensional or a buckling load)*;

Type 5: Splitting and fracture of separate fibres in laminates of the skin and main spar *(fibre failure in tension; laminate failure in compression)*;

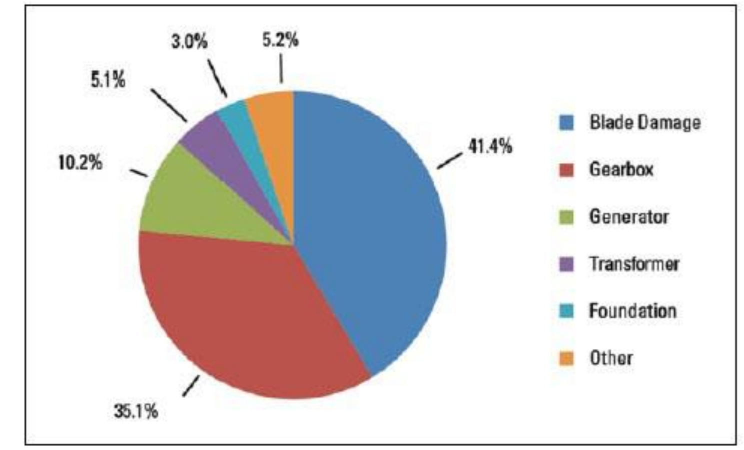
Type 6: Buckling of the skin due to damage formation and growth in the bond between skin and main spar under compressive load *(skin/adhesive debonding induced by buckling, a specific type 1 case)*;

Type 7: Formation and growth of cracks in the gel-coat; debonding of the gel-coat from the skin *(gel-coat cracking and gel-coat/skin debonding)*.

*Source: (Sørensen, et al. 2004)*




*Source: (Sørensen, et al. 2004)*




Most frequently reported component damage (based on number of 2012 US reported claims) (GCube Insurance Services Inc., 2012). Reprinted with permission from GCube Insurance Services Inc.

*Adapted from (Shohag, et al. 2017)*

About 1% to 3% of wind turbine blades would require blade replacements per year, with spikes in replacement rates in the first and fifth years of operations (Sheng 2013). Wind turbine blade replacements within the first two years of operations are normally attributed to manufacturing defects or damage during transportation and construction. (Sheng 2013). Throughout a decade of operation, an average of 2% of wind turbines per year would require blade replacements, most commonly because of lightning strikes (Sheng 2013). In the same period of a decade, the average gearbox failure rate is estimated at 5%, peaking in the eighth year, and the average generator failure rate is estimated at 3.5%, peaking in the sixth and seventh years (Sheng 2013). Gearbox failures are most likely to arise in bearings (70%), gears (26%), or other components (4%) (Sheng 2013).

## Sound and Noise

Sound is a vibration through a medium that can be measured either by its loudness, or sound pressure level, in decibels (dB) or by its pitch, or frequency, in Hertz (Hz) (Chief Medical Officer of Health (CMOH) of Ontario 2010). Frequencies that are below 200 Hz are referred to as low frequency sound and frequencies that are below 20 Hz are referred to as infrasound, though there is not a strict boundary between the two (Chief Medical Officer of Health (CMOH) of Ontario 2010). Noise is defined as unwanted sound (Chief Medical Officer of Health (CMOH) of Ontario 2010).

Wind turbines are known to produce both sound and noise (Chief Medical Officer of Health (CMOH) of Ontario 2010). Wind turbine noises can be generated either as mechanical noise, produced by the motor or the gearbox if they are malfunctioning, or aerodynamic noise, produced by the movement of the blades through the air (Australian Government National Health and Medical Research Council 2010). Additionally, wind turbines are known to generate noise in a range of Special Audible Characteristics (SACs), such as amplitude modulation, impulsivity, low frequency noise, and tonality, but there have been few published, scientifically-verified SACs cases (Australian Government National Health and Medical Research Council 2010).

**Human Perception and Annoyance**

The human ear can perceive sounds at frequencies from 20 Hz to 20,000 Hz, but only sounds of a certain pressure level can impact health (Chief Medical Officer of Health (CMOH) of Ontario 2010). High sound pressure levels of more than 75 dB could result in hearing impairment depending on the duration of exposure and individual sensitivity (Chief Medical Officer of Health (CMOH) of Ontario 2010). The generally inaudible infrasound, of 20 Hz or less, may have high enough sound pressure levels to be audible for some people (Chief Medical Officer of Health (CMOH) of Ontario 2010). The production of infrasound has not been verified in modern wind turbines (Australian Government National Health and Medical Research Council 2010). When perceived by humans, noises in general can produce subjective effects, such as annoyance, nuisance, or dissatisfaction, interference effects, such as with speech, sleep, or learning, or physiological effects, such as anxiety, tinnitus (perception of noise or ringing), or hearing loss (Australian Government National Health and Medical Research Council 2010).

Human annoyance with wind turbine noise appears to follow the nocebo effect in which people with existing negative opinions about a noise are more likely to be affected by it (Australian Government National Health and Medical Research Council 2010). Research indicates that annoyance with wind turbines is statistically associated with wind turbine noise but is more strongly associated with the visual impact of wind turbines, attitudes toward wind turbines and wind energy, individual sensitivity to noise, participation in the siting process, and whether any economic benefits were received from the wind energy developers (Knopper and Ollson 2011, Thorne, Osterberg and Johannsen 2019). There have been reports of people experiencing "wind turbine syndrome", or the health effects of being near wind turbines such as nausea, vertigo or illusory movement, blurred vision, unsteadiness, difficulty in reading, remembering, and thinking spatially, ringing in the ear or tinnitus, muffled hearing, feelings of fullness, pressure, or pain in the ear, episodes of panic, rapid heartbeat, constricted breathing, and the urge to flee (Pierpont 2012). While the validity of the "syndrome" is contentious, some studies suggest that the diagnosis of the "syndrome" was misinterpreted physiologic data and that the "syndrome" is a subset of annoyance reactions, perhaps to the "swishing" fluctuating nature of the sound from wind turbines than the intensity of the sound itself (Chief Medical Officer of Health (CMOH) of Ontario 2010, Colby, et al. 2009).

**Health Effects**

Currently, the peer-reviewed scientific literature does not provide evidence on adverse human effects from wind turbines (Australian Government National Health and Medical Research Council 2010, Thorne, Osterberg and Johannsen 2019). Some studies indicate that wind turbine sounds, infrasound and low-frequency sounds, are well below the 50 to 70 dB sound pressure level range for any direct human health effects (Australian Government National Health and Medical Research Council 2010, Chief Medical Officer of Health (CMOH) of Ontario 2010, Colby, et al. 2009). However, noise from wind turbines may be an annoyance for some and may be associated with health effects, such as sleep disturbance, with sound pressure levels greater than 40 dB(A) (Knopper and Ollson 2011). In general, wind energy is associated with fewer health effects than other forms of energy generation, such as fossil fuels, and may even result in a "net positive benefit to human health" (Australian Government National Health and Medical Research Council 2010, Thorne, Osterberg and Johannsen 2019).

## Property Values

The effects of wind turbines on neighboring property values may be classified according to three stigmas. The first is scenic stigma, in which people perceive their home may be devalued from a view of wind energy facilities and their disruption to the existing views (Hoen, Wiser, et al. 2011). Second, area stigma is the perception that wind energy facilities may cast an area as developed and negatively affect home values, even if an individual home has no views of wind turbines (Hoen, Wiser, et al. 2011). Lastly, nuisance stigma is the perception that proximity to wind turbines may have associated factors that negatively affect home values (Hoen, Wiser, et al. 2011).

Most of the available research and literature indicate wind energy facilities have little to no influence on neighboring property values. Available studies examined both the announcement of wind energy facilities and various distances and their effects. One study examined twenty-seven counties in nine states, including Carroll, Floyd, Franklin, and Sac Counties in Iowa and found no statistical evidence of house prices near wind turbines being affected either during the post-construction or post-announcement/pre-construction periods (Hoen, Brown, et al. 2013). Results from a different study suggest that wind turbines have no statistically significant impacts on house prices in either post-public announcement or post-construction phases (Lang, Opaluch and Sfinarolakis 2014). Even when residential areas where wind turbines were most likely to disrupt the surroundings were isolated, the study still found no statistically significant negative impacts to house prices with views of a wind turbine (Lang, Opaluch and Sfinarolakis 2014). In another study, the effects that did arise soon after the announcement or construction of the wind facilities appeared to fade over time (Hoen, Wiser, et al. 2011). Similarly, another study found the announcement of wind facilities and modest adverse impacts on home prices were weak and that those effects dissipated after wind turbine construction and operations (Hoen, Brown, et al. 2013).

Various distances from wind energy facilities were also found to have little to no influence on neighboring property values in at least four studies. In the first study, while there were a few homes close enough to wind facilities to be substantially impacted, those effects faded after 800 feet (Hoen, Wiser, et al. 2011). The study did concede that wind turbine effects, like noise, are difficult to quantify and not priced in the market; but their impacts, were they to exist, were too small or infrequent to have any statistical impact in the study's samples (Hoen, Wiser, et al. 2011). The second study found that it was highly unlikely for the actual average effect for houses sold within an area 1 mile from an existing wind turbine to be larger than +/-4.9% and highly unlikely that the actual average effect for houses sold in the sample area within half a mile of an existing turbine to be larger than +/-9% (Hoen, Brown, et al. 2013). In the third study, models indicated that houses within half a mile of a wind turbine experienced an estimated price change relative to houses 3 to 5 miles away of -0.4%; despite a higher standard error of 3.8%, the study still concluded that negative effects were bounded within 5.2% with 90% confidence (Lang, Opaluch and Sfinarolakis 2014). In the fourth study, urban and suburban areas of more densely-populated communities in Massachusetts were examined and results indicate that wind turbines do not appear to affect nearby home prices within half a mile (Atkinson-Palombo and Hoen 2014). The study did find negative associations, such as electricity transmission lines and major roads, as well as positive associations, such as open spaces or beaches, but did not find net effects from wind turbines (Atkinson-Palombo and Hoen 2014). Additionally, the study found no effect on the rate of home sales near wind turbines (Atkinson-Palombo and Hoen 2014).

Of the studies that did find negative impacts, one study was often referenced. Though the study found mixed results from the residential and agricultural property transactions for three counties in northern New York State, the study identified that wind facilities had significantly reduced property values in two of the three counties (Heintzelman and Tuttle 2012). The effects were dependent on distance from a home to a wind turbine: in Clinton County, the closest distance was 0.5 miles away and a decline in sales price of 8.8% to 14.9% was observed, whereas in Franklin County, the decline was from 9.64% to 15.81% (Heintzelman and Tuttle 2012). When the distance was extended to 3 miles, the effects were reduced to between 2% and 8% (Heintzelman and Tuttle 2012).

# Taxation

The State of Iowa has two tax credits for wind energy. The first is the Wind Energy Production Tax Credit and the second is the Renewable Energy Tax Credit (Girardi 2014). The Wind Energy Production Tax Credit is $0.01 per kilowatt-hour of electricity and the Renewable Energy Tax Credit is $0.015 per kilowatt-hour of electricity (Girardi 2014). Both tax credits are available for 10 years from the in-service date, nonrefundable with a 7-year carryforward, and transferable (Girardi 2014). The Wind Energy Production Tax Credit is available to both utility or independent facilities, while the Renewable Energy Tax Credit is only available to independent or rural electric cooperative facilities (Girardi 2014). Compared to other state and federal tax incentives, Iowa's Renewable Energy Production Tax Credit is the highest state tax credit for wind and other non-solar renewable energy sources (Girardi 2014). Iowa is the only state with fully transferable production tax credits and almost all of it are transferred to a third-party at less value (Girardi 2014).

There are also two means of taxing wind energy projects in Iowa. The first is through conventional property tax on wind energy conversion properties, meaning the wind turbine and electrical equipment, powerlines, substations, and transformers (Center for Rural Affairs 2019). The second is through special valuation based on the net acquisition cost, or the sum of the total cost of the property and the wind energy system (Center for Rural Affairs 2019). Under Iowa Code section 427B.26, local jurisdictions, such as cities and counties, can levy a special assessment at a graduated percentage of the net acquisition cost for wind energy conversion properties (Girardi 2014). In the first year after installation, the property is assessed at 0% of the net acquisition cost and each subsequent year is assessed by five percentage point increases until the seventh year, at which the rate remains at 30% of the net acquisition cost (Girardi 2014). Local jurisdictions in Iowa have not only experienced increases in property tax revenue but also increases in the assessed value of the property from the construction of wind energy facilities (Girardi 2014).

# Legality and Legal Challenges

**Fayette County Wind Farm Legal Challenge**

Fayette County and developer Optimum didn't pursue a special-use permit and decided to go with the wind farm as an allowed-use under the current zoning ordinance (Schmidt 2019).The current zoning ordinance allowed for "electrical transmission or regulating facilities" as an acceptable use and exempt from a special use permit (Schmidt 2019). This led to a three-year court battle where a District Court ruled in favor of land owners opposing the wind turbines. The Iowa Supreme Court then rejected an appeal to the ruling passed down by the District Court and the wind turbines had to be removed (Jamison, The Courier 2018).

