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# Powering the Future: Siting Guidelines for Renewable Wind Energy Development in Eastern Colorado

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# Powering the Future: Siting Guidelines for Renewable Wind Energy Development in Eastern Colorado

## Abstract

Wind energy is one of the fastest growing renewable energies around the world. The United States contains approximately 49,000 active wind turbines and Colorado accounts for less than 3 percent of that number, even though Colorado ranks 11<sup>th</sup> in the nation for wind development potential. The siting process for wind development is lengthy, taking from 5 to 10 years, and many facilities that are proposed end up not being built due to complications from inadequate pre-siting techniques. The research in this report aims to identify high priority areas in eastern Colorado through the examination of key variables used in the siting process, while also providing context for land owners positioned close to potential wind development on multiuse scenarios, visual blights, and monetary incentives.

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Powering the Future: Siting Guidelines for Renewable Wind Energy  
Development in Eastern Colorado

Zach Ancona

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Capstone Project

May 30, 2014

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## Abstract

Wind energy is one of the fastest growing renewable energies around the world. The United States contains approximately 49,000 active wind turbines and Colorado accounts for less than 3 percent of that number, even though Colorado ranks 11<sup>th</sup> in the nation for wind development potential. The siting process for wind development is lengthy, taking from 5 to 10 years, and many facilities that are proposed end up not being built due to complications from inadequate pre-siting techniques. The research in this report aims to identify high priority areas in eastern Colorado through the examination of key variables used in the siting process, while also providing context for land owners positioned close to potential wind development on multiuse scenarios, visual blights, and monetary incentives.

Academic Disclaimer: The information presented throughout this report was gathered for academic purposes for the University of Denver Masters of GIS Capstone class. Any site recommendations for wind facilities should only be used as a guide to begin further examination for the site selection process. Any data presented in maps created by the author were acquired publicly and may not be representative of the most current datasets held by private companies.

## Project Definition

Renewable energies are an emerging market around the world and currently the United States is making changes in the energy program to push towards a carbon-neutral future. Of the different renewable energies, wind energy has become a major factor in the large scale energy development market. Wind facilities are comprised of individual wind turbines that vary in size and power. These energy producing facilities go through a rigorous process to examine how suitable a site will be for energy production and its potential for economic viability. An important fact concerning the wind power generation process is that there currently is no cost-effective way to store the energy created. Essentially, even when a wind turbine is capable of generating power, requiring around 7 miles per hour of wind to start the turbine, the wind facility may not be able to be productive when the transmission line into which the power gets fed has already reached capacity. Wind facilities lose much of their potential because many transmission lines will often be at capacity due to a nearby coal or natural gas power plant. For future viability, an updated energy transmission network in the United States will be needed to support a large transition from the traditional energy sources currently in use. A key point to note throughout this report is that wind energy will not replace traditional sources of energy, but in combination with other renewable sources can help

supplement power in an attempt to reduce greenhouse gases along with the dependency on foreign oil.

### *Research Questions/Project Goals*

Raising awareness for renewable wind energy zones in eastern Colorado is the first step in pushing Colorado to be one of the top producers of wind energy in the United States. There are a number of issues examined throughout this report that explain the factors inhibiting the mass expansion of renewable wind energy in the eastern plains of Colorado. There are estimated to be 600 thousand megawatt-hours of potential wind energy that could be harnessed annually in Colorado, currently a handful of facilities generate a small fraction of this potential wind energy (WINDExchange 2014). However, an investment in wind energy is no small feat, the costs are very high and the return on an investment is much like solar energy, where profits will not be seen for many years past installation. In order to offset this large investment, there are tax credits and leasing incentives for wind developers and owners of private lands. Unfortunately, this information is not very well publicized, especially among the rural farmers in the eastern plains of Colorado. Comparing natural gas and other fossil fuels will help identify if wind energy could help offset the amount of fossil fuels that are consumed without competing for land and energy recipients. The research presented in this report will outline the benefits of wind energy in order to educate land owners to allow development on their land, as well as identify

large areas in eastern Colorado that have the potential for the installation of wind facilities. In order to accomplish this goal, an in depth analysis of the required wind siting regulations specific to Colorado will be conducted by using ESRI's ArcMap program to highlight variables that can be shown spatially. The information contained in this report, unlike many siting guidelines in the past, contains visual aids and maps to assist in comprehension. Currently, the public has access to certain sets of data, previously unavailable, which allows for siting documents for wind and other renewable energies to benefit from using programs like ArcMap to visually show priority areas for development. Also, examining maps containing key variables for the development of successful wind facilities can be beneficial in highlighting areas in need of infrastructure vital to the expansion of renewable energies such as transmission lines. The following section will begin with a brief history of wind energy and then quickly move into the role of wind in the United States at present, including tax incentives and state/government plans for the renewable energy sector.

## **Project Foundations**

### *History of Wind Energy*

Harnessing wind power for energy is an idea that has been around for thousands of years. However, in the last 200 years there has been more focus on wind energy for electricity rather than for pumping water, moving



ships, and grinding grain. Larger wind turbines used primarily for electricity came into existence in Denmark around the 1890s, but it wasn't until the 1940s that the largest turbine of the time was installed at Grandpa's Knob in Vermont, rated at 1.25 megawatts. Throughout history, the popularity of new energy developments has been largely dependent on the price of the most widely-used current energy source at the time, presently oil and natural gas. The world was hit by the Oil Crisis in 1973 caused by breakdowns in negotiations between the Organization of Petroleum Exporting Countries (OPEC) and Western oil companies over petroleum production. The price of oil spiked significantly and the renewable energy sector began to see a rise in popularity to reduce our dependency on foreign energy sources (Oil Crisis 2013).

Fluctuating oil and gas prices, the talk of climate change, and the need to reduce greenhouse gas emissions gave wind power a promising future, as the carbon dioxide emissions throughout the life cycle of a wind turbine are very low. Measuring emissions depends on multiple factors: wind speeds, materials used, location, and the amount of time that a turbine is actually producing energy. Based on research by the Intergovernmental Panel on Climate Change (IPCC), estimates on global warming emissions from wind are between 0.02 and 0.04 pounds of carbon dioxide per kilowatt hour. Compare this to natural gas which contributes between 0.6 and 2 pounds of carbon dioxide per kWh, and then to coal which generates between 1.4 and

3.6 pounds of carbon dioxide per kWh (Environmental Impacts of Wind Power 2013). From these statistics anyone can see that in terms of reducing greenhouse gas emissions, wind energy is a clear leader while not being subject to fluctuating prices due to the natural exhaustion of oil and gas wells. While wind energy was part of a carbon-neutral energy program and reduced dependency on foreign oil, the high cost of planning and installing large commercial wind facilities still existed.

In 1992 the Energy Policy Act started offering incentives to energy developers of 1.3 cents per kWh for any wind turbine energy generation that was sold to an unrelated person during that year. This act has been amended over the past 20 years, bringing an era of increased wind development in the United States, and currently the 2013 Production Tax Credit (PTC) stands at 2.3 cents per kWh for wind energy (Zichella 2013). The cash incentive allowed for developers, investors, and manufacturers in the wind energy sector to have more faith that a multi-million dollar facility would be productive and more willing to participate in these large projects. In Colorado, this extension of the renewable energy credit gave way to the executive order that Governor John W. Hickenlooper signed into law on June 5th, 2013. Executive Order SB13-252 will serve to increase economic opportunities in Colorado by allowing more construction of large scale renewable energies such as wind and solar in rural areas. This executive order also helps protect consumers by ensuring lower long-term energy

costs from renewable energies. SB13-252's purpose is to generate large amounts of renewable energy areas by allowing developers to take advantage of the historically low prices for renewable energy this year, siting the 2013 PTC. The duration of this executive order has no specific ending date, but it has set goals for 20 percent of Colorado's energy to be derived from renewable sources by 2020. This executive order has since evolved into the Renewable Portfolio Standards (RPS) that many States are adopting which requires investor-owned utilities along with electric cooperatives to acquire upwards of 30 percent of their energy from renewable sources (Freeman 2010). This call for an increase in renewable energy development has spurred the interest for research that will attempt to highlight suitable areas in eastern Colorado that not only will have high wind energy potential and lower costs, but also will not raise much opposition due to the inputs taken into consideration during the site selection process detailed in this report.

### *Literature Review*

This literature review will focus on three topics which all play important roles in the development of successful wind facilities, and will be essential to providing context for land owners, developers and investors looking into wind energy. The first section concerns the high-capacity electric grid that exists in the United States today. Wind energy will need access to these high capacity transmission lines that provide electricity through a series of

substations and lower capacity power lines to large population centers. Identifying what the grid currently looks like around the nation and in Colorado will bring to light the biggest hurdle when considering the expansion of wind energy in high potential areas that lack proper infrastructure. The second section describes the controversy between natural gas and wind energy by looking at the costs associated with both forms of energy. An examination of current energy production and consumption in Colorado shows the current dominance of coal and natural gas in the market and trends can be seen in recent years that are shifting Colorado towards a more sustainable energy future with renewables. This leads into the last section which examines the misunderstanding concerning land use and wind facilities. The area occupied during construction compared to when the wind facility is in a production phase is drastically less, and many multiuse scenarios exist. Also included in this section is an introduction to siting regulations created by other States specific to wind development. The research presented in this literature review will assist in identifying the most important variables to include on maps in order to locate large areas of potential wind development, as well as providing an understanding to some of the major barriers preventing wind facilities from being developed.

### *Americas Power Grid*

The demand for energy in America motivates all decisions regarding where, when, and why large transmission networks exist. The grid is

currently built around a traditional energy structure which focuses on hydroelectric and fossil-fueled power plants. The National Renewable Energy Laboratory's Futures Study, "finds that it's feasible to produce 80 percent of America's power from renewables by 2050. However, doing so would require enormous changes in the way we plan for, site, permit, generate, transmit, and consume renewable electricity" (Mai 2013). These changes can be accomplished by having resources such as the siting procedures created in this report, covering large areas so developers and investors avoid confrontations before they exist. Many of the issues involved in the siting of wind resources will apply to the electric grid and should be used collaboratively to develop new resource areas. This type of collaboration can be seen by the renewable energy boom that Texas experienced over the past decade. The Electricity Reliability Council of Texas (ERCOT) has been primarily responsible for the construction of new transmission lines that now contribute to the states 11,000 megawatts of new wind energy (Zichella 2013). By defining zoning procedures that establish areas of low conflict for environmental and cultural reasons, developers can get funding and support quicker to take advantage of the low price of wind energy with the potential availability of new transmission networks.

