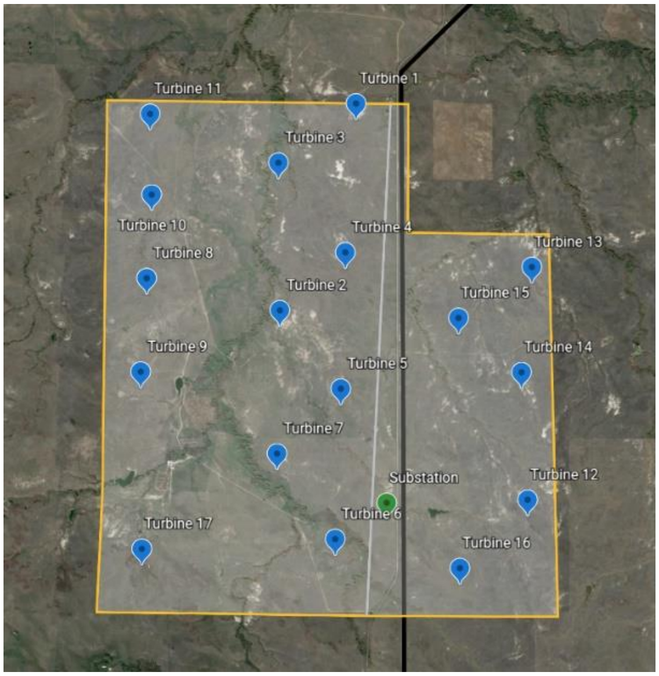
2021 Collegiate Wind Competition

Northern Arizona University:

Project Development - Perkins Windfarm Report



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COLLEGIATE WIND COMPETITION
U.S. DEPARTMENT OF ENERGY

Energy Club at NAU

Contents

1 Introduction/Site Description and Energy Estimation

The presented wind farm is in Perkins, South Dakota. This site is accessible through the 212 highway and Bixby Road. The site is next to two transmission lines, a 230 Kilovolt (kV) and a lower kV transmission line that the team will not be connecting to through the site's substation. The site location is owned by one landowner, that is not identified due to personal reasons, with approximately 5,457 acres. This relatively flat site is away from cities and airports with an IEC wind class rating of 1A with an average elevation of 843.7 meters(m), in the south western part of Perkins county. To determine sites with a high wind resource, the team used WINDExchange's 80-meter wind map [1]. The final and potential sites are shown in Figure 1, also included is the final iteration of wind turbine placement within the wind farm. To get to this final site, the team had 19 potential sites and factored in populated areas, terrain/vegetation, number of landowners, access to transmission lines, accessibility, available land, and being near protected areas/environmental factors. Table 1 is the team's decision matrix for determining the final site. Sites not included in this table were excluded due to low scoring.