**Black Hawk County Wind Farm Legal Challenge**

A 70 mega-watt large-scale wind farm with 35 wind turbines was approved by the Black Hawk County Board of Adjustment (Jamison, The Courier 2019). The argument is being made by a landowner that Iowa Law and County Zoning Code prevents any regulation of land used for farming. There is also an argument being made based on an illegal taking. The taking would be based on the negative externalities extending onto other surrounding properties (Jamison, The Courier 2019).

**Wildlife**

Prosecution against wind energy and wildlife fatalities have been limited, given that in 2005 there have been no states that prosecuted any wind energy facilities for wildlife mortalities that have occurred (Government Accountability Office 2005).

**Legal References**

For reference to legal issues associated with individual farmers and land owners seeking wind energy developments, please consult the Farmers' Legal Action Group's publication, "Farmers' Guide to Wind Energy: Legal Issues in Farming the Wind" (Shoemaker, Brekken and Krub 2007). Of note are (Shoemaker, Brekken and Krub 2007):

- Chapter 4 "Siting a Wind Project"
    - "Practical Siting Considerations"
    - "Land Use Permitting"
    - "Environmental Permitting and Review"
    - "Other Permitting and Review Issues"
- Chapter 5 "Liability Concerns for Wind Development"
    - "Contract Liability"
    - "Tort Liability"
    - "Regulatory Liability"

For reference to a sample wind energy easement or lease agreement, please consult Windustry's "Wind Energy Easement and Lease Agreements" (Nardi and Daniels 2005). Though dated, Windustry also provides "Wind Energy Easements and Leases: Compensation Packages" as a review of landowner compensation payments and general factors that influence the amount of compensation (Windustry's Wind Easement Work Group 2009).

In the 2008 suit of Dale Rankin, et al. v. FPL Energy, LLC in the Court of Appeals of Texas, Eastland, the Court decided that aesthetic impact was not considered evidence of nuisance (Diffen 2017). Since then, the case has been widely cited in nuisance claims against utility-scale wind energy projects (Diffen 2017).

In the 2016 case of Terra Walker, et al. v. Kingfisher Wind, LLC, seven individual landowners with the Oklahoma Wind Action Association filed suit against the development of the Kingfisher wind project in Kingfisher and Canadian Counties, Oklahoma through claims of anticipatory nuisance and anticipatory trespass (Diffen 2017). Plaintiffs claimed health effects caused by shadow flicker and sound from the wind turbines as well as aesthetic annoyance (Diffen 2017). However, the court found that the plaintiffs did not satisfy the requirement of "likely harm – a reasonable probability that an injury would occur beyond mere speculation" and that the plaintiffs did not sustain "substantial interference with the use and enjoyment" of their property (Diffen 2017). The summary judgement was ultimately in favor of the defendants, but the case indicates that anticipatory nuisance claims, though not normally upheld, can delay projects and affect project financing and construction (Diffen 2017). Additionally, there is risk that the use of anticipatory nuisance and trespass as legal strategies may lead to future challenges for the wind energy industry (Diffen 2017).

# Repowering

**MidAmerican Repowering Case Study**

In 2017, MidAmerican Energy Company announced a $1 billion project to repower seven Iowa wind farms, commissioned between 2004 and 2008 (Ford 2018). The 176 MW Intrepid, 200 MW Century, and 105 MW Victory windfarms were repowered in 2017 and MidAmerican is currently repowering the 75 MW Charles City facility (Ford 2018). Afterwards, the 286 MW Pomeroy, 150 MW Carroll, and 153 MW Walnut facilities will be repowered (Ford 2018).

MidAmerican's repowering includes installing larger blades and hubs and replacing nacelle components. Following the repowering, the total annual energy production of the seven wind farms is expected to increase between 19% and 28% and provide over 20 years of revenue (Ford 2018).

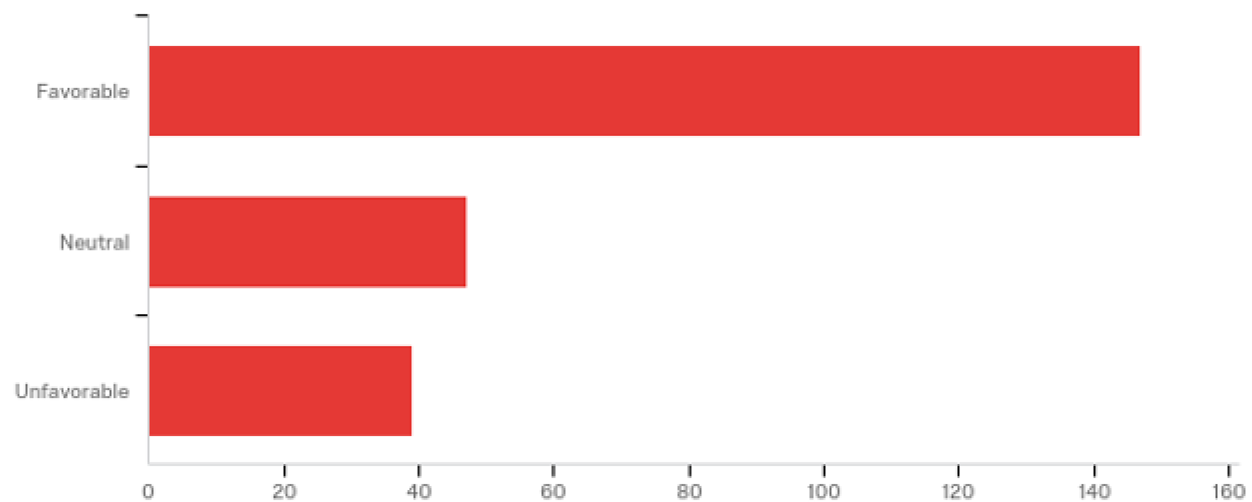
The seven repowering projects qualified for 100% of the production tax credit (PTC) of $23/MWh (Ford 2018). According to a consultancy, the internal rate of return (IRR) after tax for the seven repowering projects is estimated to be 11% based on a flat energy price of $24/MWh, capital expenditure of $950/kW, and asset life extension of 10 years (Ford 2018).

**Repowering from an Engineering Perspective**

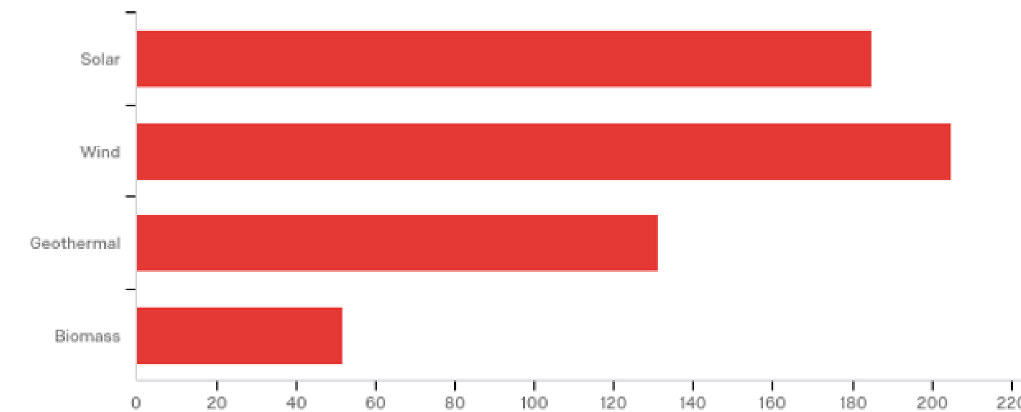
From an engineering perspective, there are three components to review during repowering considerations. First, an original design review focusing on structural and geotechnical evaluations and the site-specific design lives of critical components (Nguyen and Rogers 2018). Second, a current foundation review including geotechnical and structural analysis and an assessment of the loading the foundation is subjected to throughout its operational life (Nguyen and Rogers 2018). Third, fatigue performance evaluation on the foundation focusing on whether the repowering is possible given cumulative fatigue from both the original and repowered conditions (Nguyen and Rogers 2018).

# Survey Results

## Q1 - What are your attitudes towards renewable energy?

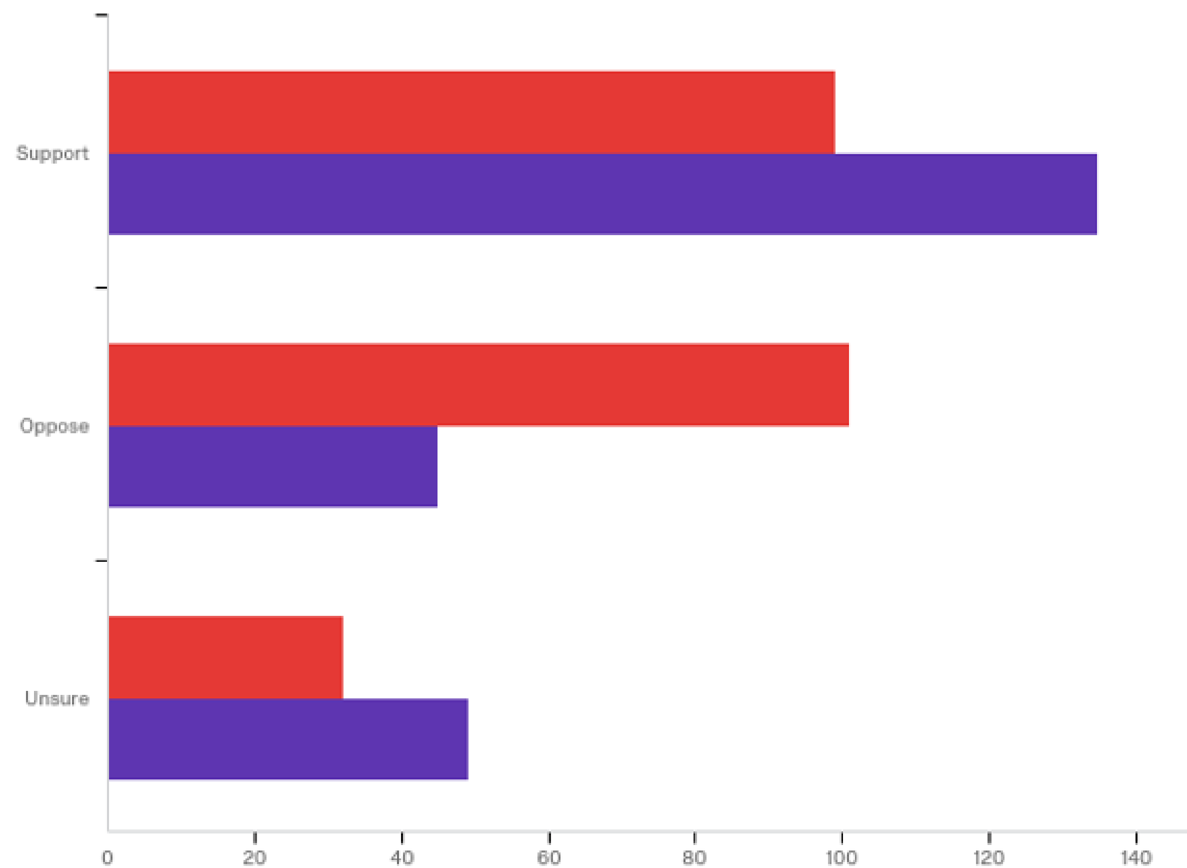



## Q2 - Which renewable energy production sources are you most familiar with? Choose all that apply.




| # | Answer | % | Count |
|---|---|---|---|
| 1 | Solar | 32.29% | 185 |
| 2 | Wind | 35.78% | 205 |
| 3 | Geothermal | 22.86% | 131 |
| 4 | Biomass | 9.08% | 52 |
| | Total | 100% | 573 |

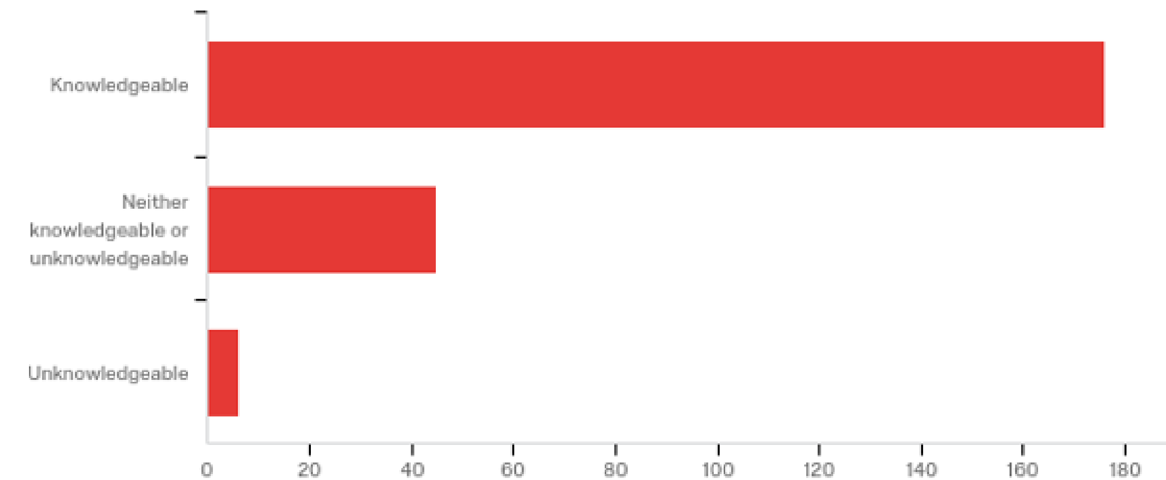
## Q3 - Would you support or oppose large-scale wind or solar energy development in Linn County?




| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | Wind | 1.00 | 3.00 | 1.71 | 0.69 | 0.48 | 232 |
| 2 | Solar | 1.00 | 3.00 | 1.62 | 0.81 | 0.66 | 229 |

| # | Question | Support | | Oppose | | Unsure | | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Wind | 42.67% | 99 | 43.53% | 101 | 13.79% | 32 | 232 |
| 2 | Solar | 58.95% | 135 | 19.65% | 45 | 21.40% | 49 | 229 |

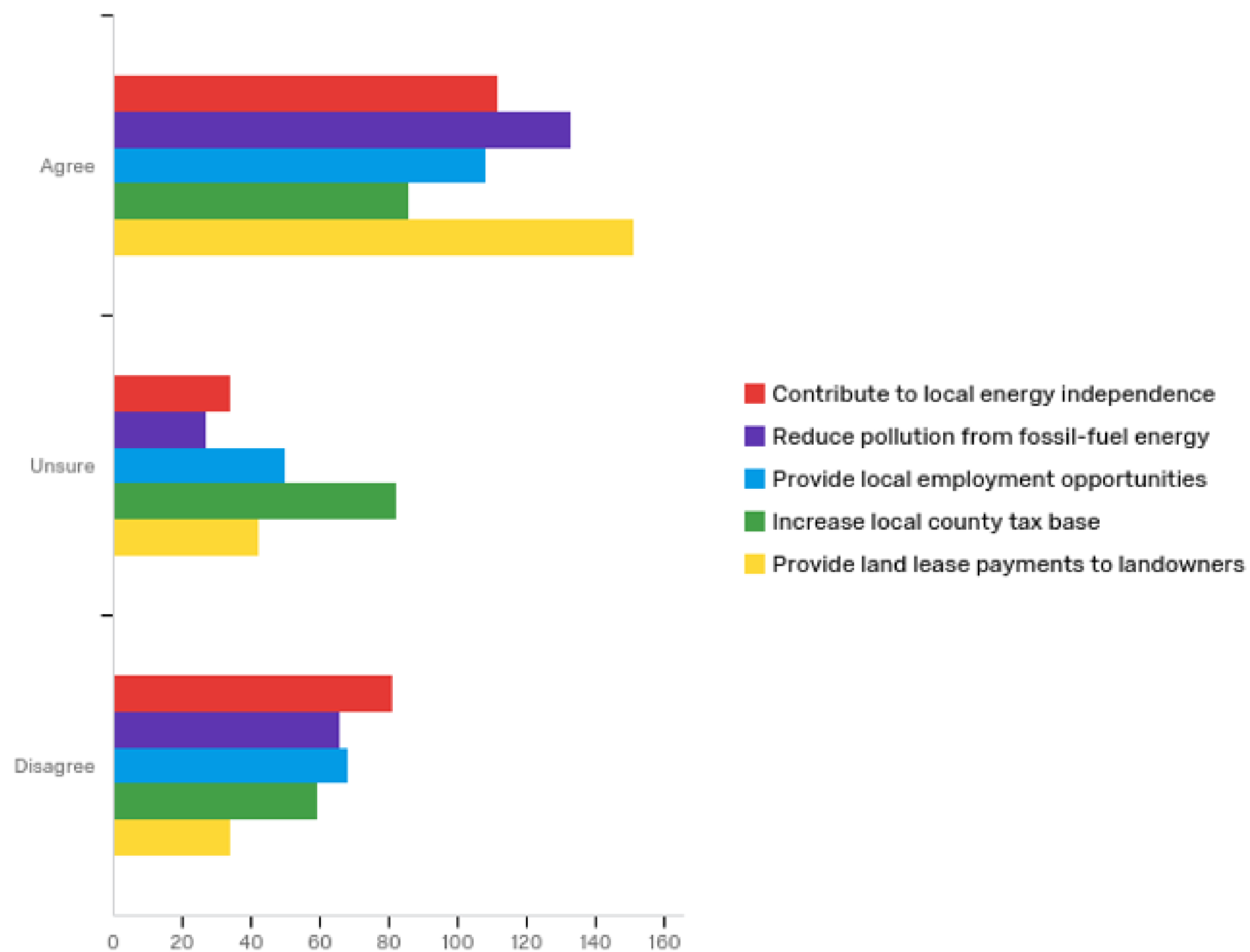
## Q4 - How knowledgeable are you about the benefits and concerns of wind energy?



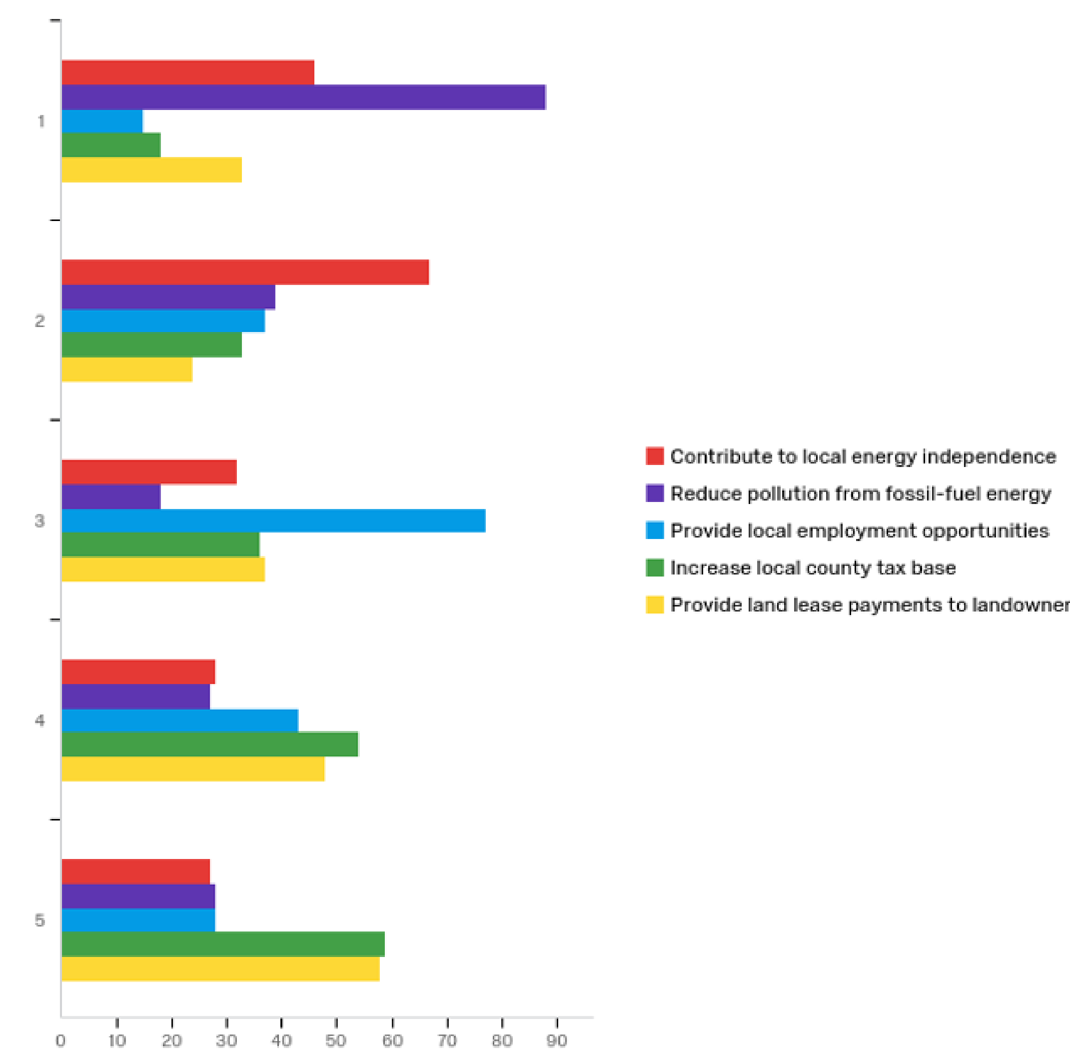

| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | How knowledgeable are you about the benefits and concerns of wind energy? | 6.00 | 11.00 | 6.53 | 1.08 | 1.17 | 227 |

| # | Answer | % | Count |
|---|---|---|---|
| 6 | Knowledgeable | 77.53% | 176 |
| 8 | Neither knowledgeable or unknowledgeable | 19.82% | 45 |
| 11 | Unknowledgeable | 2.64% | 6 |
| | Total | 100% | 227 |

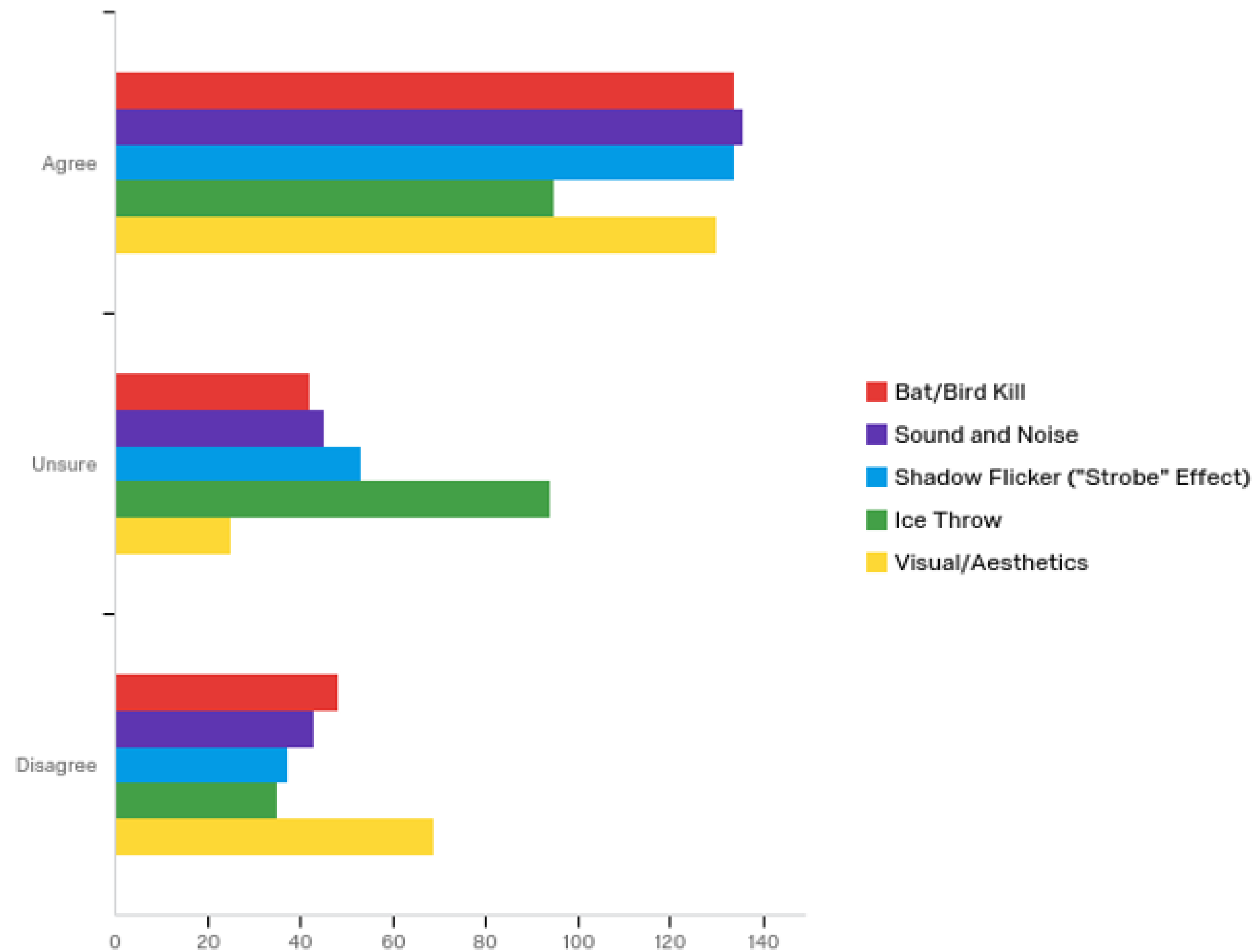
Q5 - Do you agree or disagree that these are benefits of large-scale wind energy?