The Renewable Electricity Futures Study by the NREL has performed studies showing the need for an improved transmission network in order to meet the needs of an America that has an energy program powered by 80

percent renewables by 2050 (Mai 2013). The fact that there are very few cost-effective strategies to storing energy produced by large wind facilities makes this even more urgent. Figure 1(a) displays the current electrical transmission network simplified to show major connections around the United States, while Figure 1(b) shows the new transmission lines proposed by the Futures study which would connect some of the major renewable zones in the country to the large population centers where energy can be used more efficiently. The main area of concern for the analysis of eastern Colorado's wind potential will be connecting Colorado's transmission network to the east, servicing more of the central plains states.

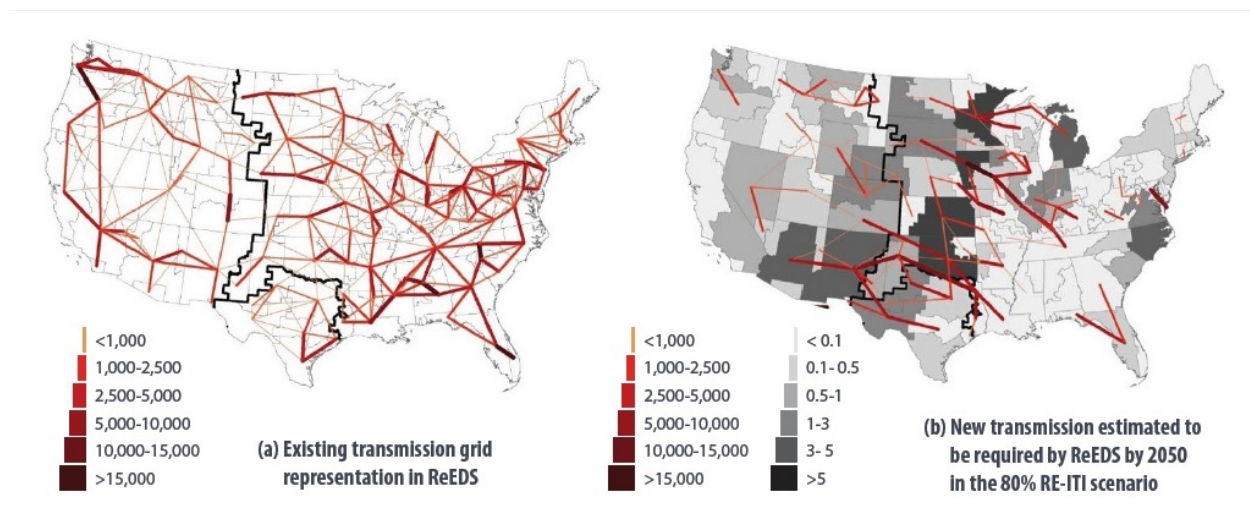


Figure 1: Existing Transmission (a) and potential 2050 transmission (b), Mai 2013

This figure not only shows how complex the east coast's electric grid system is, but also how the grid is generally built to service the local needs of specific areas, and does not cater to the long-distance transportation of energy. The proposed transmission network will aim to connect large

regional transmission networks to better assist in the long distance energy transmission from renewable energy sources. The black line in the figures above show the regional splits that currently exist in our energy network and for renewable energy to really capture the energy market there will need to be an upgrade to this network like the one suggested in Figure 1(b) to support the transport of energy to new areas. Figure 2 below shows the transmission network zones for the United States. These boundaries correspond with the black lines seen in the NREL Future Energy Study maps seen above.

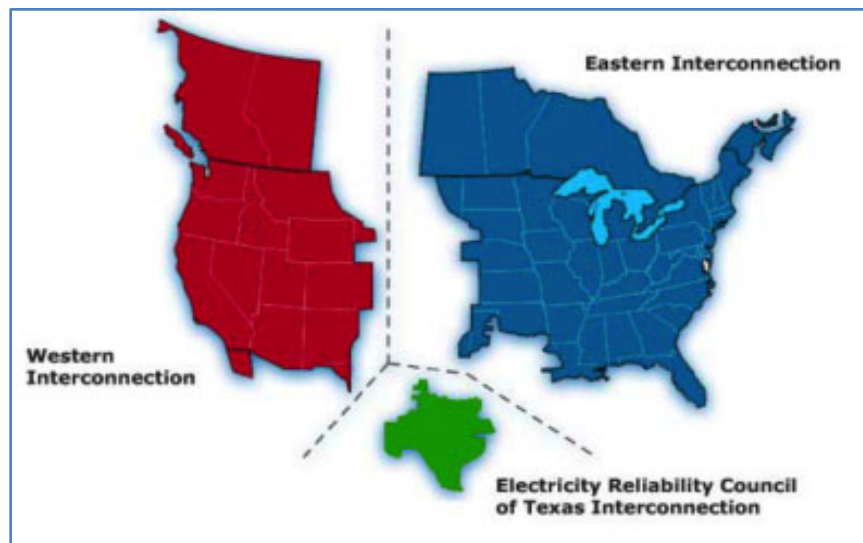


Figure 2: USA Transmission Network Zones, AWEA 2013

The existing infrastructure was constructed primarily for the use of fossil fuels and hydroelectric systems. With the current outlook of renewables as a driver in America's energy, the electric grid must adapt to meet the needs of

long distance transportation of energy, since the electricity created from wind cannot be stored efficiently.

The Colorado Energy Office has expressed a need for the expansion of this energy network to help supply the large urban areas in Colorado. Currently the population of Colorado is around 5 million and is expected to grow to 9 million residents by 2050 (Colorado Energy Office 2014). This expansion of the transmission network will allow for new development of renewable energy in the eastern part of Colorado. Figure 3 (below) is a map provided by Colorado's Energy Office showing the locations of medium and high capacity transmission lines throughout Colorado. This is one of the better maps of the transmission networks. The proprietary nature of transmission line data does not allow for datasets to be shown at scales below the state level, unless purchased from the energy companies who own the transmission lines. The high capacity transmission lines, of 345 kV, (shown in pink in figure 3) are of most concern to wind development as the energy being produced is only occurring when the wind is at the proper speeds and must be either used or transported elsewhere for use.



### Colorado's Transmission Infrastructure:

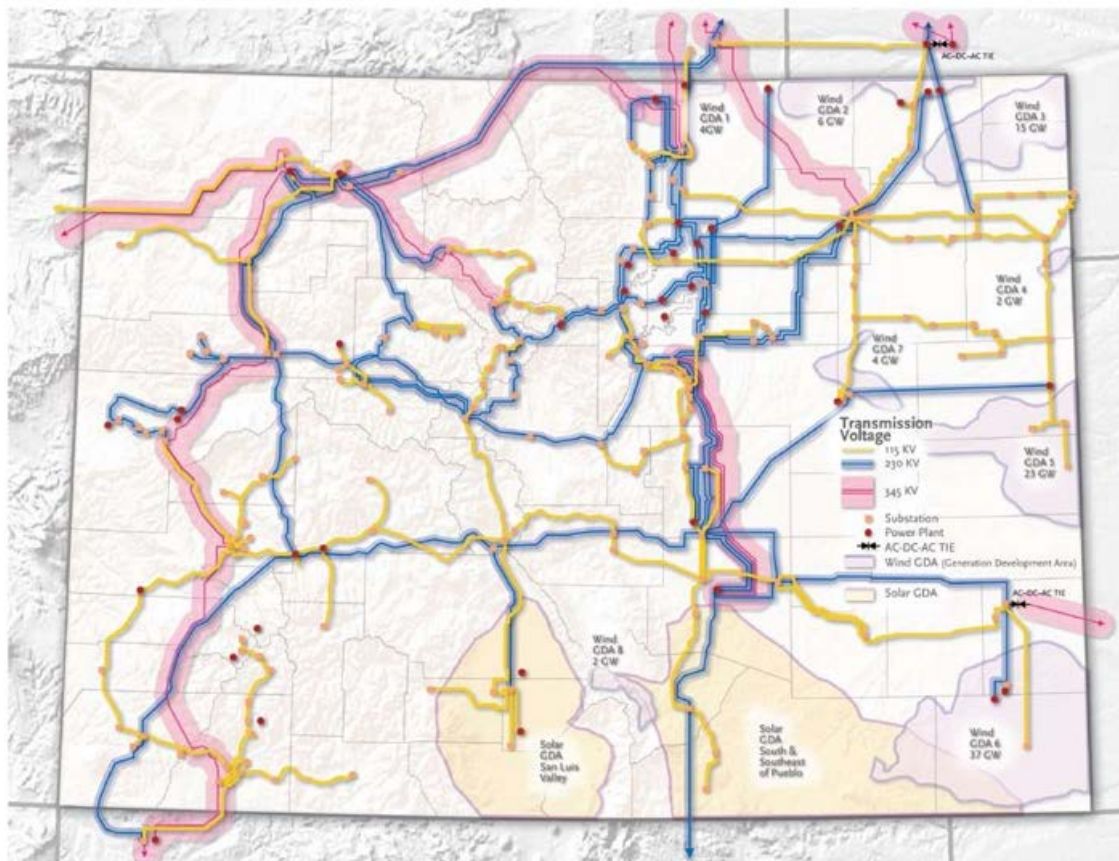


Figure 3: Colorado Transmission Infrastructure, Colorado Energy Office

One of the biggest hurdles to installing massive renewable energy zones in eastern Colorado is that the eastern border of Colorado is a cutoff point for how the transmission network is currently divided in the United States. These points are the Western Interconnection, Eastern Interconnection and the Electricity Reliability Council of Texas Interconnection. These different regions operate for the most part independent of each other, and there are few opportunities to connect with large pre-existing transmission networks that could carry wind energy produced in Colorado to the east and south (AW EA 2013). The American Wind Energy Association has been working with state and federal agencies to improve the ways that new transmission lines

are being constructed which could double the areas currently available to wind development (AWEA 2013). The analysis conducted on eastern Colorado in this report will expose developers and land owners to the areas that will likely be developable for wind energy once new transmission networks are proposed.

Energy transmission is not the only setback currently to wind. With more efficient ways to extract and process coal, oil and natural gas, many areas around the nation will continue to see lower energy prices from these conventional sources. This makes the capital costs of new wind facilities seem unappealing to investors, but the 'green' revolution happening in the United States keeps renewable energy relevant. The U.S. is starting to look overseas at some of the more energy independent countries as a result of a commitment to renewable energy. An examination of natural gas and wind energy in this next section shows how the U.S. is starting to accept renewable energy practices and move away from conventional fossil fuels as a primary residential and industrial energy source.