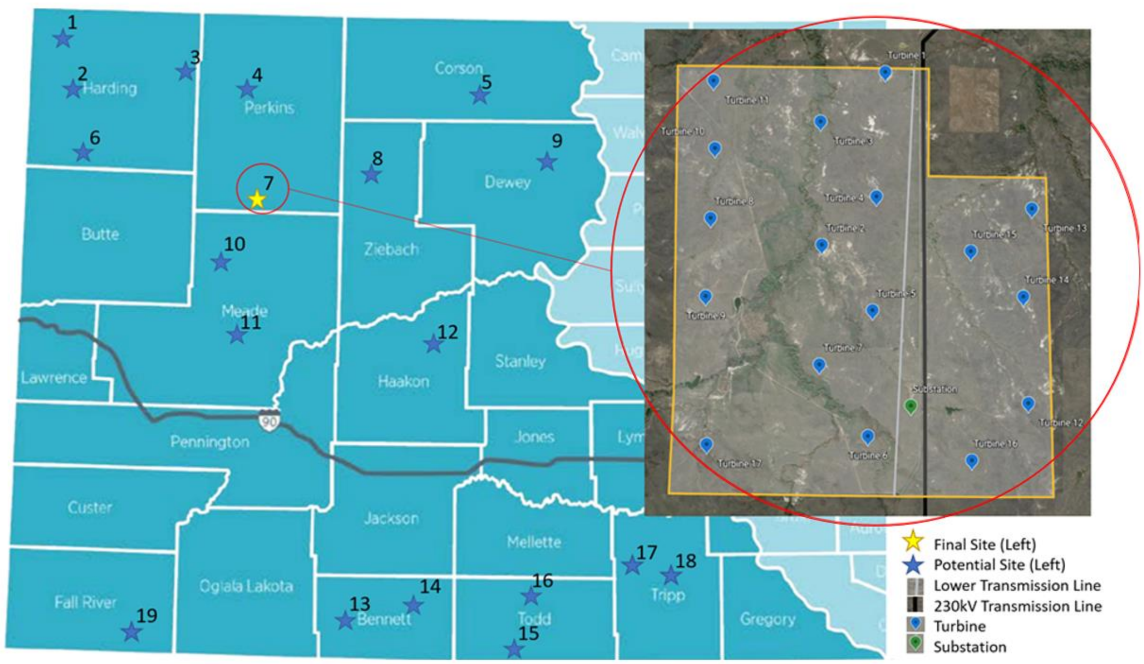


Figure 1 – Final Site Process

Table 1 - Site Decision Matrix

			Sites					
Criteria	Weight	Percentage	7	8	9	13	15	19
Land Available	5	0.17	5	3	3	2	4	4
Landowners	4	0.13	5	2	4	3	3	5
Access to Transmission Lines	5	0.17	5	4	5	3	1	1
Accessible	3	0.10	5	3	2	4	4	4
Vegetation/Terrain	3	0.10	4	3	3	3	3	3
Wind Resource	2	0.07	5	5	5	5	5	5

2 Preliminary Wind Farm

The team has decided to use the largest turbine that is available for the site, SG5.8-155. By choosing the biggest turbine the team would need less turbines, less turbine sites, lowered overall project costs, and a higher Annual Energy Production (AEP). By setting the array in a parallel circuit, a failed turbine is isolated from the system and would not affect the operation of nearby turbines. 0

Displayed in Table 2 is the Siemens Gamesa turbine data [2]. The team decided to use the SG 5.8-155 because it has a power output of 5.8MW. The team plans to use the SG5.0-132 if the SG5.8-155 is not produced at Siemens Gamesa manufacturing plant in Iowa. Siemens Gamesa turbines are being used due to the proximity of relevant factories along with these two turbines currently being circulated [3].

Table 2

SG 5.8-155	
Rated Power Output	5.8 MW
Rotor Diameter	155 m
Wind Class	IEC IA
Hub Height	102.5 m
Cut-in Speed	3 m/s
Cut-out Speed	25 m/s

The team plans to follow standards set by the Federal Aviation Administration (FAA) to have the turbines equipped with a system that not only alerts planes but also alerts the wind farm's system when a turbine is in potential contact with birds and other obstacles [4]. The turbines will also be equipped with a system that would completely stop the turbine when birds are near the site.

2.1 Site Characteristics

2.1.1 Land Characteristics

Figure 2 is a generated image of the final wind farm design elevation and roughness. The land elevation map was generated with the use of the United States Geological Survey's National Map viewer (USGS) [5], Quantum Geographic Information System (QGIS) [6], and Continuum [7]. The final site roughness was created through the same programs in tandem with USGS' Multi-Resolution Land Characteristics (MRLC) viewer [8]. These maps helped dictate the final site wind resource affects and terrain advantages. **Due to the constraints of Continuum, the team was not able to export any of the generated maps with a higher resolution.** The team was able to gather the wind resource data at 80 meter and 100 meters through the four wind measurement towers (MET) [9] to produce and analyze the power output of the wind farm. The location of the MET towers and turbine locations is also shown in Figure 2.