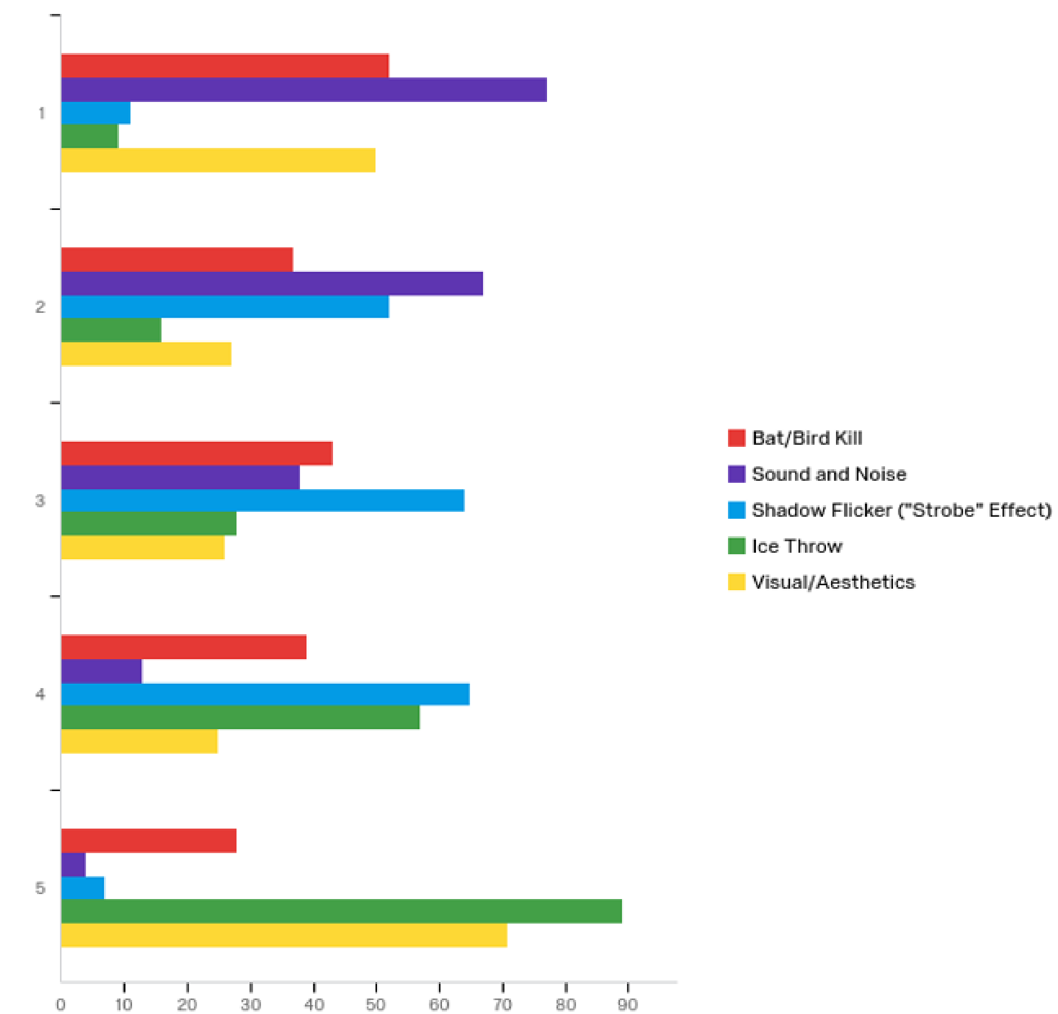

Q6 - Please rank the following benefits of large-scale wind energy in the order you consider most important. (Click and drag to order from 1-5. 1 being the most important and 5 being the least. )



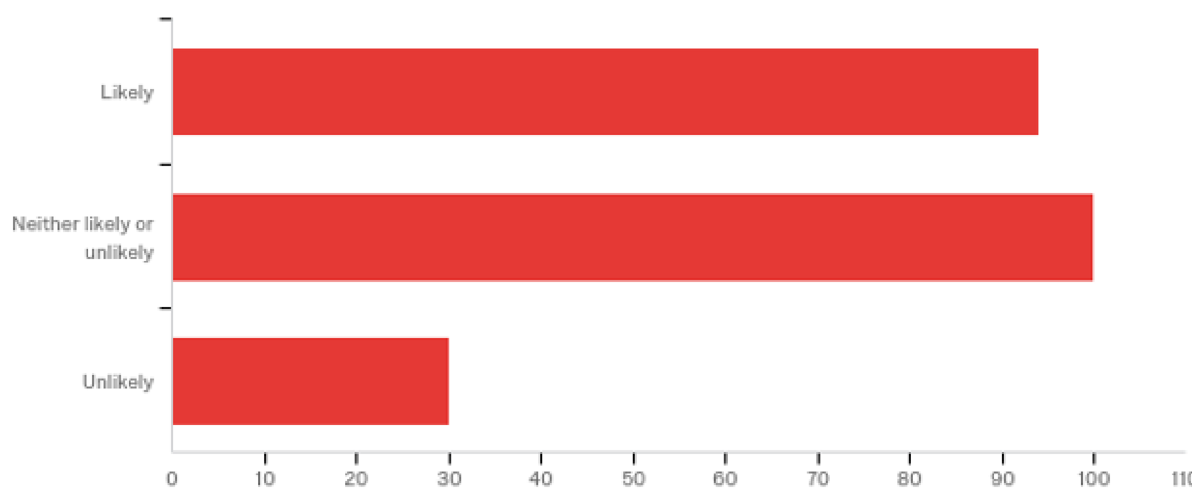
Q7 - Do you agree or disagree that these are concerns about large-scale wind turbines?




Q8 - Please rank the following concerns about large-scale wind energy in the order you consider most important. (Click and drag 1-5. 1 being the most important and 5 being the least)



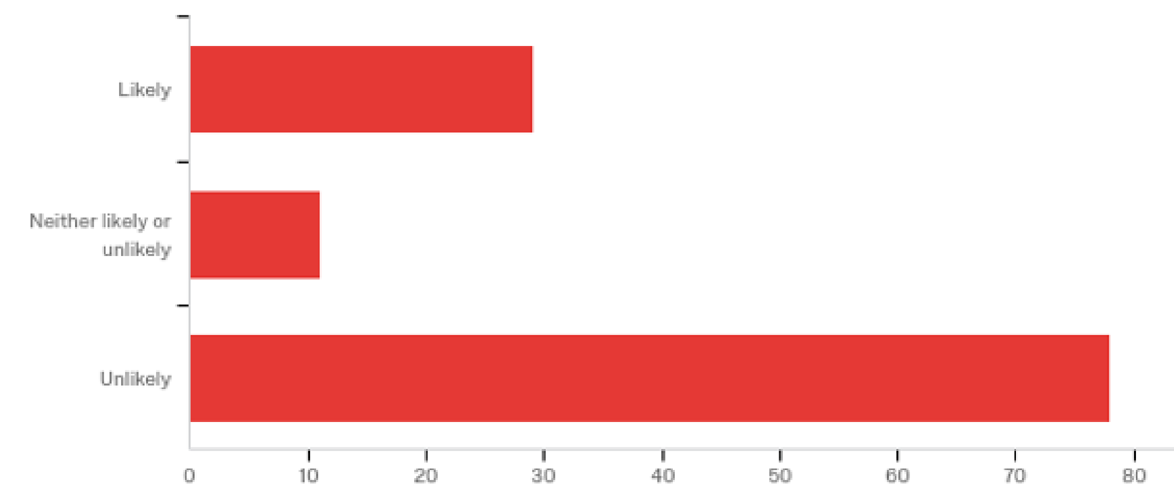
**Q9 - How likely would you participate in any public meetings for large-scale wind energy projects in Linn County?**




| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | How likely would you participate in any public meetings for large-scale wind energy projects in Linn County? | 15.00 | 21.00 | 18.04 | 2.60 | 6.77 | 224 |

| # | Answer | % | Count |
|---|---|---|---|
| 15 | Likely | 41.96% | 94 |
| 20 | Neither likely or unlikely | 44.64% | 100 |
| 21 | Unlikely | 13.39% | 30 |
| | Total | 100% | 224 |

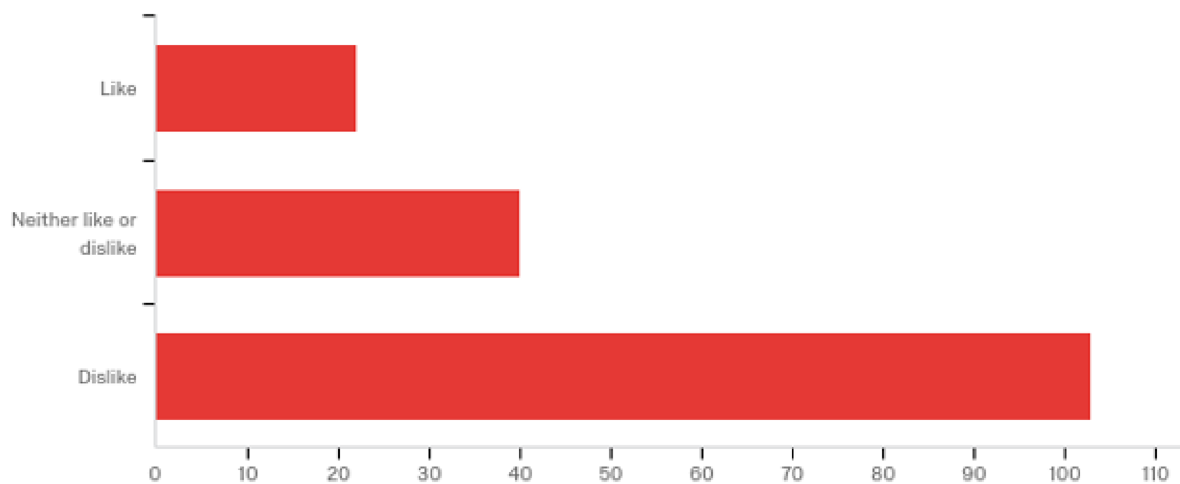
**Q10 - If you own land in rural Linn County, how likely would you rent your land to host large-scale wind turbines in return for lease payments?**




| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | If you own land in rural Linn County, how likely would you rent your land to host large-scale wind turbines in return for lease payments? | 1.00 | 3.00 | 2.42 | 0.86 | 0.73 | 118 |

| # | Answer | % | Count |
|---|---|---|---|
| 1 | Likely | 24.58% | 29 |
| 2 | Neither likely or unlikely | 9.32% | 11 |
| 3 | Unlikely | 66.10% | 78 |
| | Total | 100% | 118 |

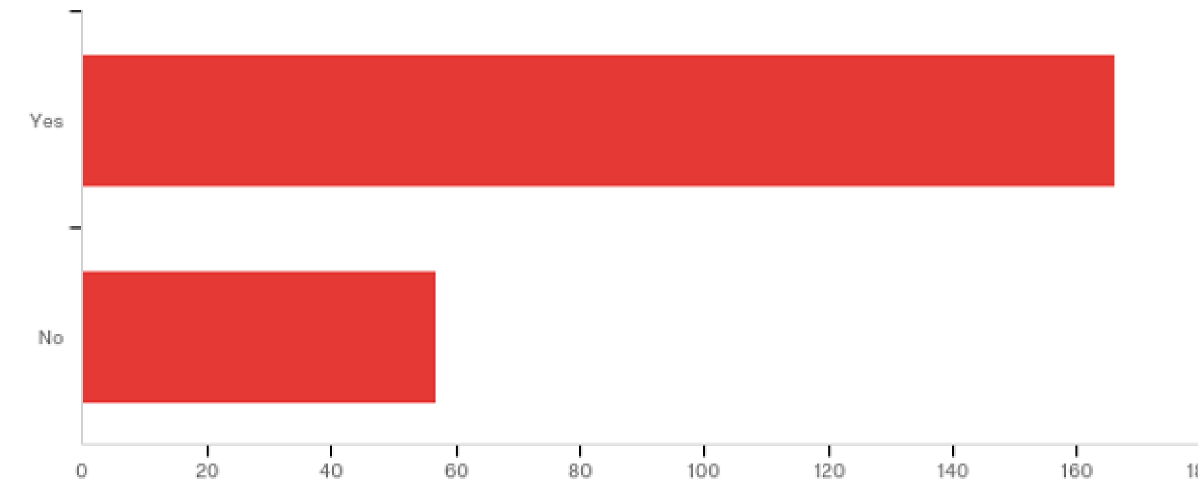
## Q11 - How would you feel if your neighbor rented their land to host large-scale wind turbines?




| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | How would you feel if your neighbor rented their land to host large-scale wind turbines? | 1.00 | 3.00 | 2.49 | 0.72 | 0.52 | 165 |

| # | Answer | % | Count |
|---|---|---|---|
| 1 | Like | 13.33% | 22 |
| 2 | Neither like or dislike | 24.24% | 40 |
| 3 | Dislike | 62.42% | 103 |
| | Total | 100% | 165 |