### *Natural Gas and Wind Energy*

Natural gas has become one of the main forms of energy to use in America. Heating, cooking, and manufacturing in the residential, commercial and industrial sectors are largely supplied by natural gas. One of the only industries in which natural gas use is low is the transportation sector, which

is not particularly concerned with wind energy; unless there is a massive shift towards electric cars in the future. Natural gas has low capital costs and variable fuel costs, while wind and other renewable energies have higher capital costs but almost no fuel costs (Lee 2013). New technologies, like shale gas production, have made it difficult to predict the future rates of natural gas prices, which in turn make it difficult for renewable energies to get investors, especially if the gas rates continue to stay low. Natural gas prices being subject to market fluctuations in the future could allow for investors to look toward the current tax incentives for wind energy along with the predictability of the market price for wind energy because of a lack of fuel costs. This gives the sense of a higher-risk investment with natural gas while maintaining some more conservative investments by choosing wind energy development (Electricity from Wind 2013). The Oil and Gas Journal reported that "Texas, which produces one third of the nation's gas, must drill 6,400 new wells per year, or 17 wells per day, to keep its production from plummeting" (Electricity from Wind 2013). This begs the question, whether there is a correlation between this statistic and the large amount of new wind energy generated in Texas over the past 10 years.

The connection between natural gas and wind energy will be crucial in order to provide the consumers with the electricity they need in the future. Wind energy has the downside of actually needing wind to produce power, this means that in times of low wind production, natural gas will work as an

energy substitute, and the same can be said about times of high wind production. Natural gas facilities can store energy more efficiently than wind in order to prepare for times of low wind and peak energy use. Figure 2 compares electric-generating sources from 2006 to 2012 (Zichella 2013). Trends can be seen between natural gas and wind energy due to tax incentives and economic issues in the United States.

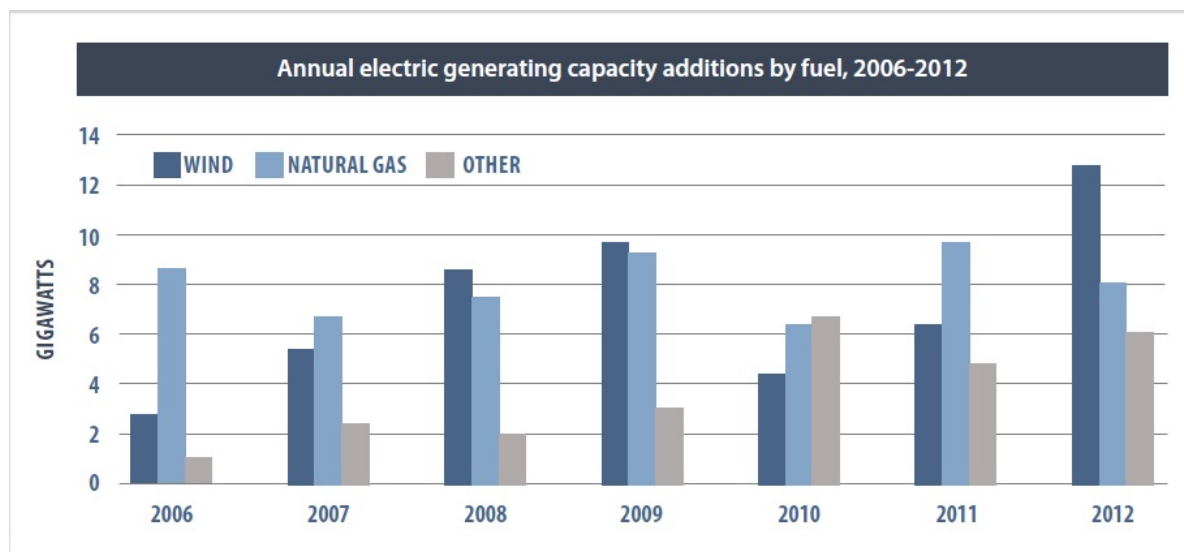
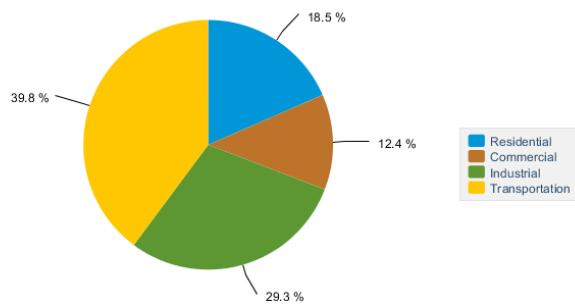


Figure 4: New power capacity additions by year. Zichella 2013

With improved siting procedures, the potential capacity in the future for wind energy would continue to grow based on trends seen in states that have implemented such strategies. There is no need for natural gas to pose a threat to the wind industry, and instead should work cooperatively to develop new resource areas. The collaborative use of power will be relatively the same and may have many of the same investors.

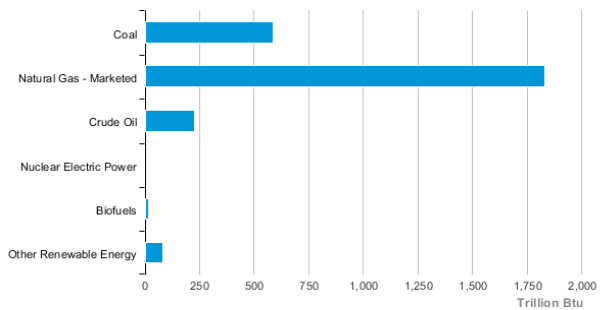
The United States Energy Information Administration, or EIA, provides state wide estimates of energy production and consumption for Colorado. The EIA has estimated that "In 2013, 64% of the electricity generated in Colorado came from coal, 20% from natural gas, and 17% from renewable energy sources" (EIA 2014). This statistic tells us that around 85% of the energy produced in Colorado is from fossil fuels and there is good reason for this. According to the EIA, household energy costs in Colorado are around 23 percent below the national average. An example of this can be seen in the bottom right graph on the following page. The upper left graph titled 'Colorado Energy Consumption by End-Use Sector, 2012' illustrates that transportation makes up for a large portion of the energy used in Colorado, around 40%, which unfortunately is difficult to offset using wind energy. This does allow wind and other renewables to tap into the remaining 60% of the market with the increased pressure on investor-owned electric utility companies to provide 30% of the energy they produce to be generated by renewable energy by the year 2020 (EIA 2014). The ongoing tax credits for wind energy generation along with the pressure from state governments enacting renewable portfolio standards will help offset the large gap seen between coal-fired energy and renewable sources.

Colorado Energy Consumption by End-Use Sector, 2012



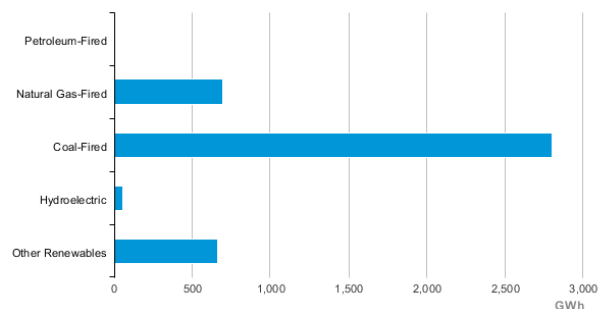
Source: Energy Information Administration, State Energy Data System

Colorado Energy Production Estimates, 2011



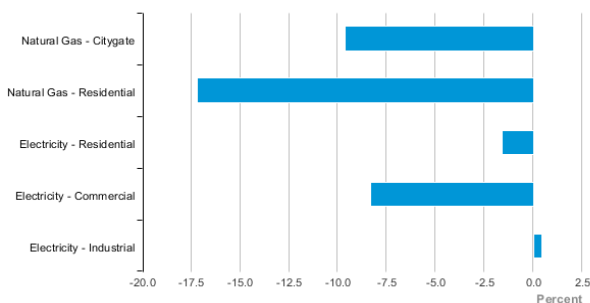
Source: Energy Information Administration, State Energy Data System

Colorado Net Electricity Generation by Source, Nov. 2013



Source: Energy Information Administration, Electric Power Monthly

Colorado Price Differences from U.S. Average, Most Recent Monthly



Source: Energy Information Administration, Petroleum Marketing Monthly; Natural Gas Monthly; Electric Power Monthly

Fossil fuels and wind energy will always have some degree of conflict for market share, but that does not mean that multi-use facilities cannot exist. With proper site planning and land use management, opportunities can be found where a high quality wind resource and an abundance of natural gas or oil can coexist with one another. Wind turbines take up a small fraction of the land they are leased on, this makes eastern Colorado's private farmlands the perfect place for large scale wind facilities to intermix with grazing and also take advantage of land not being used on traditional center pivot irrigation agricultural areas.

*Land Use and State Specific Guidelines for Wind Facilities*

Environmental and land use issues that occur repeatedly in siting recommendations created by the state or private agencies will help identify key points of data that need to be analyzed when choosing areas to develop new wind facilities in eastern Colorado. Land use is important for this region because much of the developable land for wind turbines is privately owned and would require multi-use scenarios. Wind turbines take up a large portion of land area when being built because of the distance needed between rotor blades to avoid interference with each other's wind production (Wilburn 2012). The way that wind turbines are sited, the large portion of land set aside for wind production is leased, but much of the land goes unused because of the spacing required between wind turbines. This leaves much of the land available for grazing, agriculture, hiking, or roadways. Wind energy could also be built in superfund sites or contaminated areas since none of these factors will affect wind production (Environmental 2013). This report indicated that much of the land disturbed by the development of a wind facility comes from the road development for getting materials to the sites. By using existing roads and infrastructure, the direct impact of a renewable energy zone can be mitigated by a large amount. The U.S. Fish and Wildlife Service developed a general framework for minimizing the impacts to wildlife which can be seen on the flow chart located in Appendix A (USFWS 2011). This tiered approach requires extensive data to be collected and analyzed to

identify potential issues with wildlife and habitat considerations before a project gets too far into the planning process. Wildlife concerns are only one step in the proper siting process of future wind facilities, and records showing extensive research done on an area will help combat opposition from environmental groups who oppose wind energy. The highest concern to wind development and wildlife is the impacts they have on the avian population along with honoring the Endangered Species Act which protects both the animals and the ecosystems they inhabit.