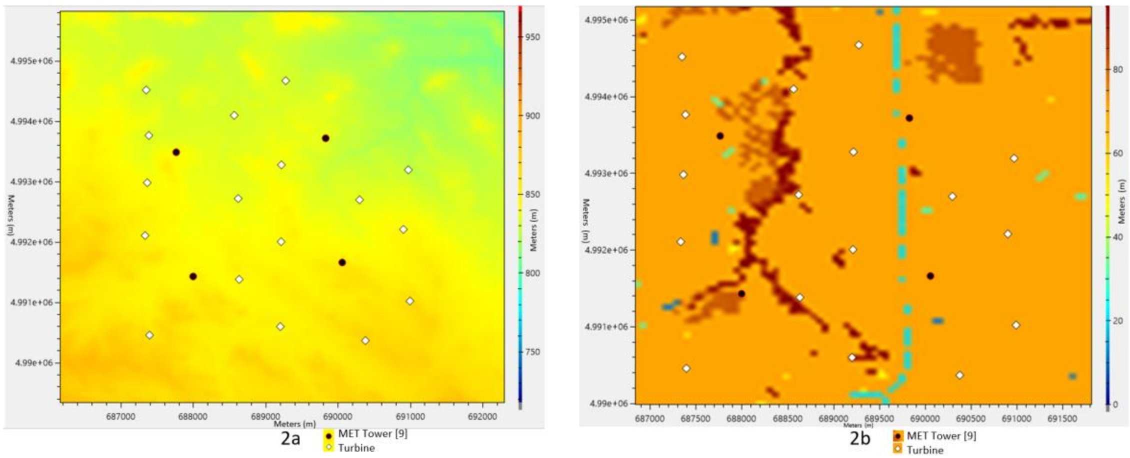


Figure 2 – (2a) Land Elevation (700-1000m), (2b) Land Roughness (0-90m)

Through this final array Continuum further analyzed the amount of shadow flicker hours, sound levels, and ice hits over an annual period throughout the wind farm as shown in Figure 3. These models were used to also help avoid the landowner and other surrounding buildings in the area while also abiding by Perkins County property rules. As per codified of laws 43-13-24, the turbines must be placed either 1.5 times the tower height or 500 feet away from property lines [10].

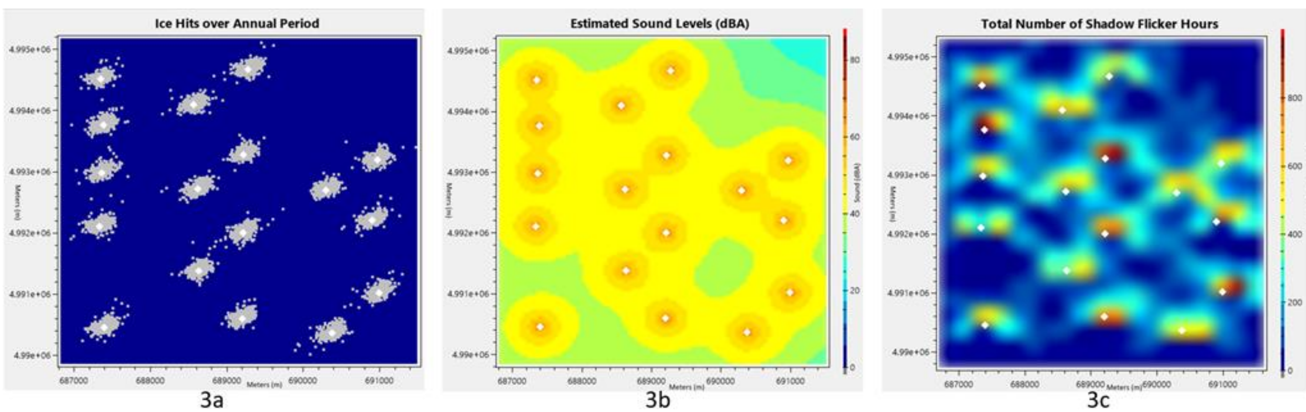


Figure 3 – (3a) Ice Hits over Annual Period, (3b) Estimated Sound Levels (0-90dBA), (3c) Total Number of Shadow Flicker Hours (0-900hrs)

The 17 turbines are spaced approximately 1.1 rotor diameters away from respective turbines. By using a staggering array that avoids the transmission lines, roads, on-site buildings, and city boarders, the team has optimized land usage and reduced wake losses. The next step of this process is to contact the landowner to get approval for the wind farm and to create a leasing contract.

2.1.2 Wind Resource

Through the MET data, the team generated Figure 4, a wind rose and a directional wind speed ratio at the MET sites. The team gathered this information from Wind Prospector [9] and determined the predominant wind direction of 290°-315° at the final site with average wind speeds of 8 m/s. With bankable wind conditions and by satisfying the decision matrix, this site is the most optimal.