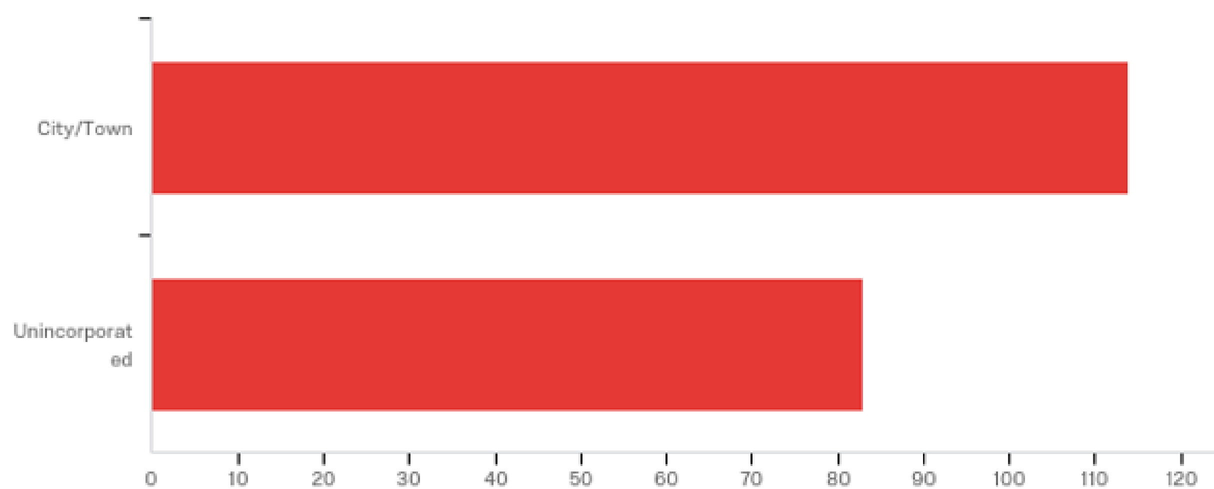
## Q12 - Do you currently live in Linn County?




| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | Do you currently live in Linn County? | 1.00 | 2.00 | 1.26 | 0.44 | 0.19 | 223 |

| # | Answer | % | Count |
|---|---|---|---|
| 1 | Yes | 74.44% | 166 |
| 2 | No | 25.56% | 57 |
| | Total | 100% | 223 |

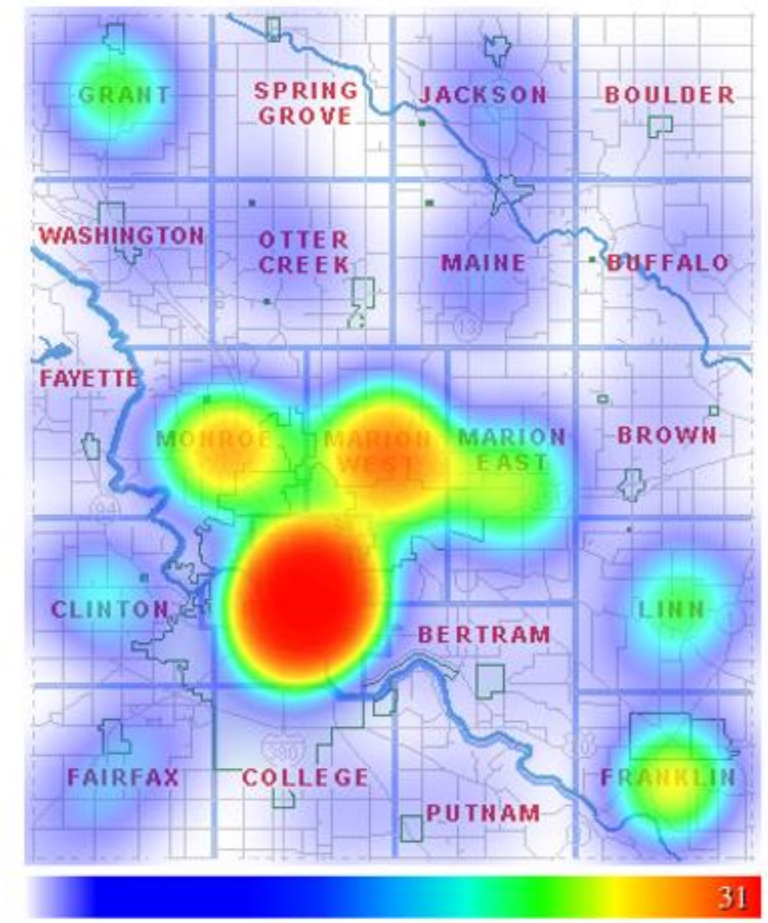
### 13 - Do you currently live in a city/town or in rural unincorporated Linn County?



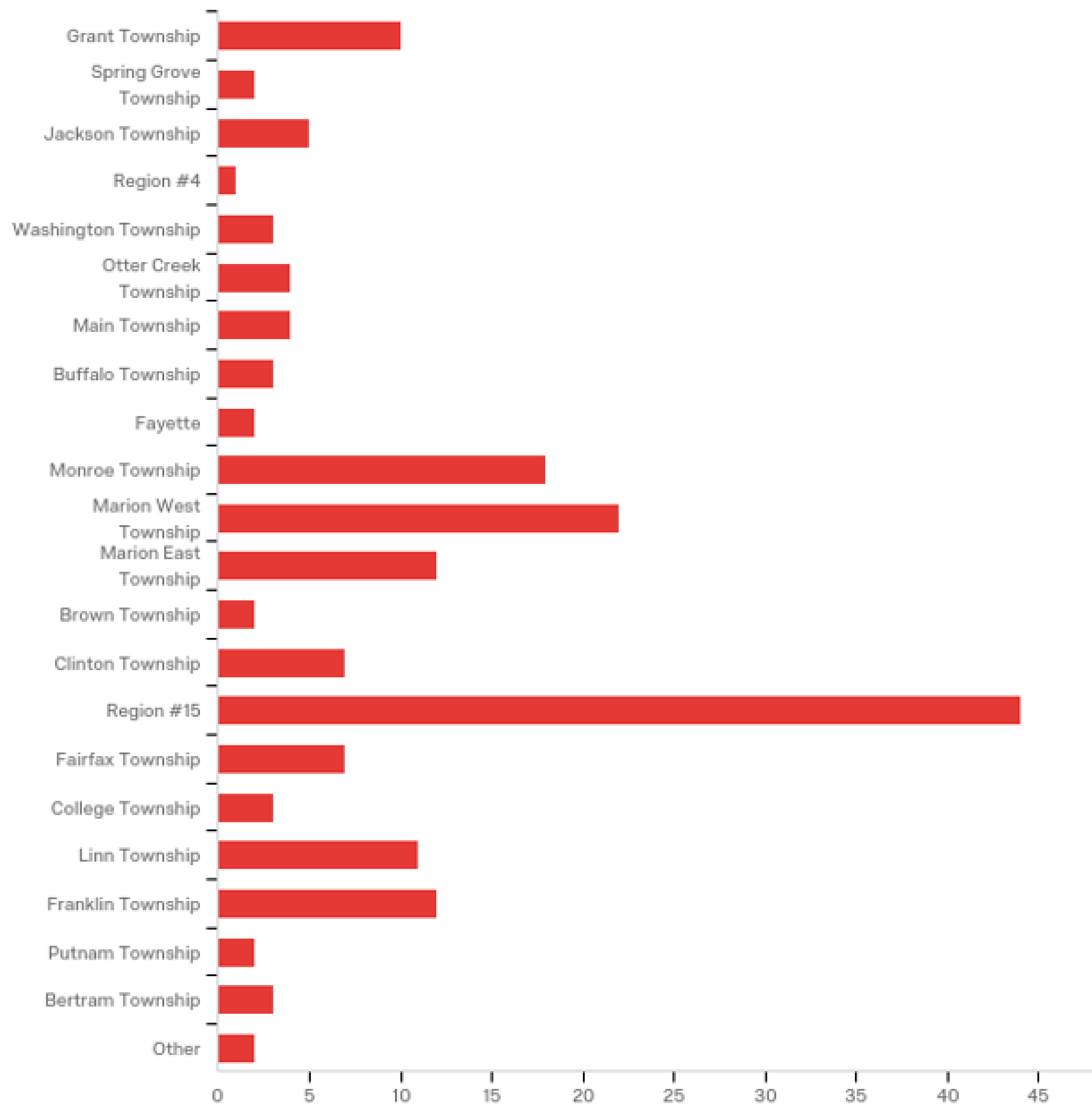

| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | Do you currently live in a city/town or in rural unincorporated Linn County? | 1.00 | 2.00 | 1.42 | 0.49 | 0.24 | 197 |

| # | Answer | % | Count |
|---|---|---|---|
| 1 | City/Town | 57.87% | 114 |
| 2 | Rural/Unincorporated | 42.13% | 83 |
| | Total | 100% | 197 |

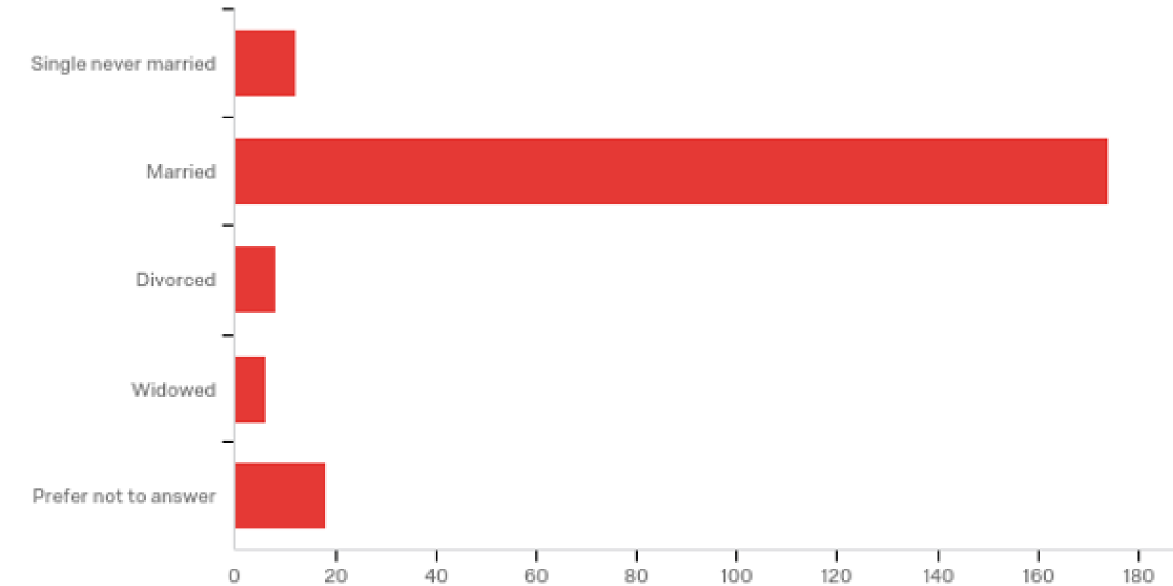
### Q14 - In which township is your primary residence located?