In addition to government agencies like NREL and the USFWS, private state groups create siting guidelines that can help establish the importance of certain variables to the siting process. When state guidelines exist, there are broad categories that are seen in many siting documents, but that also have a tendency to focus on geographic specific issues applicable to the area of concern. South Dakota has a multi-agency effort to create its first wind facility siting plan at the state level. The variables of greatest concern for South Dakota are as follows: land use, natural and biological resources, noise, visual resources, public interaction, soil erosion and/or water quality, health and safety, cultural, archaeological, and paleontological resources, socioeconomic, public service and infrastructure, solid and hazardous wastes, air quality and climate (Siting Guidelines South Dakota 2013). It is clear to see that this list of variables can result in extensive efforts in data collection. State reports currently outline guidelines for the general siting of



wind development by providing general rules and priorities for developers to consider. This report will contain much of the same information specific to Colorado, but also provide visual maps of available data to easily identify areas of high development potential.

Nebraska has incredible wind potential and population centers that allow for massive amounts of wind production, approximately 3.5 million gigawatts. These are some of the major reasons why Nebraska's state agencies have been working together to bring wind energy to the area and begin a transition towards a renewable energy market in Nebraska. However, there are concerns with building additional large commercial wind facilities in Nebraska, specifically due to the fact that the state has 14 federal and 27 state plant or animal species that are listed as endangered or threatened (Guidelines for Wind Energy 2013). This fact leads the Nebraska siting document to focus more heavily on wildlife and habitat issues, though there are sections of the planning document in reference to cultural areas, community impacts, and existing infrastructure. The following section will outline the siting guidelines created for Colorado's high wind potential areas and identify datasets that can be displayed spatially for better recognition of key areas for development.

## Approach

### *Colorado Siting Guidelines*

Colorado has a number of environmental groups and law firms that provide basic siting guidelines and precautions to take when developing new wind facilities. This section will examine different wind facility siting guidelines that have been compiled for Colorado over the past few years to meet the increasing rise in renewable energy production. Identifying key variables to the siting process and how they specifically can be applied to Colorado will help expedite the process for developers to investigate issues concerning future wind facilities. Due to current environmental laws and testing requirements for wind potential, the process of siting wind facilities will be hard pressed to complete in less than a year or two. This timeframe is still significantly less than the current length of time it can take to get the proper approvals for wind development. The process of conducting the environmental assessment alone, in some cases, can take anywhere from several months to upwards of two years for a full Environmental Impact Statement (Freeman 2010). The variables outlined below explain in detail some of the more important aspects of wind facility siting to avoid conflicts before or after development. The information examined in the following section is referenced from a variety of different siting documents created for Colorado.

### Variables of Importance to Wind Siting

- I. Wind Potential
- II. Transmission Availability
- III. Environmental Issues
- IV. Zoning and Permitting Considerations
- V. Oil/Gas Development and Wind Facilities Conflicts
- VI. Public Acceptance and Incentive Options for Developers/Landowners
- VII. Land Use and Urban Areas
- VIII. Flight Obstacle and Radar Interference
- IX. Aesthetic Considerations

#### *Wind Potential*

The ability to gauge wind potential for wind facilities is dependent on the height at which the facility wishes to capture the wind along with the actual site of the proposed facility. Colorado ranks 11<sup>th</sup> in the nation for the ability to generate energy from wind and most of this potential wind energy lies on the eastern part of the state. The map below was created by the National Renewable Energy Laboratory in Golden, Colorado and identifies the high wind potential areas in Eastern Colorado in addition to listing the Wind Power Classification table used to gauge wind resource potential. Figure 5 below, along with the maps created using ArcMap later in this report, are

only estimates of possible wind potential and should only be used as a guide.

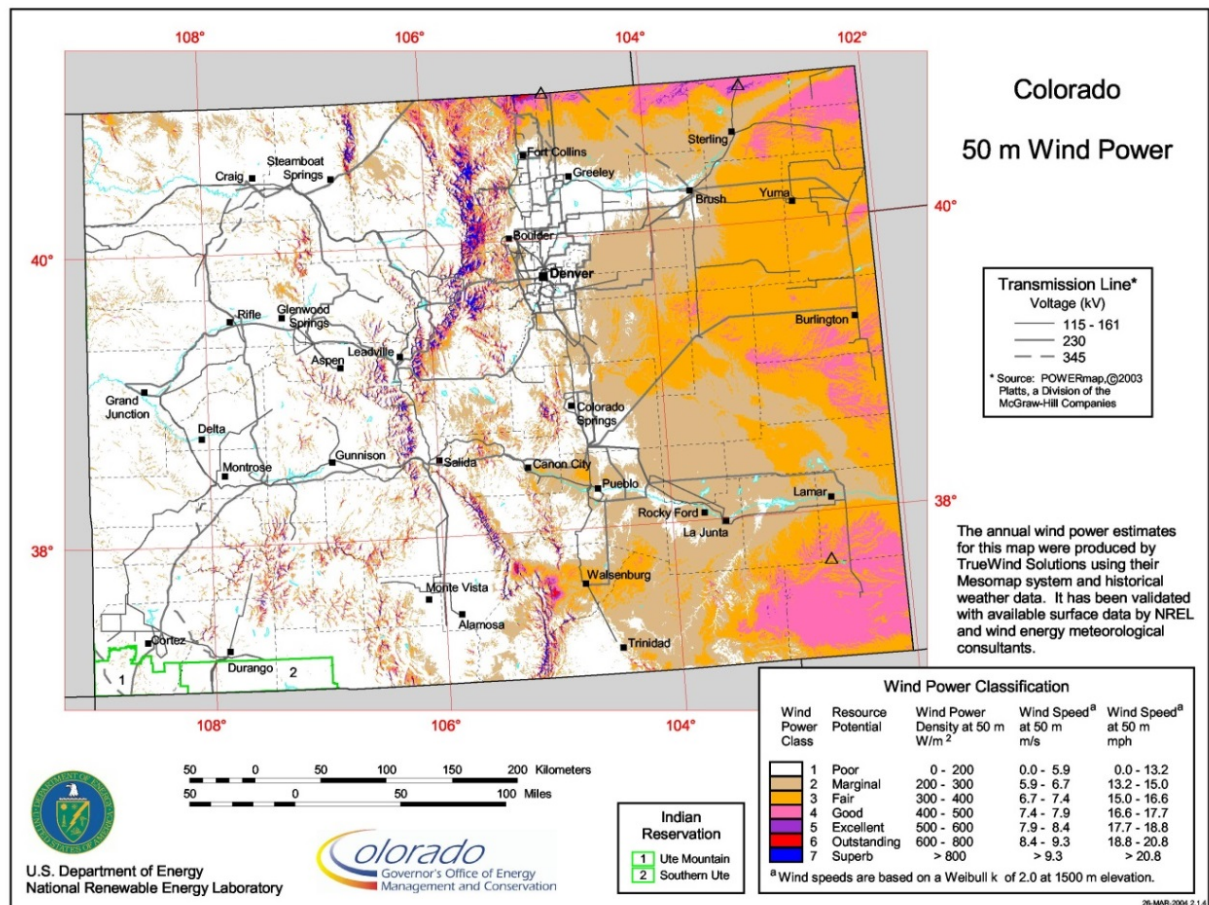


Figure 5: NREL Colorado 50 m Wind Potential, NREL Wind Estimates website – WINDEXchange, U.S. Department of Energy

The areas of highest concern for wind potential are classified as 3 and above in the map provided by the NREL. These classifications correspond with areas that have sustained winds of 15 mph at a height of 50 meters. Since many new turbine models stand closer to 80 meters and above wind speeds can be estimated to be more significant at higher altitudes. The public data provided in shapefile format by the NREL is of the 50 meter wind potential and can be used as a general reference to gauge site potential.

Once a potential wind energy site is predetermined from maps like the above, landowners and developers can acquire Anemometers on loan programs from the state and build Meteorological towers that can accurately capture wind readings over a desired period of time (Forston). Getting the accurate wind estimates started early in the siting process is good practice to reduce startup time while the other barriers to development are investigated.

### *Transmission Availability*

Earlier in the report was an examination of the current transmission network present around the United States and in Colorado, shown in Figures 2 and 3. Reliable transmission is still one of the major obstacles to wind development. It is beneficial for future projects to not only be as close to existing high capacity transmission lines as possible, but also, developers should acquire transmission capacity on the grid before any construction or planning takes place (Freeman 2010). The U.S. Census Bureau's TIGER lines provide small chunks of the transmission network in a shapefile format and were used for some analysis of the data. Since many of the lower capacity transmission lines are owned by private companies, the data for these are unable to be publicly distributed due to privacy rights. The lower capacity transmission network is not as crucial to siting major wind facilities because of the fact that wind energy must be used at the time it is produced and cannot be stored efficiently. With access to high capacity lines this energy

could be fed back into the grid and used where it is needed at time of production (Freeman 2010). The space needed to build these large wind facilities are usually in rural areas far away from where the actual energy is used (Forston). This is another reason why existing or new high capacity transmission networks will be needed because many of these rural areas lack the transmission infrastructure because of the current conventional energy resource being oil and gas. During the time a transmission plan is being worked out, there should be research being done on the environmental concerns surrounding the wind industry on the site under consideration.

### *Environmental Issues*

There have been a number of studies done on the environmental side effects of large scale wind facilities. These side effects include things like the need for rare-earth metal usage, similar to those of the electric car industry. Weather and climate change are also something of concern with the massive expansion of renewable wind energy in the United States. These concerns rarely get the spotlight over the largest environmental obstacle to wind development, avian mortality. Altamont Pass has been one of the more notorious areas in terms of creating conflict from environmental groups to oppose wind development. This area, comprised of over 5,200 wind turbines created in the 1980's and 90's, is a result of bad site planning and poor turbine design. The Altamont Pass area is located in one of the most heavily

used flyways for birds in the United States and has been the site of many environmental lawsuits against wind companies resulting in the repowering or decommission of a large number of wind turbines (Freeman 2010).

The Colorado Division of Wildlife and the Fish and Wildlife Service require any large scale project to address any concerns on state and federally listed wildlife species along with their habitats. Colorado currently is home to three species of endangered birds, the Whooping Crane, Least Tern, and the Southwest Willow Flycatcher. These birds along with a few threatened species such as the Piping Plover and the Mexican Spotted Owl make up the majority of avian concerns for wind development in eastern Colorado (Freeman 2010). Much of the land in eastern Colorado that holds wind potential covers mainly agricultural areas that have been developed for some time. This makes following environmental regulations a bit easier due to the fact that very few of the potential sites correspond with areas of environmental concern, which includes habitats for terrestrial threatened and endangered species. The United States Fish and Wildlife Service releases shapefiles showing areas of particular concern and much of eastern Colorado is not included, making it a prime area to receive little opposition from environmental groups.

### *Zoning and Permitting Considerations*

The zoning and permits required to develop a new wind facility will vary from place to place, but for the most part a wind facility will need a "conditional or special use permit, a building permit, and a road permit" (Freeman 2010). A general rule for setback laws concerning wind turbines are two times the structures height from any sort of above ground public utility, public road or railroad and most any residential, commercial, or industrial building (Yuma County Land Use Code 2011). Once a site is discovered by narrowing down the availability to transmission, concerns with environmental regulations, as well as wind potential; special county permits and setback laws will exist that need to be looked into before construction can be approved by that city or counties land use committees. Specific setbacks apply directly to the height of the turbine being used along with any individual city/county regulations that may apply which make it difficult to pre-plan before turbine specifications are known. Shadow flicker, Ice Throw, and Noise are common issues that developers must be aware of when looking into acceptable locations for wind turbines. Shadow flicker occurs during sunrise and sunset when the sun hit the blades at a certain angle causing flickering shadows a good distance from the turbine itself. Though there are no proven health risks from shadow flicker, numerous law suits have been taken against wind developers because proper setbacks during the siting process were not taken into consideration (Freeman 2010).



Colorado also has the added risk of ice throw because of the low temperatures randomly throughout the year. Similar setback distances from occupied structures and commonly used roads will be sufficient to deal with ice throw, but there have still been litigations against wind facilities concerning ice throw and potential risks for the surrounding area (Freeman 2010). The noise generated from wind turbines has been compared to the sound of a car travelling at 40 miles per hour from 100 meters away, or the amount of noise generated by a refrigerator from the same distance (Freeman 2010). Much of the noise generated by the actual wind turbines is masked by the sound of the wind itself, but setbacks and decibel levels should still be considered when placing turbines close to residential areas. There is no spatial data available for this section until a site is selected and a potential wind turbine can be identified as a best fit economically. Once the initial steps of locating a potential site for a wind facility occurs, planning can begin for turbine placement according to city and county setback and zoning laws.

### *Oil/Gas Development and Wind Facilities*

Competition with oil and natural gas is for the most part a non-issue in eastern Colorado because of the lack of economically viable sites for fossil fuel extraction. The issue for wind development and conventional oil, or gas wells, is the conflict of mineral and surface rights to a particular region. When dealing with privately owned lands, developers must be weary of

purchasing surface rights to install wind turbines without a full understanding of the resource below the surface of the earth. If reserves of oil or natural gas are found beneath a proposed area for wind development there could be conflicting lease agreements on the land and development issues could arise. Building large facilities upwind of a proposed wind site could have negative effects on the wind resource itself, and also the building of oil and gas infrastructure could inhibit the ability to access transmission lines or even construct new transmission lines to service a new renewable energy area. These issues along with the obvious case of an oil or gas well being drilled and hitting underground high voltage wires connected to wind development could be a huge risk (Freeman 2010). Collaboration between these two energy sources is crucial to being able to expand the renewable energy sector to something more than a niche in the market. The lack of viable fossil fuel resources in eastern Colorado contributes to the fact that no shapefiles were used in the analysis to represent zones of lower or higher priority for wind, but should always be considered before planning and development begins for a particular area.

#### *Public Acceptance and Incentive Options for Developers/Landowners*

A large driver of expanding the wind energy sector on private lands in eastern Colorado is the monetary incentives both for landowners and developers of the wind facility. The landowners have a few options; they may either lease their land or outright sell it for energy use. Typically a

landowner will get around 3,000 to 5,000 dollars per turbine, per year on their land (Forston). By leasing land instead of selling it, landowners can participate in multi-use scenarios both for farming and grazing while collecting payments for the leasing of small portions of their land. In Ohio, the Blue Creek Wind facility, a 300 megawatt facility, pays out 2 million dollars annually in lease payments to landowners with over 2.7 million dollars annually in local taxes from the owners of the wind power themselves (Utility Scale Wind Energy Development 2013). The amount of revenue a wind facility creates through energy production generates massive amounts of tax dollars for the state along with providing a number of job opportunities during the construction phase and beyond.

The developers and investors of wind energy also see large incentives for the creation of new wind facilities. The Production Tax Credit, or PTC, is one of the main drivers behind wind development and currently provides 2.3 cents per kilowatt-hour produced. There is also an Investment Tax Credit which can offset costs of installing new wind facilities up to 30 percent (Freeman 2010). These types of incentives help drive the wind industry in Colorado to comply with the Renewable Portfolio Standards requiring electric utility companies to acquire up to 30 percent of their energy from renewable sources.

### *Land Ownership and Urban Areas*

Most all of the developable land for wind facilities in the eastern plains of Colorado is privately owned agricultural land. There are a few cases in northern Colorado like the Cedar Creek Wind Facility, which resides on federal lands, but much the area considered in this report for potential wind development is privately owned. Knowing the proximity to large urban areas where wind energy would be used is also good practice for developers until the transmission network can be updated to be able to transport large electric loads to areas in need. The Census Bureau provides up to date shapefiles showing federal lands along with urban areas. Knowing land ownership and the location of potential consumers for the energy produced will help indicate if the construction of a wind facility is possible.

### *Flight Obstacle and Radar Interference*

The Federal Aviation Administration requires that any structure extending 200 feet or above and in some cases shorter when near runways, to develop a Notice of Proposed Construction outlining the plans for lighting and marking of tall structures (Freeman 2010). This notice will be reviewed by the FAA to ensure proper techniques were used along with highlighting any special cases due to nearby facilities or radar interference. There have been ongoing studies assessing the impacts wind facilities have on civilian and military radar systems in the United States. The rotation of the turbine

blades and the backscatter produced can be linked to some radar interference (Freeman 2010). It is recommended that developers of wind facilities consult with the Department of Defense and locate nearby radar installations during the siting process before construction begins.

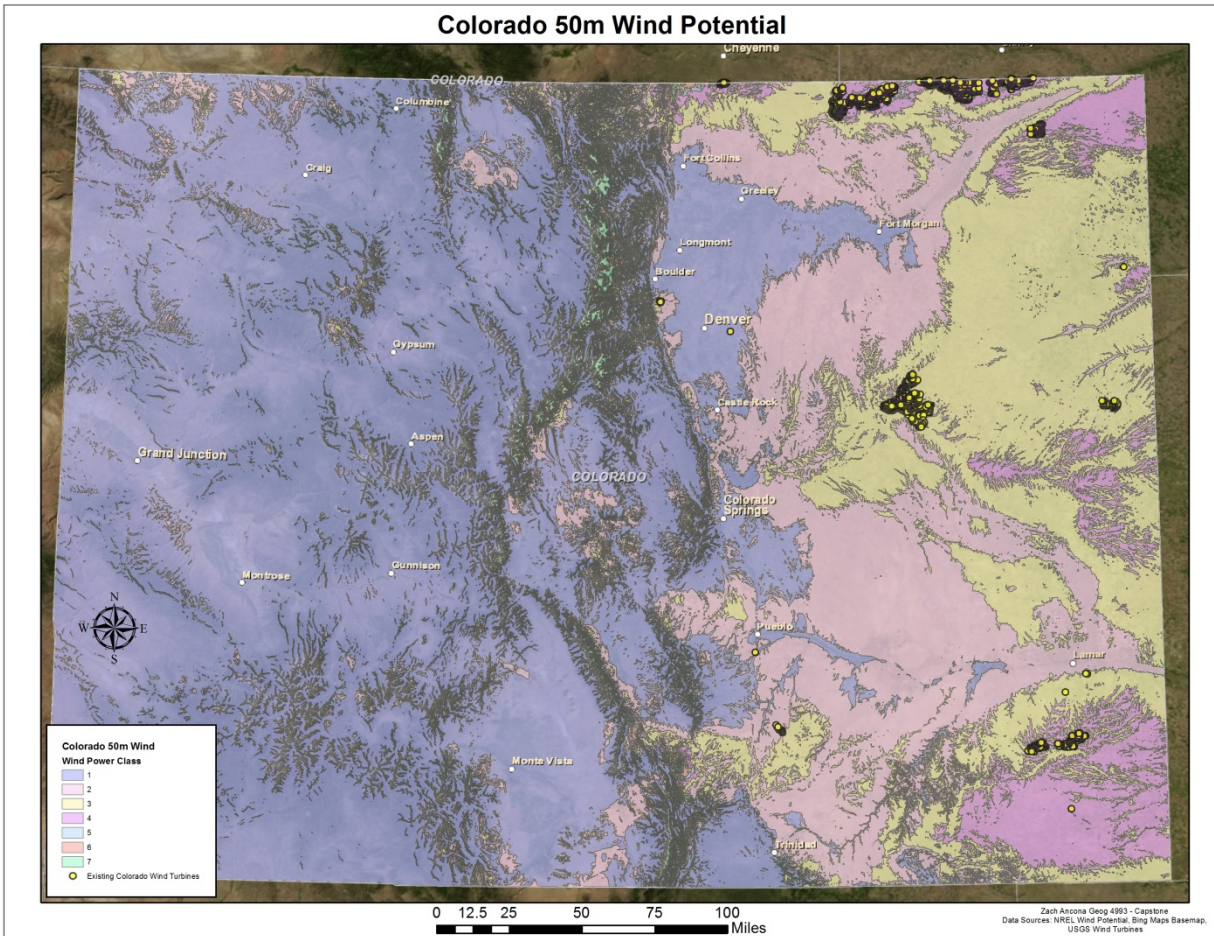
### *Aesthetic Considerations*

Gauging public opinion towards the aesthetics of a wind facility is one of the more difficult steps to acquire information on. Developers can hold city council meetings to gauge opinions or issue surveys to the surrounding population. Developers must provide the state and local agencies with sufficient background on the visual impact of a wind facility according to the specific sites selected. There is a system created by the BLM to quantify visual impacts of wind development for federal lands and can be valuable for providing general information on potential wind facility sites (Freeman 2010). Eastern Colorado is relatively flat and lacks considerable visual regulations which makes this process easier for this region, but must still be taken into consideration as visual impacts on the surrounding area from wind turbines is a highly debated topic.