## Q14 - In which township is your primary residence located? - Regions



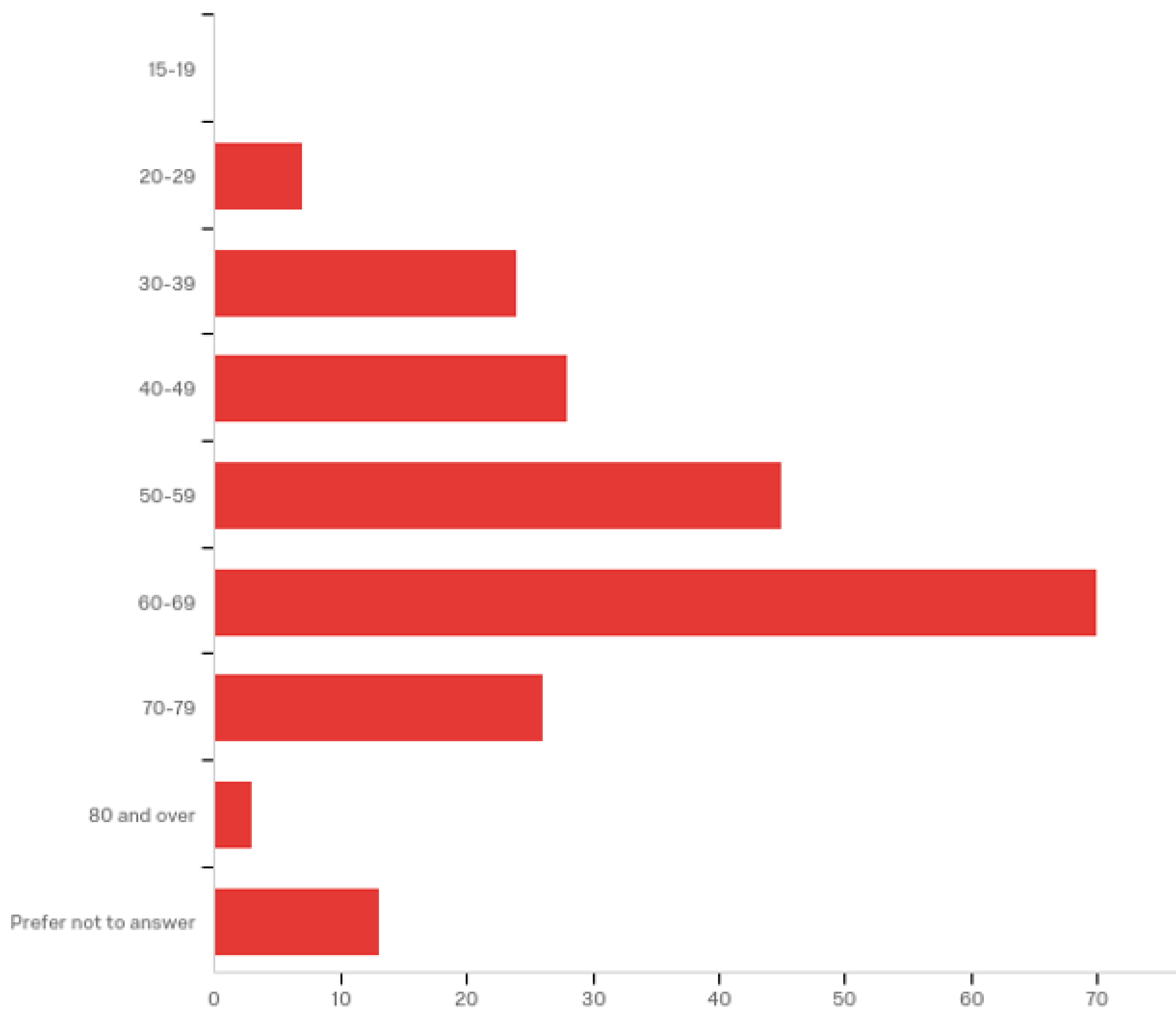

## Q15 - What is your marital status?



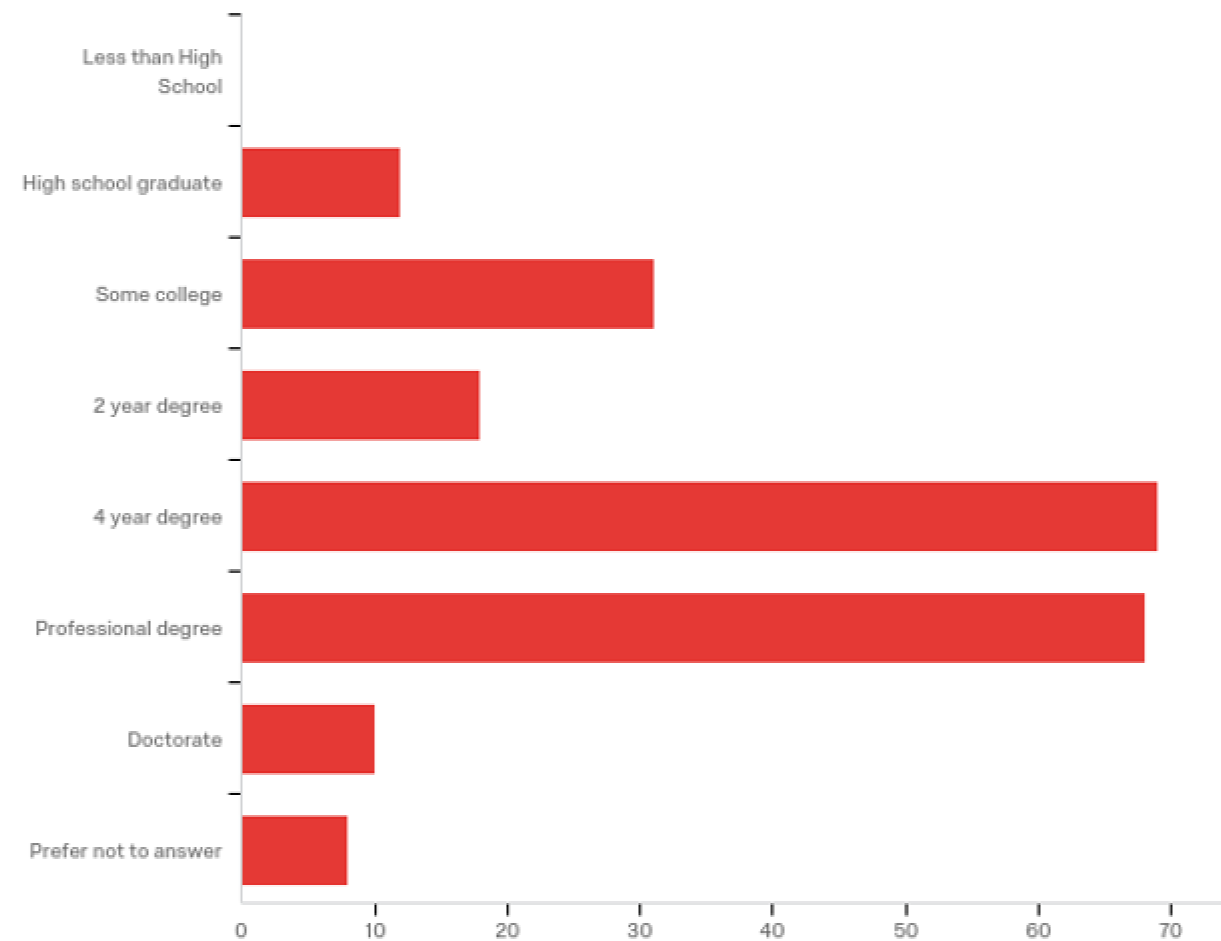

| # | Field | Minimum | Maximum | Mean | Std Deviation | Variance | Count |
|---|---|---|---|---|---|---|---|
| 1 | What is your marital status? | 1.00 | 5.00 | 2.28 | 0.93 | 0.86 | 218 |

| # | Answer | % | Count |
|---|---|---|---|
| 1 | Single never married | 5.50% | 12 |
| 2 | Married | 79.82% | 174 |
| 3 | Divorced | 3.67% | 8 |
| 4 | Widowed | 2.75% | 6 |
| 5 | Prefer not to answer | 8.26% | 18 |
| | Total | 100% | 218 |

Q16 - What is your age group?




Q17 - What is your highest educational attainment?



# Multi-Criteria Decision Support System – Model Scripts

## Regulatory Model Script

```
# -*- coding: utf-8 -*-
# ---------------------------------------------------------------------------
# RegulatoryScript.py
# Created on: 2019-05-08 17:18:17.00000
#   (generated by ArcGIS/ModelBuilder)
# Usage: RegulatoryScript <Rural_Zoning> <Allowed_Zones> <Parcel_Ownership> <Rural_Residential_Structures_Addresses> <Residential_Buffer_Distance> <Regulatory_Output>
# Description:
# This model identifies areas where utility-scale wind turbines could legally be sited based on Zoning District, Residential Structure Proximity, and Contiguous Parcel Ownership Buffers.
#
# Created by Luke Foelsch as a component of a group project completed in partnership between the University of Iowa Office of Outreach & Engagement, The University of Iowa School of Urban & Regional Planning, and Linn County Planning & Development.

# ---------------------------------------------------------------------------

# Set the necessary product code
# import arcinfo


# Import arcpy module
import arcpy

# Script arguments
Rural_Zoning = arcpy.GetParameterAsText(0)
if Rural_Zoning == '#' or not Rural_Zoning:
    Rural_Zoning = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\RuralZoning.shp" # provide a default value if unspecified

Allowed_Zones = arcpy.GetParameterAsText(1)
if Allowed_Zones == '#' or not Allowed_Zones:
    Allowed_Zones = "\"ZoningDist\" = 'AG' OR \"ZoningDist\" = 'CNR'" # provide a default value if unspecified

Parcel_Ownership = arcpy.GetParameterAsText(2)
if Parcel_Ownership == '#' or not Parcel_Ownership:
    Parcel_Ownership = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Regulatory\\Parcel_Ownership.shp" # provide a default value if unspecified

Rural_Residential_Structures_Addresses = arcpy.GetParameterAsText(3)
if Rural_Residential_Structures_Addresses == '#' or not Rural_Residential_Structures_Addresses:
    Rural_Residential_Structures_Addresses = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Regulatory\\RuralResidences.shp" # provide a default value if unspecified

Residential_Buffer_Distance = arcpy.GetParameterAsText(4)
if Residential_Buffer_Distance == '#' or not Residential_Buffer_Distance:
    Residential_Buffer_Distance = "1000 Feet" # provide a default value if unspecified

Regulatory_Output = arcpy.GetParameterAsText(5)
if Regulatory_Output == '#' or not Regulatory_Output:
    Regulatory_Output = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\FinalOutputs.gdb\\RegulatoryOutput" # provide a default value if unspecified

# Local variables:
Reg1 = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Reg1"
ResBuffers = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\ResBuffers"
Reg2 = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Reg2"
Reg2__3_ = Reg2
Reg4 = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Reg4"

# Process: Select
arcpy.Select_analysis(Rural_Zoning, Reg1, Allowed_Zones)

# Process: Buffer (2)
arcpy.Buffer_analysis(Rural_Residential_Structures_Addresses, ResBuffers, Residential_Buffer_Distance, "FULL", "ROUND", "ALL", "", "PLANAR")

# Process: Erase
arcpy.Erase_analysis(Reg1, ResBuffers, Reg2, "")

# Process: Join Field
arcpy.JoinField_management(Reg2, "GPN", Parcel_Ownership, "GPN", "Owner")

# Process: Dissolve
arcpy.Dissolve_management(Reg2__3_, Reg4, "Owner", "", "MULTI_PART", "DISSOLVE_LINES")
```

```
# Process: Buffer
arcpy.Buffer_analysis(Reg4, Regulatory_Output, "-100 Feet", "FULL", "ROUND", "NONE", "", "PLANAR")
```