### **Project Solution**

Publicly available data for certain variables was acquired and mapped in the ArcMap program according to the site identification process listed in the previous Approach section. The use of maps to aid in the identification of

suitable wind facilities can help speed up the site selection and development currently involved in the siting process, though not all variables necessary to site selection have publicly available datasets. The map on the following page displays the wind potential at 50 meters for the state of Colorado. The dots represent wind facilities currently in operation, most of which fall into wind classes of 3 or higher. This map illustrates the eastern side of Colorado's high wind potential compared to the rest of the state which lacks suitable wind for sustainable development. The table shown below the map explains how the wind speed classes are split. The 50 meter columns on the right hand side are of most importance to large commercial scale wind facilities, as many new industrial size turbines are closer to 80 and 100 meters tall. Wind speed data for Colorado is only available publicly at the 50 meter height in a shapefile format, but for the most part the same areas align with wind classes of 3 and above at the 80 meter height and even extends into some of the surrounding areas in the eastern plains that are displayed as a class 2 in the map shown on the next page.



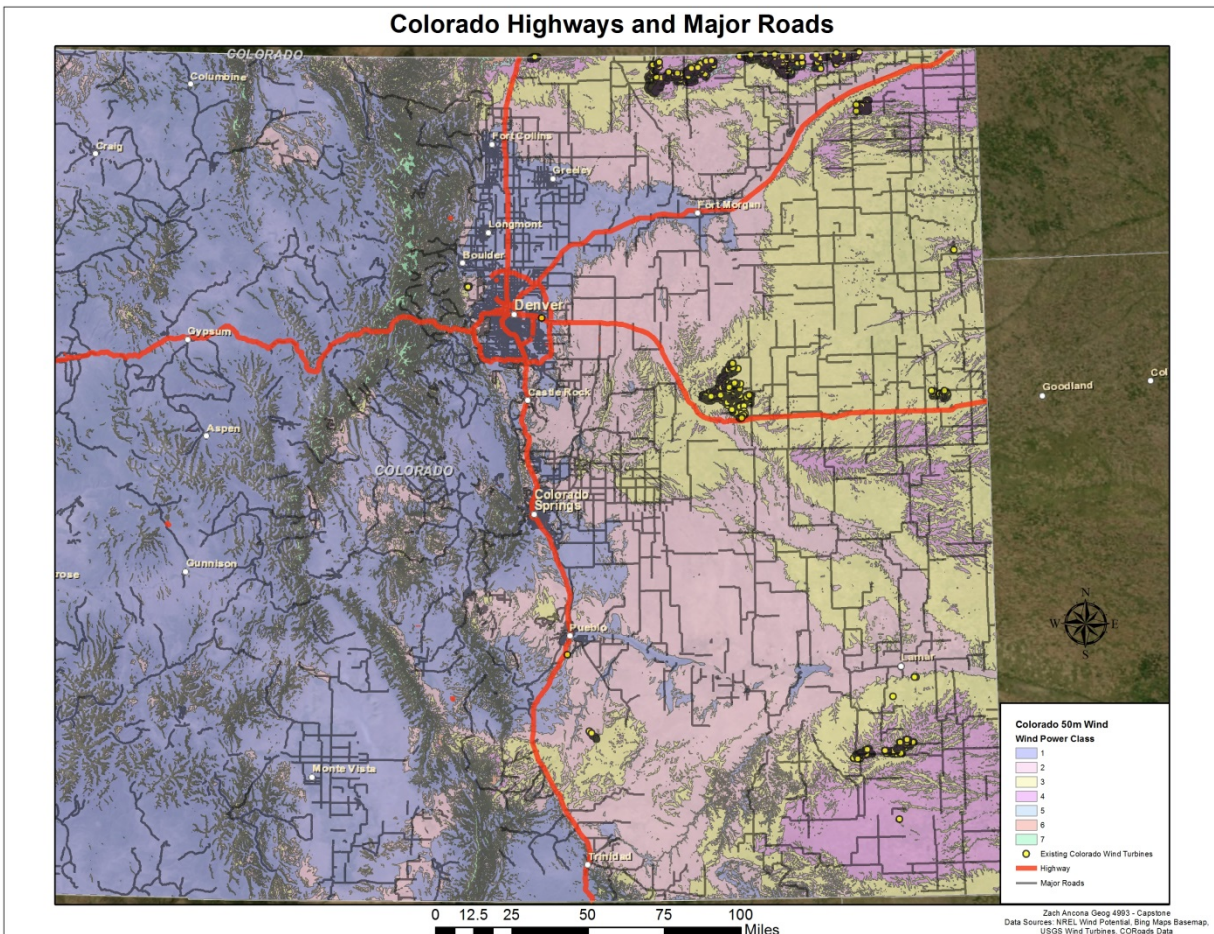
**Table 1-1. Classes of wind power density at 10 m and 50 m(a)**

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density (W/m <sup>2</sup> )	Speed (b) m/s (mph)	Wind Power Density (W/m <sup>2</sup> )	Speed (b) m/s (mph)
1	0	0	0	
2	100	4.4 (9.8)	200	5.6 (12.5)
3	150	5.1 (11.5)	300	6.4 (14.3)
4	200	5.6 (12.5)	400	7.0 (15.7)
5	250	6.0 (13.4)	500	7.5 (16.8)
6	300	6.4 (14.3)	600	8.0 (17.9)
7	400	7.0 (15.7)	800	8.8 (19.7)
	1000	9.4 (21.1)	2000	11.9 (26.6)

The map displayed below shows the current road network acquired from the TIGER/Line public road network layer. The red lines represent major highways, while the black lines display the major road network



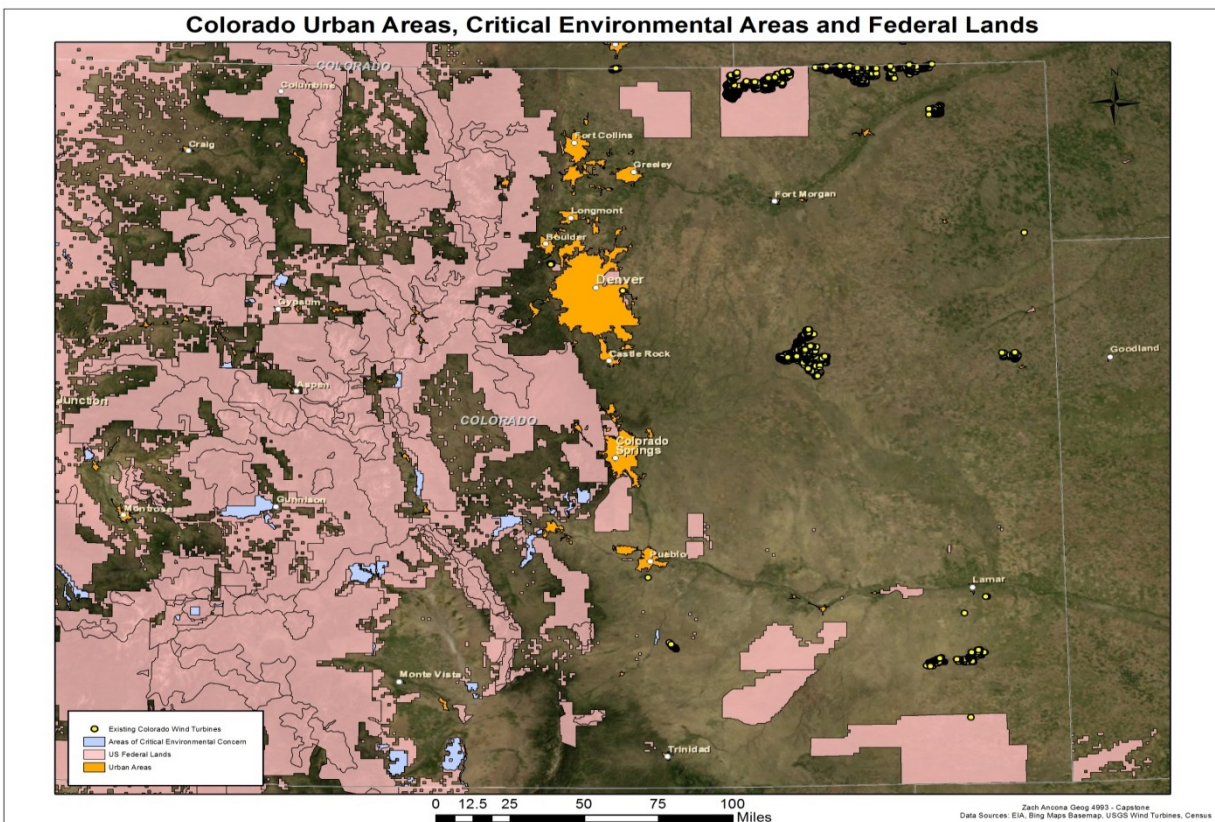
needed to transport items as large as turbine towers and blades. Smaller local roads are omitted from this map as they would need to be altered to support the transport of wind turbine materials and are also in great abundance throughout eastern Colorado.