## Suitability Model Script

```
# -*- coding: utf-8 -*-
# ---------------------------------------------------------------------------
# SuitabilityScript.py
# Created on: 2019-05-08 17:18:39.00000
#   (generated by ArcGIS/ModelBuilder)
# Usage: SuitabilityScript <Regulatory_Output> <Rural_Zoning> <Road_Centerlines> <Major_Roads> <Railroad_Lines> <Electric_Transmission_Lines> <Unclipped_Suitability_Raster> <Output_Suitability_Map>
# Description:
# This model identifies areas where utility-scale wind turbines would be most suitable based on Wind Resource, Grid Proximity, Transportation Infrastructure, Karst Presence, and Slope.
#
# Created by Luke Foelsch as a component of a group project completed in partnership between the University of Iowa Office of Outreach & Engagement, The University of Iowa School of Urban & Regional Planning, and Linn County Planning & Development.

# ---------------------------------------------------------------------------

# Set the necessary product code
# import arcinfo


# Import arcpy module
import arcpy

# Script arguments
Regulatory_Output = arcpy.GetParameterAsText(0)
if Regulatory_Output == '#' or not Regulatory_Output:
    Regulatory_Output = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\FinalOutputs.gdb\\RegulatoryOutput" # provide a default value if unspecified

Rural_Zoning = arcpy.GetParameterAsText(1)
if Rural_Zoning == '#' or not Rural_Zoning:
    Rural_Zoning = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\RuralZoning.shp" # provide a default value if unspecified

Road_Centerlines = arcpy.GetParameterAsText(2)
if Road_Centerlines == '#' or not Road_Centerlines:
```

```
    Road_Centerlines                                                                        =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Suitability\\Road_Centerline.sh
p" # provide a default value if unspecified

Major_Roads = arcpy.GetParameterAsText(3)
if Major_Roads == '#' or not Major_Roads:
    Major_Roads = "\"ALPHATAG\" = 'Interstate' OR \"ALPHATAG\" = 'State Highway' OR \"ALPHATAG\" = 'US
Business Highway' OR \"ALPHATAG\" = 'US Highway'" # provide a default value if unspecified

Railroad_Lines = arcpy.GetParameterAsText(4)
if Railroad_Lines == '#' or not Railroad_Lines:
    Railroad_Lines                                                                          =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Suitability\\Railroad.shp"        #
provide a default value if unspecified

Electric_Transmission_Lines = arcpy.GetParameterAsText(5)
if Electric_Transmission_Lines == '#' or not Electric_Transmission_Lines:
    Electric_Transmission_Lines                                                             =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Suitability\\Electric_Transmissi
on_Lines.shp" # provide a default value if unspecified

Unclipped_Suitability_Raster = arcpy.GetParameterAsText(6)
if Unclipped_Suitability_Raster == '#' or not Unclipped_Suitability_Raster:
    Unclipped_Suitability_Raster = "MakeRas_Suitabi2" # provide a default value if unspecified

Output_Suitability_Map = arcpy.GetParameterAsText(7)
if Output_Suitability_Map == '#' or not Output_Suitability_Map:
    Output_Suitability_Map                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Suit3"           #
provide a default value if unspecified

# Local variables:
Grid_RZ                                                                                     =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Grid_RZ"
CountyBuffer_shp                                                                            =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\StaticInputs\\Suitability\\CountyBuffer.shp"
Grid_Clip                                                                                   =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Grid_Clip"
Grid_Clip_MultiBuffer                                                                       =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Grid_Clip_Mul
tiBuffer"
RZ_Grid_ID                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_Grid_ID"
RZ_Grid_HI                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_Grid_HI"
RZ_Grid_ID_HI__2_ = RZ_Grid_HI
RZ_Grid_ID_HI__3_ = RZ_Grid_ID_HI__2_
RZ_Grid_MED                                                                                 =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_Grid_MED
"
RZ_Grid_ID_MED__2_ = RZ_Grid_MED
RZ_Grid_ID_MED__3_ = RZ_Grid_ID_MED__2_
RZ_Grid_LO                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_Grid_LO"
RZ_Grid_ID_LO__2_ = RZ_Grid_LO
RZ_Grid_ID_LO__3_ = RZ_Grid_ID_LO__2_
Grid_Merge                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Grid_Merge"
Grid_Raster                                                                                 =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Grid_Raster"
Transpo_RZ                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_RZ"
Big_Roads                                                                                   =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Big_Roads"
Transpo_Lines                                                                               =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_Lines
"
Transpo_Lines_Buffer                                                                        =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_Lines
_Buffer"
Transpo_RZ_Identity                                                                         =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_RZ_I
dentity"
Transpo_HI                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_HI"
Transpo_HI__2_ = Transpo_HI
Transpo_HI__3_ = Transpo_HI__2_
Transpo_MED                                                                                 =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_MED
"
Transpo_MED__2_ = Transpo_MED
Transpo_MED__3_ = Transpo_MED__2_
Transpo_LO                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_LO"
Transpo_LO__2_ = Transpo_LO
Transpo_LO__3_ = Transpo_LO__2_
```

```
Transpo_Merge =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_Merg
e"
Transpo_Rast =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_Rast"
karstinput =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\StaticInputs\\Suitability\\karstinput"
slopeinput =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\StaticInputs\\Suitability\\slopeinput"
windinput =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\StaticInputs\\Suitability\\windinput"
Suitability =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\FinalOutputs.gdb\\Suitability"
Suit_Raster__3_ = Suitability
Suit_Raster__4_ = Suit_Raster__3_

# Process: Copy Features
arcpy.CopyFeatures_management(Rural_Zoning, Grid_RZ, "", "0", "0", "0")

# Process: Clip
arcpy.Clip_analysis(Electric_Transmission_Lines, CountyBuffer_shp, Grid_Clip, "")

# Process: Multiple Ring Buffer
arcpy.MultipleRingBuffer_analysis(Grid_Clip, Grid_Clip_MultiBuffer, "16000;32000", "Feet", "dist", "ALL",
"FULL")

# Process: Identity
arcpy.Identity_analysis(Grid_RZ, Grid_Clip_MultiBuffer, RZ_Grid_ID, "ALL", "", "NO_RELATIONSHIPS")

# Process: Select
arcpy.Select_analysis(RZ_Grid_ID, RZ_Grid_HI, "dist = 16000")

# Process: Add Field
arcpy.AddField_management(RZ_Grid_HI, "Grid_Rank", "SHORT", "", "", "", "", "NULLABLE",
"NON_REQUIRED", "")

# Process: Calculate Field
arcpy.CalculateField_management(RZ_Grid_ID_HI__2_, "Grid_Rank", "2", "VB", "")

# Process: Select (2)
arcpy.Select_analysis(RZ_Grid_ID, RZ_Grid_MED, "dist = 32000")

# Process: Add Field (2)
arcpy.AddField_management(RZ_Grid_MED, "Grid_Rank", "SHORT", "", "", "", "", "NULLABLE",
"NON_REQUIRED", "")

# Process: Calculate Field (2)
arcpy.CalculateField_management(RZ_Grid_ID_MED__2_, "Grid_Rank", "1", "VB", "")

# Process: Select (3)
arcpy.Select_analysis(RZ_Grid_ID, RZ_Grid_LO, "dist = 0")

# Process: Add Field (3)
arcpy.AddField_management(RZ_Grid_LO, "Grid_Rank", "SHORT", "", "", "", "", "NULLABLE",
"NON_REQUIRED", "")

# Process: Calculate Field (3)
arcpy.CalculateField_management(RZ_Grid_ID_LO__2_, "Grid_Rank", "0", "VB", "")

# Process: Merge
arcpy.Merge_management("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\Intermedi
ateData.gdb\\RZ_Grid_HI;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\Intermediate
Data.gdb\\RZ_Grid_MED;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\Intermediate
Data.gdb\\RZ_Grid_LO", Grid_Merge, "FID_Grid_RZ \"FID_Grid_RZ\" true true false 4 Long 0 0
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_HI,FI
D_Grid_RZ,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_MED,FID_
Grid_RZ,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_LO,FID_Gri
d_RZ,-1,-1;dist \"dist\" true true false 8 Double 0 0
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_HI,dis
t,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_MED,dist,-
1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_LO,dist,-
1,-1;Grid_Rank \"Grid_Rank\" true true false 0 Short 0 0
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_HI,Gr
id_Rank,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_MED,Grid_
Rank,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\RZ_Grid_ID_LO,Grid_R
ank,-1,-1")

# Process: Polygon to Raster
arcpy.PolygonToRaster_conversion(Grid_Merge, "Grid_Rank", Grid_Raster, "CELL_CENTER", "Grid_Rank",
"20")

# Process: Copy Features (2)
```

```
arcpy.CopyFeatures_management(Rural_Zoning, Transpo_RZ, "", "0", "0", "0")

# Process: Select (4)
arcpy.Select_analysis(Road_Centerlines, Big_Roads, Major_Roads)

# Process: Merge (2)
arcpy.Merge_management("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Suitability\\Railroad.shp;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Big_Roads", Transpo_Lines, "Shape_Length \"Shape_Length\" false true true 8 Double 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\Big_Roads,Shape_Length,-1,-1")

# Process: Multiple Ring Buffer (2)
arcpy.MultipleRingBuffer_analysis(Transpo_Lines, Transpo_Lines_Buffer, "16000;32000", "Feet", "distance", "ALL", "FULL")

# Process: Identity (2)
arcpy.Identity_analysis(Transpo_RZ, Transpo_Lines_Buffer, Transpo_RZ_Identity, "ALL", "", "NO_RELATIONSHIPS")

# Process: Select (5)
arcpy.Select_analysis(Transpo_RZ_Identity, Transpo_HI, "distance = 16000")

# Process: Add Field (4)
arcpy.AddField_management(Transpo_HI, "Transpo_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (4)
arcpy.CalculateField_management(Transpo_HI__2_, "Transpo_Rank", "2", "VB", "")

# Process: Select (6)
arcpy.Select_analysis(Transpo_RZ_Identity, Transpo_MED, "distance = 32000")

# Process: Add Field (5)
arcpy.AddField_management(Transpo_MED, "Transpo_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (5)
arcpy.CalculateField_management(Transpo_MED__2_, "Transpo_Rank", "1", "VB", "")

# Process: Select (7)
arcpy.Select_analysis(Transpo_RZ_Identity, Transpo_LO, "distance = 0")

# Process: Add Field (6)
arcpy.AddField_management(Transpo_LO, "Transpo_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (6)
arcpy.CalculateField_management(Transpo_LO__2_, "Transpo_Rank", "0", "VB", "")

# Process: Merge (3)
arcpy.Merge_management("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_HI;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_MED;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_LO", Transpo_Merge, "FID_Transpo_RZ \"FID_Transpo_RZ\" true true false 4 Long 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\Transpo_HI,FID_Transpo_RZ,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\Transpo_MED,FID_Transpo_RZ,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\Transpo_LO,FID_Transpo_RZ,-1,-1;Transpo_Rank \"Transpo_Rank\" true true false 0 Short 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\Transpo_HI,Transpo_Rank,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\Transpo_MED,Transpo_Rank,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\SuitabilityOutputs.gdb\\Transpo_LO,Transpo_Rank,-1,-1")

# Process: Polygon to Raster (2)
arcpy.PolygonToRaster_conversion(Transpo_Merge, "Transpo_Rank", Transpo_Rast, "CELL_CENTER", "Transpo_Rank", "20")

# Process: Combine
arcpy.gp.Combine_sa("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Grid_Raster;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Transpo_Rast;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\StaticInputs\\Suitability\\karstinput;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\StaticInputs\\Suitability\\slopeinput;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\StaticInputs\\Suitability\\windinput", Suitability)

# Process: Add Field (7)
arcpy.AddField_management(Suitability, "Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (7)
arcpy.CalculateField_management(Suit_Raster__3_, "Rank", "[Grid_Raster] + [Transpo_Rast] + [karstinput] + [slopeinput] + [windinput]", "VB", "")

# Process: Make Raster Layer
```

```
arcpy.MakeRasterLayer_management(Suit_Raster__4_, Unclipped_Suitability_Raster, "", "5373045.55831839 3417505.18532906 5502325.55831839 3578105.18532906", "")

# Process: Extract by Mask
arcpy.gp.ExtractByMask_sa(Unclipped_Suitability_Raster, Regulatory_Output, Output_Suitability_Map)
```

## Compatibility Model Script

```
# -*- coding: utf-8 -*-
# ---------------------------------------------------------------------------
# CompatibilityScript.py
# Created on: 2019-05-08 17:18:56.00000
#   (generated by ArcGIS/ModelBuilder)
# Usage: CompatibilityScript <Regulatory_Output> <Rural_Zoning> <Airports> <Remove_Non_Public_or_Defunct_Airports> <Municipal_Boundaries> <CCSG_Agreements> <Full_Compatibility_Map> <Clipped_Compatibility_Map>
# Description:
# This model identifies areas where utility-scale wind turbines would be most compatible based on Future Land Use Classification, CCSG Fringe Areas, Airport Proximity, and the Grant Wood's "Fall Plowing" Rural Historic Landscape District.
#
# Created by Luke Foelsch as a component of a group project completed in partnership between the University of Iowa Office of Outreach & Engagement, The University of Iowa School of Urban & Regional Planning, and Linn County Planning & Development.

# ---------------------------------------------------------------------------

# Set the necessary product code
# import arcinfo


# Import arcpy module
import arcpy

# Script arguments
Regulatory_Output = arcpy.GetParameterAsText(0)
if Regulatory_Output == '#' or not Regulatory_Output:
    Regulatory_Output = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\FinalOutputs.gdb\\RegulatoryOutput" # provide a default value if unspecified

Rural_Zoning = arcpy.GetParameterAsText(1)
if Rural_Zoning == '#' or not Rural_Zoning:
    Rural_Zoning = "C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\RuralZoning.shp" # provide a default value if unspecified

Airports = arcpy.GetParameterAsText(2)
if Airports == '#' or not Airports:
```

```
    Airports                                                                                             =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Compatibility\\Airport.shp"     #
provide a default value if unspecified

Remove_Non_Public_or_Defunct_Airports = arcpy.GetParameterAsText(3)
if Remove_Non_Public_or_Defunct_Airports == '#' or not Remove_Non_Public_or_Defunct_Airports:
    Remove_Non_Public_or_Defunct_Airports = "\"PlaceName\" <> 'McBride Airport'" # provide a default
value if unspecified

Municipal_Boundaries = arcpy.GetParameterAsText(4)
if Municipal_Boundaries == '#' or not Municipal_Boundaries:
    Municipal_Boundaries                                                                                 =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\DynamicInputs\\Compatibility\\Municipality.shp
" # provide a default value if unspecified

CCSG_Agreements = arcpy.GetParameterAsText(5)
if CCSG_Agreements == '#' or not CCSG_Agreements:
    CCSG_Agreements = "\"TOWNSHIP\" = 'Bertram' OR \"TOWNSHIP\" = 'Ely' OR \"TOWNSHIP\" = 'Palo' OR
\"TOWNSHIP\" = 'Springville'" # provide a default value if unspecified

Full_Compatibility_Map = arcpy.GetParameterAsText(6)
if Full_Compatibility_Map == '#' or not Full_Compatibility_Map:
    Full_Compatibility_Map = "CompOutput" # provide a default value if unspecified

Clipped_Compatibility_Map = arcpy.GetParameterAsText(7)
if Clipped_Compatibility_Map == '#' or not Clipped_Compatibility_Map:
    Clipped_Compatibility_Map                                                                            =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\FinalOutputs.gdb\\CompClip"           #
provide a default value if unspecified

# Local variables:
RZ_FLU                                                                                                   =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_FLU"
FLU_HI                                                                                                   =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_HI"
FLU_Select_Hi__2_ = FLU_HI
FLU_Select_Hi_Dissolve__3_ = FLU_Select_Hi__2_
FLU_LO                                                                                                   =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_LO"
FLU_Select_Low__2_ = FLU_LO
FLU_Select_Low_Dissolve__3_ = FLU_Select_Low__2_
FLU_Ranked                                                                                               =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_Ranked"
FLU_Raster                                                                                               =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_Raster"
RZ_AP                                                                                                    =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_AP"
Airport_Public                                                                                           =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Airport_Public
"
AP_Buffer                                                                                                =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_Buffer"
RZ_AP_Identity                                                                                           =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_AP_Identit
y"
AP_LO                                                                                                    =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO"
AP_Select_Low__2_ = AP_LO
AP_Select_Low__3_ = AP_Select_Low__2_
AP_HI                                                                                                    =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI"
AP_Select_Hi__2_ = AP_HI
AP_Select_Hi__3_ = AP_Select_Hi__2_
AP_Ranked                                                                                                =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_Ranked"
AP_Raster                                                                                                =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_Raster"
RZ_CCSG                                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_CCSG"
CCSGTowns                                                                                                =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSGTowns"
CCSG_Buffers                                                                                             =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_Buffers"
CCSG_Identity                                                                                            =
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"
CCSG_HI                                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI"
CCSG_Select_HI__2_ = CCSG_HI
CCSG_Select_HI__3_ = CCSG_Select_HI__2_
CCSG_LO                                                                                                  =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO"
CCSG_Select_LO__2_ = CCSG_LO
CCSG_Select_LO__3_ = CCSG_Select_LO__2_
CCSG_Ranked                                                                                              =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_Ranked
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```

```
CCSG_Raster =
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RZ_VIZ =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\RZ_VIZ"
Grant_Wood_Viewshed =
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ped.shp"
VIZ_Identity =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\VIZ_Identity"
VIZ_HI =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\VIZ_HI"
VIZ_Select_HI__2_ = VIZ_HI
VIZ_Select_HI__3_ = VIZ_Select_HI__2_
VIZ_LO =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\VIZ_LO"
VIZ_Select_LO__2_ = VIZ_LO
VIZ_Select_LO__3_ = VIZ_Select_LO__2_
VIZ_Ranked =
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VIZ_Raster =
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Comp_Raster =
"C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\Comp_Raster"
Comp_Raster__2_ = Comp_Raster
Comp_Raster__3_ = Comp_Raster__2_

# Process: Copy Features
arcpy.CopyFeatures_management(Rural_Zoning, RZ_FLU, "", "0", "0", "0")

# Process: Select
arcpy.Select_analysis(RZ_FLU, FLU_HI, "\"LandUseAre\" = 'AA'")

# Process: Add Field
arcpy.AddField_management(FLU_HI, "FLU_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED",
"")

# Process: Calculate Field
arcpy.CalculateField_management(FLU_Select_Hi__2_, "FLU_Rank", "2", "VB", "")

# Process: Select (2)
arcpy.Select_analysis(RZ_FLU, FLU_LO, "\"LandUseAre\" <> 'AA'")

# Process: Add Field (2)
arcpy.AddField_management(FLU_LO, "FLU_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED",
"")

# Process: Calculate Field (2)
arcpy.CalculateField_management(FLU_Select_Low__2_, "FLU_Rank", "0", "VB", "")

# Process: Merge
arcpy.Merge_management("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\Intermedi
ateData.gdb\\FLU_HI;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData
.gdb\\FLU_LO", FLU_Ranked, "GPN \"GPN\" true false false 15 Text 0 0
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GPN,-1,-
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1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_LO,GPN,
-1,-1;ZoningDist \"ZoningDist\" true false false 25 Text 0 0
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gDist,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_LO,Zonin
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hwestS,-1,-1;Acres \"Acres\" true false false 19 Double 0 0
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ments,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_LO,Com
ments,-1,-1;Shape_Leng \"Shape_Leng\" true false false 19 Double 0 0
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Shape_Area,-1,-

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# Process: Polygon to Raster
arcpy.PolygonToRaster_conversion(FLU_Ranked, "FLU_Rank", FLU_Raster, "CELL_CENTER", "FLU_Rank", "20")

# Process: Copy Features (2)
arcpy.CopyFeatures_management(Rural_Zoning, RZ_AP, "", "0", "0", "0")

# Process: Select (3)
arcpy.Select_analysis(Airports, Airport_Public, Remove_Non_Public_or_Defunct_Airports)

# Process: Buffer
arcpy.Buffer_analysis(Airport_Public, AP_Buffer, "20000 Feet", "FULL", "FLAT", "NONE", "", "PLANAR")

# Process: Identity
arcpy.Identity_analysis(RZ_AP, AP_Buffer, RZ_AP_Identity, "ALL", "", "NO_RELATIONSHIPS")

# Process: Select (4)
arcpy.Select_analysis(RZ_AP_Identity, AP_LO, "BUFF_DIST = 20000")

# Process: Add Field (3)
arcpy.AddField_management(AP_LO, "AP_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (3)
arcpy.CalculateField_management(AP_Select_Low__2_, "AP_Rank", "0", "VB", "")

# Process: Select (5)
arcpy.Select_analysis(RZ_AP_Identity, AP_HI, "BUFF_DIST = 0")

# Process: Add Field (4)
arcpy.AddField_management(AP_HI, "AP_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (4)
arcpy.CalculateField_management(AP_Select_Hi__2_, "AP_Rank", "2", "VB", "")

# Process: Merge (2)
arcpy.Merge_management("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI", AP_Ranked, "FID_RZ_AP \"FID_RZ_AP\" true true false 0 Long 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,FID_RZ_AP,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI,FID_RZ_AP,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,FID_RZ_AP,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI,FID_RZ_AP,-1,-1;GPN \"GPN\" true false false 15 Text 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,GPN,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI,GPN,-
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unty,-1,-1;NorthwestS \"NorthwestS\" true false false 10 Long 0 10
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westS,-1,-
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westS,-1,-1;Acres \"Acres\" true false false 19 Double 0 0
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,
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,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,Y
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,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,L
ongitude,-1,-
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ude,-1,-1;Latitude \"Latitude\" true false false 24 Double 15 23
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,L
atitude,-1,-
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e,-1,-1;ModifiedDa \"ModifiedDa\" true false false 80 Text 0 0
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,
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edDa,-1,-1;BUFF_DIST \"BUFF_DIST\" true true false 0 Double 0 0
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DIST,-1,-1;ORIG_FID \"ORIG_FID\" true true false 0 Long 0 0
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FID,-1,-
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FID,-1,-1;Shape_length \"Shape_length\" true true false 0 Double 0 0
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,S
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,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,S
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1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI,Shape
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,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_LO,
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1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI,AP_Ra
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nk,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_HI,AP_Ra
nk,-1,-1")

# Process: Polygon to Raster (2)
arcpy.PolygonToRaster_conversion(AP_Ranked, "AP_Rank", AP_Raster, "CELL_CENTER", "AP_Rank", "20")

# Process: Copy Features (3)
arcpy.CopyFeatures_management(Rural_Zoning, RZ_CCSG, "", "0", "0", "0")

# Process: Select (6)
arcpy.Select_analysis(Municipal_Boundaries, CCSGTowns, CCSG_Agreements)

# Process: Buffer (2)
arcpy.Buffer_analysis(CCSGTowns, CCSG_Buffers, "2 Miles", "FULL", "ROUND", "NONE", "", "PLANAR")

# Process: Identity (2)
arcpy.Identity_analysis(RZ_CCSG, CCSG_Buffers, CCSG_Identity, "ALL", "", "NO_RELATIONSHIPS")

# Process: Select (7)
arcpy.Select_analysis(CCSG_Identity, CCSG_HI, "BUFF_DIST = 0")

# Process: Add Field (5)
arcpy.AddField_management(CCSG_HI, "CCSG_Rank", "SHORT", "", "", "", "", "NULLABLE",
"NON_REQUIRED", "")

# Process: Calculate Field (5)
arcpy.CalculateField_management(CCSG_Select_HI__2_, "CCSG_Rank", "2", "VB", "")

# Process: Select (8)
arcpy.Select_analysis(CCSG_Identity, CCSG_LO, "BUFF_DIST = 10560")

# Process: Add Field (6)
arcpy.AddField_management(CCSG_LO, "CCSG_Rank", "SHORT", "", "", "", "", "NULLABLE",
"NON_REQUIRED", "")

# Process: Calculate Field (6)
arcpy.CalculateField_management(CCSG_Select_LO__2_, "CCSG_Rank", "0", "VB", "")

# Process: Merge (3)
arcpy.Merge_management("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\Intermedi
ateData.gdb\\CCSG_HI;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateDa
ta.gdb\\CCSG_LO", CCSG_Ranked, "GPN \"GPN\" true false false 15 Text 0 0
,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_H
I,GPN,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,GP
N,-1,-
1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,GPN
,-1,-
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```

N,-1,-1;ZoningDist \"ZoningDist\" true false false 25 Text 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,ZoningDist,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,ZoningDist,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,ZoningDist,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,ZoningDist,-1,-1;LandUseAre \"LandUseAre\" true false false 25 Text 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,LandUseAre,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,LandUseAre,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,LandUseAre,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,LandUseAre,-1,-1;Conditiona \"Conditiona\" true false false 10 Long 0 10 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,Conditiona,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,Conditiona,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,Conditiona,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,Conditiona,-1,-1;SpecialUse \"SpecialUse\" true false false 10 Long 0 10 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,SpecialUse,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,SpecialUse,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,SpecialUse,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,SpecialUse,-1,-1;DeedRestri \"DeedRestri\" true false false 10 Long 0 10 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,DeedRestri,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,DeedRestri,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_HI,DeedRestri,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_LO,DeedRestri,-1,-1;ZoningViol \"ZoningViol\" true false false 10 Long 0 10 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# Process: Polygon to Raster (3)
arcpy.PolygonToRaster_conversion(CCSG_Ranked, "CCSG_Rank", CCSG_Raster, "CELL_CENTER", "CCSG_Rank", "20")

# Process: Copy Features (4)
arcpy.CopyFeatures_management(Rural_Zoning, RZ_VIZ, "", "0", "0", "0")

# Process: Identity (3)
arcpy.Identity_analysis(RZ_VIZ, Grant_Wood_Viewshed, VIZ_Identity, "ALL", "", "NO_RELATIONSHIPS")

# Process: Select (9)
arcpy.Select_analysis(VIZ_Identity, VIZ_HI, "FID_GW_Viewshed_Clipped = -1")

# Process: Add Field (8)
```

```
arcpy.AddField_management(VIZ_HI, "VIZ_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (7)
arcpy.CalculateField_management(VIZ_Select_HI__2_, "VIZ_Rank", "2", "VB", "")

# Process: Select (10)
arcpy.Select_analysis(VIZ_Identity, VIZ_LO, "FID_GW_Viewshed_Clipped = 0")

# Process: Add Field (7)
arcpy.AddField_management(VIZ_LO, "VIZ_Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (8)
arcpy.CalculateField_management(VIZ_Select_LO__2_, "VIZ_Rank", "0", "VB", "")

# Process: Merge (4)
arcpy.Merge_management("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\VIZ_HI;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\VIZ_LO", VIZ_Ranked, "FID_RuralZoning_Viz \"FID_RuralZoning_Viz\" true true false 4 Long 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_HI,FID_RuralZoning_Viz,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_LO,FID_RuralZoning_Viz,-1,-1;GPN \"GPN\" true true false 15 Text 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_HI,GPN,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_LO,GPN,-1,-1;ZoningDist \"ZoningDist\" true true false 25 Text 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_HI,ZoningDist,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_LO,ZoningDist,-1,-1;LandUseAre \"LandUseAre\" true true false 25 Text 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_HI,LandUseAre,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_LO,LandUseAre,-1,-1;VIZ_Rank \"VIZ_Rank\" true true false 0 Short 0 0 ,First,#,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_HI,VIZ_Rank,-1,-1,C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\ModelOutputs.gdb\\VIZ_Select_LO,VIZ_Rank,-1,-1")

# Process: Polygon to Raster (4)
arcpy.PolygonToRaster_conversion(VIZ_Ranked, "VIZ_Rank", VIZ_Raster, "CELL_CENTER", "VIZ_Rank", "20")

# Process: Combine
arcpy.gp.Combine_sa("C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\FLU_Raster;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\AP_Raster;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\CCSG_Raster;C:\\Users\\lfoelsch\\Desktop\\LinnCountyWindModels\\Outputs\\IntermediateData.gdb\\VIZ_Raster", Comp_Raster)

# Process: Add Field (9)
arcpy.AddField_management(Comp_Raster, "Rank", "SHORT", "", "", "", "", "NULLABLE", "NON_REQUIRED", "")

# Process: Calculate Field (9)
arcpy.CalculateField_management(Comp_Raster__2_, "Rank", "[FLU_Raster] + [AP_Raster] + [CCSG_Raster] + [VIZ_Raster]", "VB", "")

# Process: Make Raster Layer
arcpy.MakeRasterLayer_management(Comp_Raster__3_, Full_Compatibility_Map, "", "5372725.15655209 3417231.40833375 5502485.15655209 3578331.40833375", "")

# Process: Extract by Mask (2)
arcpy.gp.ExtractByMask_sa(Full_Compatibility_Map, Regulatory_Output, Clipped_Compatibility_Map)
```

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