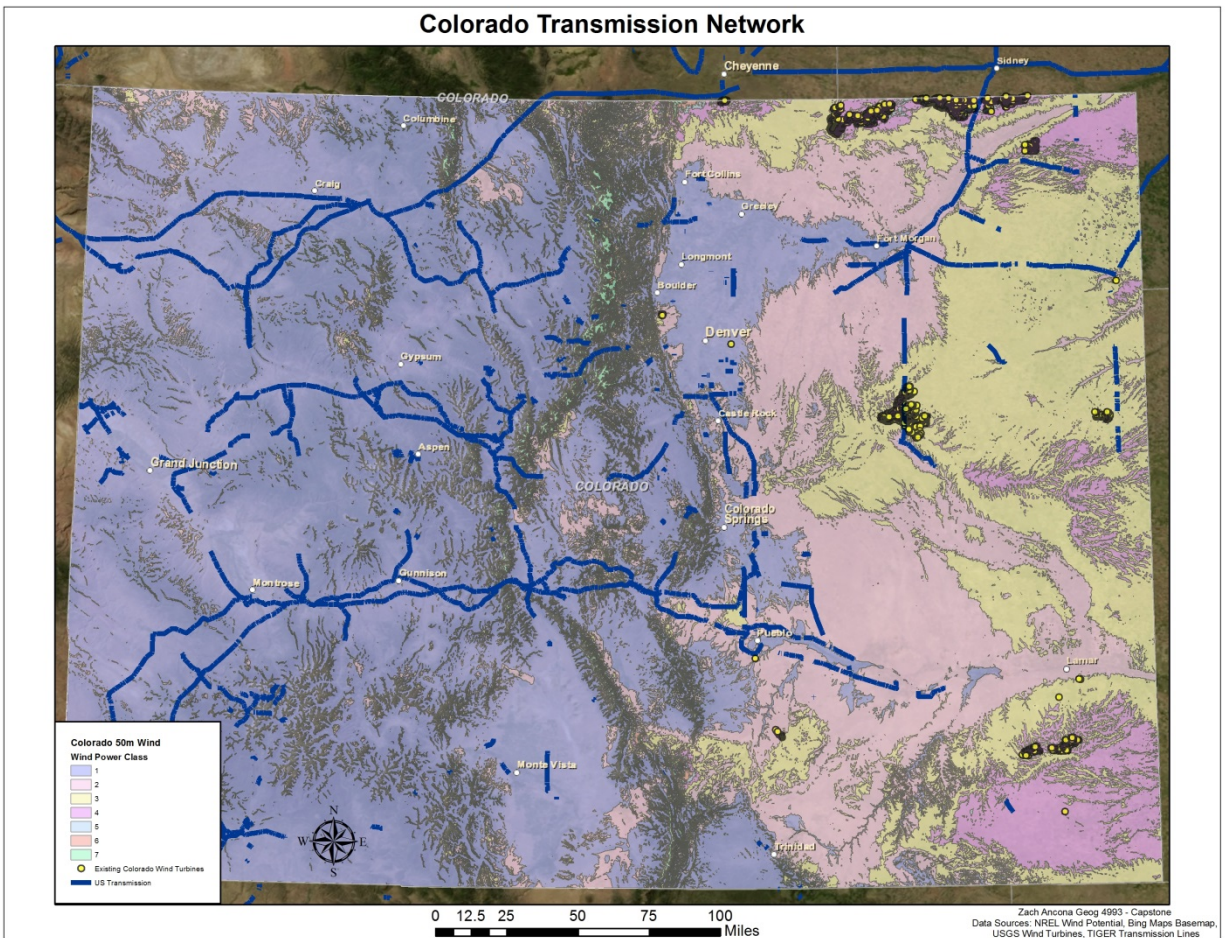
The next map is in reference to the identification of federal lands, large urban areas and areas of critical environmental concern. The map shows that none of the urban areas are close enough to the wind potential areas to pose any development concerns and are close enough that the energy produced in the eastern plains could supply much of the front range, i.e.



Denver, Colorado Springs, Fort Collins and Pueblo with renewable energy. Colorado Areas of Critical Environmental Concern and federal lands do not coincide with potential wind generation areas for the most part and are generally found throughout the Rocky Mountains instead of in the eastern plains. This massive amount of private land in the high wind potential areas is a good thing for wind developers as it allows them to bypass some of the more rigorous environmental regulations that federal lands require such as the National Environmental Policy Act, or NEPA. Examples of this type of regulation on federal lands versus a privately owned parcel of land can be seen during the construction of the Cedar Creek Wind Facility in northeastern Colorado.



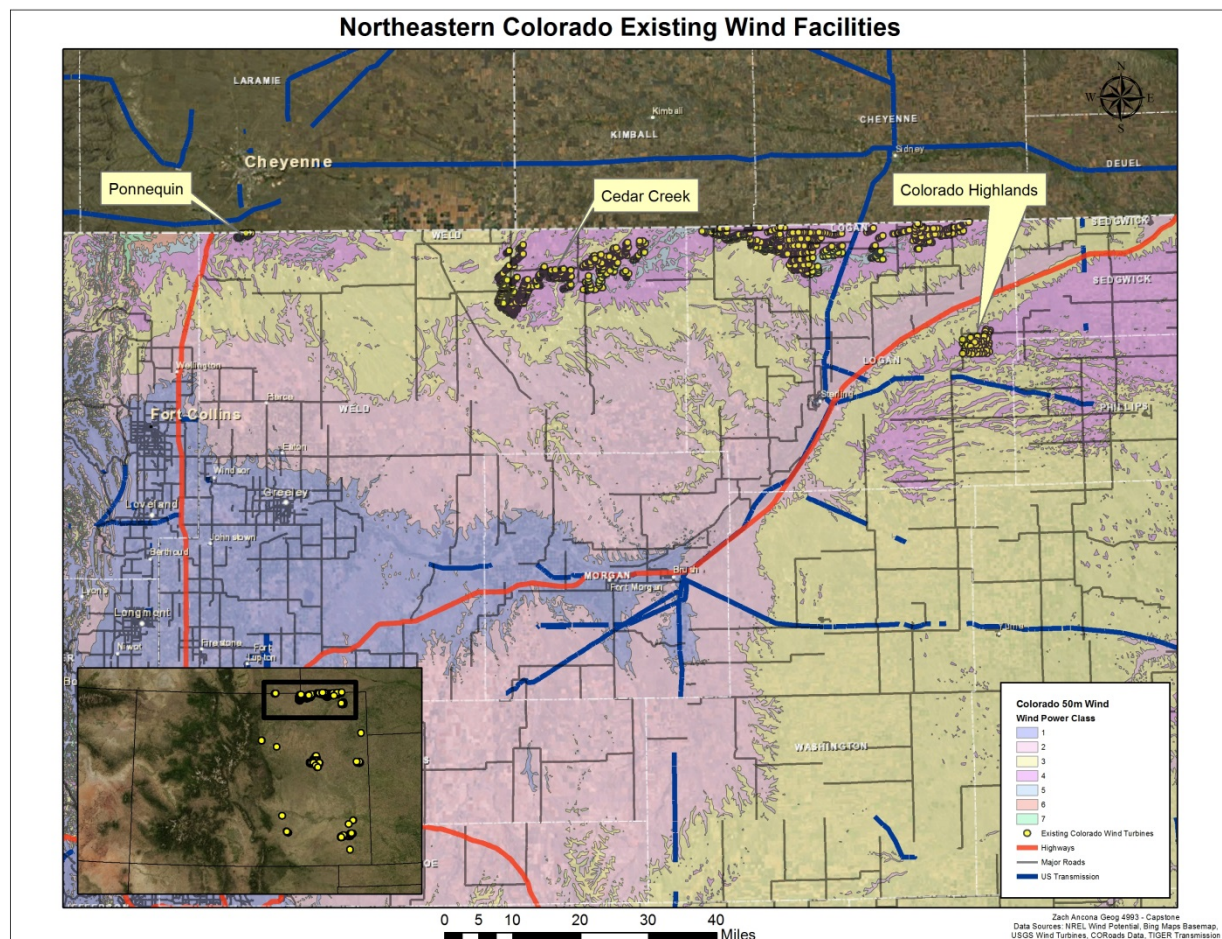
Arguably one of the largest barriers to wind development and coincidentally one of the most proprietary and hard to acquire datasets is portrayed in the map found on the following page which shows Colorado's high capacity transmission network. The western part of the state is a connected network of high capacity transmission lines to serves the various coal fired power plants and oil/natural gas refineries. On the other hand, the eastern half of the state lacks the transmission infrastructure to support a large influx of new wind facilities. The blue transmission lines in this map appear sectioned and incomplete due to the fact that they were merged together from hundreds of polyline sections downloaded from the TIGER/Line FTP website. Only certain high capacity transmission lines are able to be released at this scale due to proprietary datasets held mostly by Ventyx. Figure 3, shown earlier in the report, includes a more detailed picture of the transmission network in Colorado, but the Colorado Energy Division provides no accompanying shapefile for further examination.



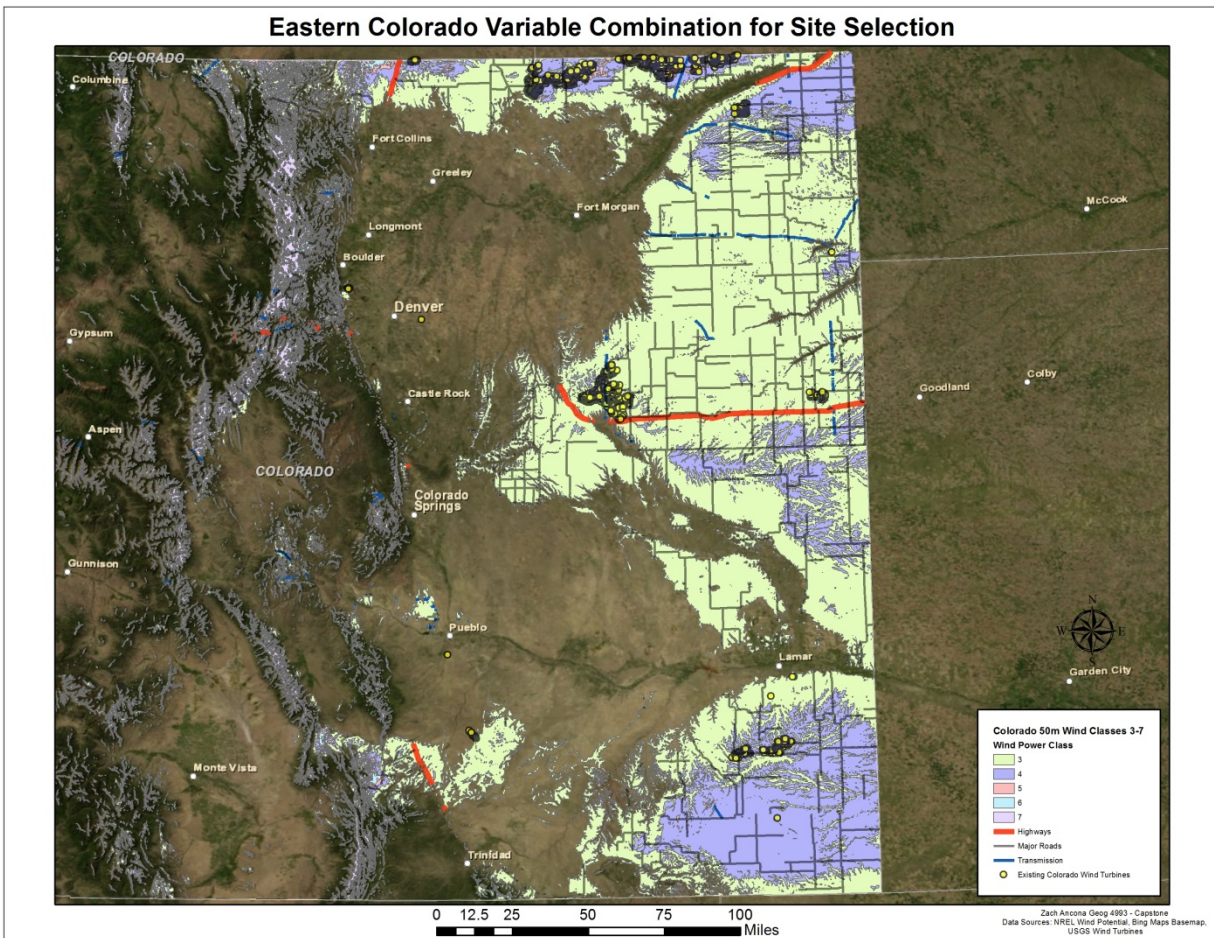
The map shown below focuses on northeastern Colorado's wind potential zones showcasing the proximity of the existing wind facilities to the most important variables for wind development being access to high capacity transmission lines, wind potential, and existing road infrastructure. One large area of turbines is left unnamed on the northern border in this map due to the turbines present being a conglomeration of 5 different smaller facilities. In this small area there are numerous other wind facility sites that could be potential areas for development after further research is done on the other variables examined throughout this report. This map



details how northeastern Colorado wind facilities took advantage of the close proximity to existing transmission lines, high wind potential and existing road infrastructure to reduce startup costs. This area differs from much of eastern Colorado solely on the access to reliable high capacity transmission lines for new wind facilities. The way power is distributed from energy facilities in Colorado makes it easier to transport to the west and north because of the regional splits in the national grid seen in Figure 2 earlier in the report.



The last map included in this series can be seen below and displays the variables of greatest importance to wind siting that were able to be acquired through various sources. The wind potential areas seen in the map below correspond with wind classes of 3 and above, which equate to sustained winds of 15mph or more. Areas that met these wind speeds were included on the map and from this point the road and transmission networks that intersected with these areas were clipped to show the areas with existing infrastructure. There are many more variables that go into the siting process, but are difficult to display visually at this scale without knowing the size of wind turbines and estimated capacities. Once a site is selected based on the wind potential, transmission availability and existing road infrastructure shown in the map below, the more site specific variables specific to county zoning regulations and setback laws can be examined. The areas within the wind potential zones in eastern Colorado severely lack the transmission infrastructure for an expansion of wind energy according to these overlays. The southeastern portion of Colorado in this map displays massive areas of wind potential with a sufficient road infrastructure to support wind development, but lacks the high capacity transmission lines to transport power to where it is needed.



Colorado's transmission network currently caters heavily to the coal, oil, and natural gas energy sources. The transmission network in eastern Colorado must be upgraded to be able to handle an influx of renewable wind facilities in areas not previously developed for energy production. The final map shown above helps to identify areas that are in need of new transmission infrastructure to allow for the expansion of renewable energies on private lands in eastern Colorado.

## Discussion and Recommendations

The previous approach and project solution sections encompass the overall purpose of this project. The identification of variables in the approach section can be used as a checklist for developers to be sure standards are met when looking to start the process of developing new wind facilities. Some of the variables identified in the approach section have spatial datasets created by state or federal organizations and are publicly available. These datasets have been included in the maps seen in the project solution section. The real setback to wind potential in eastern Colorado can start to be seen with the maps created in the previous sections, being the current transmission network. A large portion of this project's literature review was concerned with the transmission network around the United States and in Colorado. It requires huge upfront capital costs to start the process of wind development and most of the areas without a close proximity to transmission lines are removed from potential sites even though the wind potential and other important variables may line up perfectly. Proximity to transmission lines is not the only factor because many of the high capacity transmission lines have maximized the amount of energy they can hold from other energy sources. Even if a potential wind site is close enough to existing transmission lines, they may have no way to actually transport the electricity through those existing lines because the lines are at full capacity. This lack of publicly available information from the energy companies on

transmission loads and general line locations is a major barricade to wind development in eastern Colorado.

I believe the approach taken to identify variables and identify areas in eastern Colorado was partially successful. The lack of spatial data pertaining to wind siting guidelines severely degraded the value of using ArcMap to conduct a thorough examination of eastern Colorado for wind development. I feel that poor results often can speak volumes about the problems facing the wind industry to try and expedite the time it takes to develop new wind facilities. There are a number of other reports going through the siting requirements for wind facilities in Colorado which examine many of the same variables seen in the approach section for this report. This report differentiates and expands on previously completed siting guidelines by providing available spatial data along with general criteria necessary for successful wind facility development. In addition to siting guidelines this report also identifies the various incentives and monetary benefits from wind energy production for landowners and developers which can help educate the public on the benefits from wind and influence further development on private lands in eastern Colorado.

The barriers to acquire data along with general lack of transmission infrastructure are two of the main things I have learned from this research. This project initially began an idea to create a spatial database containing all necessary information pertaining to the siting of wind turbines. As the



project advanced, I quickly realized that the majority of the data needed to site wind facilities is based on specific local laws and zoning regulations that cannot be mapped on a large scale. This led to the creation of the approach section which highlights certain variables needed to be examined before development can begin on a new wind facility. The maps that ended up being created for this project should be used for reference only, because of the inconsistencies and quality of the acquired and referenced datasets. The road and transmission layers are updated infrequently and the 50 meter wind speed map is based off of wind speed estimates using statistical models of historic wind speed in a region. The massive amounts of privately owned lands in eastern Colorado make it difficult to produce accurate wildlife data for use in wind siting, though Environmental Impact Assessments and Statements are required by the state before construction can begin on a new facility site. Identifying the threatened species of birds in Colorado is a start to these documents, and can help to reduce time of the overall process to site development.

I believe this project contributes to the field of GIS and the wind industry by identifying problems with the public acquisition of necessary data to wind facility siting. If data pertaining to electric transmission loads along with planned installments of transmission lines was more publicly available, developers of wind facilities could start pre-construction research on other variables knowing that the systems to deliver power generated will be in

place. There is a dichotomy that exists in the wind industry to the power industry similar to the chicken and the egg analogy. Without reliable electric networks to renewable energy zones, developers and investors cannot start planning a new wind facility due to high startup costs with no reliable way to sell the power. While on the other hand transmission lines cannot be built without knowing the potential energy generation that will be available for a certain area. The type of research presented in this report can help to identify those large zones of wind potential where transmission lines are absent. Since much of the high capacity electric grid is regulated by federal agencies, there is little transparency to what will happen next in the energy sector. Recommendations for further research must include a detailed assessment of the transmission network and the current electric loads on the few transmission lines near wind potential zones. Colorado has started changing energy policies to encourage the generation of renewable energy in place of conventional fossil fuel sources and the majority of this energy potential will rest upon the views of private landowners to allow parts of their land to be developed for wind. Outlining the monetary benefits from lease payments and tax revenues would be a good start to influence landowners to allow for wind development on parts of their land. These monetary benefits along with private landowners being able to continue agricultural and grazing practices will be the key to tapping into this amazing wind resource on the eastern plains of Colorado.

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## Appendix A

General Framework for Minimizing Impacts of Wind Development on Wildlife in the Context  
of the Siting and Development of Wind Energy Projects

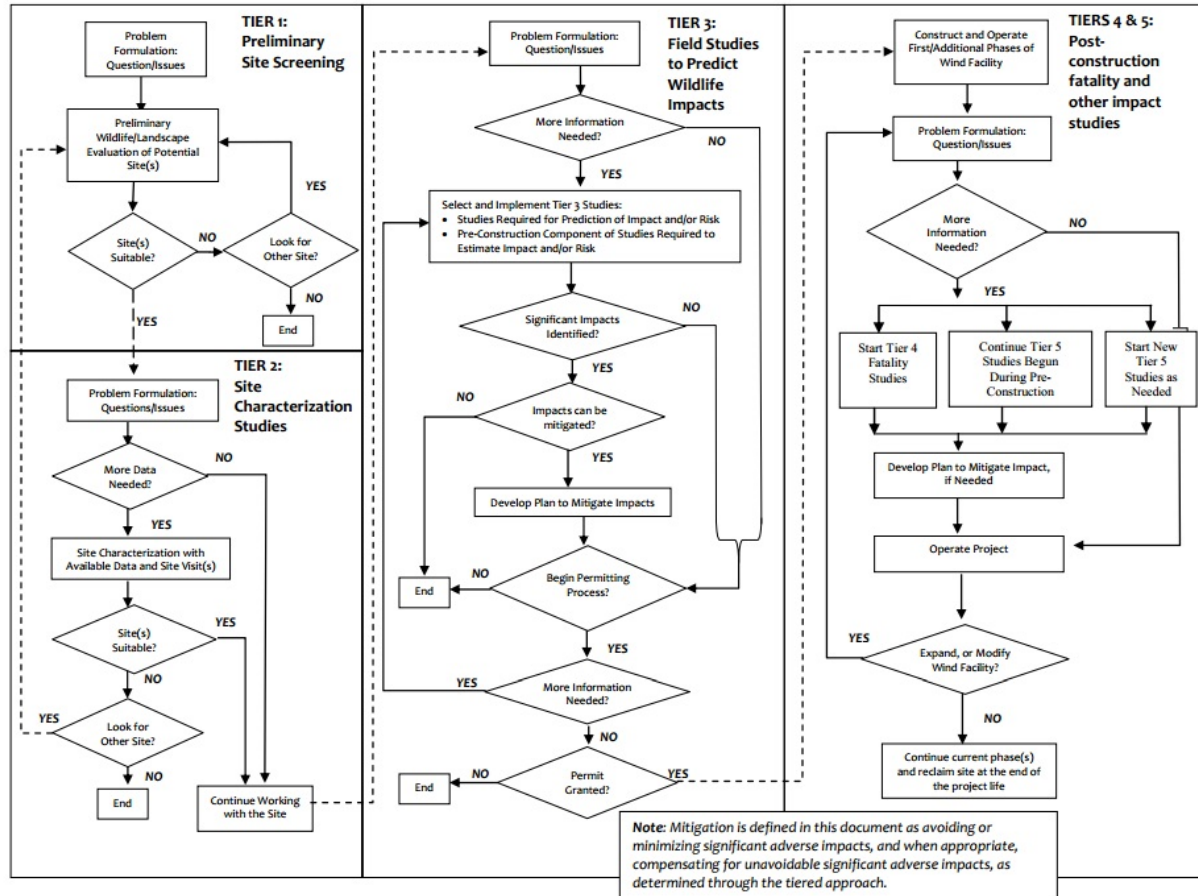


Figure 6: Tiered Approach to Wind Siting, USFWS 2011