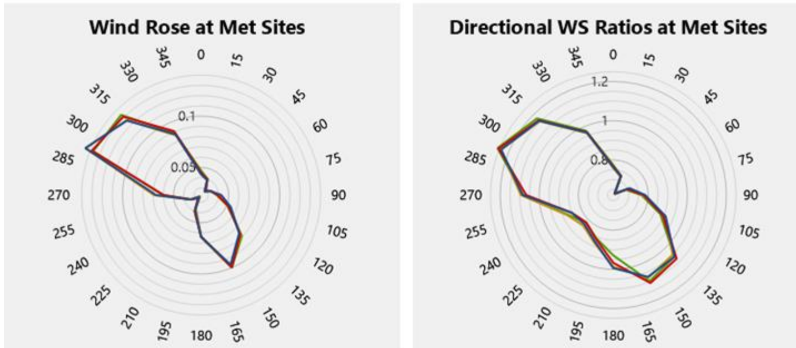


Figure 4

2.1.3 Wildlife

The known endangered species in Perkins, South Dakota is the Whooping Crane, Northern Long-eared Bat, and the Swift Fox [10]. Using Wind Prospector, the current site avoids the Whooping Crane migration and sightings of the Northern Long-eared Bat [9] as shown in Appendix A: Whooping Crane Migration and Appendix B: Northern Long-eared Bat Sighting. A site analysis would be performed to ensure that the project avoids the Whooping Crane migration while a wake permit will be filed with the Fish, Parks, and Game department for the Northern Long-eared Bat and the Swift Fox [11]. By having an environmental analysist, the land will be surveyed for wildlife habitats and potential archeological sites. When the wind farm hits oncoming birds, this will be documented and sent to the U.S. Fish and Wildlife Administration. Through the yearly impacts report, the U.S. Fish and Wildlife Administration would determine if the wind farm had high fatalities and if the wind farm needs to be shut down. The team plans to preserve the local species and will abide by the *Endangered and Threatened Wildlife and Plants: Regulations for Listing Endangered and Threatened Species and Designating Critical Habitat* standard along with the Fish and Wildlife Conservation Act of 1980 [12, 13].

Although not stated in the county website, nearby bald eagle sightings were confirmed through Wind Prospector [9], Appendix C: Bald Eagle Sightings. In accordance with the Migratory Bird Treaty Act (MBTA), there are four international treaties that give worldwide protection of migratory birds. Violation of the MBTA would result in a criminal penalty for anyone without proper wake permits [14]. Violations include the pursuing, hunting, taking, capturing, killing, possessing, offering for sale, selling, purchasing, shipping, exporting, importing, transporting, or cause the transportation, of any migratory bird, nest, or eggs without the proper permits and needed communication to the Department of the Interior 16 U.S.C. 703 [14, 15]. This would not only apply to the Bald Eagle but also the Whooping Crane. This current wind energy guideline expires on November 30, 2021. The team expects the current guideline to be updated in the near future and will comply with the new/updated guidelines. Although the team did not find any sensitive plant species, the construction and deconstruction of the windfarm will affect the landowner’s property and will avoid the sensitive parts of the area.

2.2 Permitting/Ordinances

Perkins County does not have specific ordinances/permits and according to South Dakota Wind Power Projects Guidelines [16] the main decision is up to the county and landowners. The state does warn to not take advantage of the counties and landowners due to the absence of wind farm technology. Once the team contacts, Rownea Gerbracht, director of equalization, the team would work with Rownea Gerbracht for specific county zoning instructions [17, 18]. The team also plans on notifying the executive director of the public utilities commission four months prior to construction. This notification will be for informational purposes only and will include planned location, number of wind turbines, nameplate capacity, planned method of interconnection, and the estimated construction start and end date [17].

During this process, the team would also present the generated sound, shadow flicker and ice throw models to both the landowner and the county to prove that the wind farm would not be negatively affecting the community. If the project were to be approved, the team plans to have county meetings to answer the community's concerns including subsidies for renewable energy, property values, wind resource not having a huge net capacity factor, and wind not being a reliable resource [19]. Internationally, community outreach has been a major factor in community approval of the projects and in some cases securing local funding[20].

By going through the FAA, the team will submit the turbine layout of the site to be evaluated for the relevant guideline: obstruction of lighting [21]. Along with the turbine array, the team will submit a Notice of Proposed Construction or Alteration through the FAA [13]. By submitting these forms, the team would guarantee that the turbines do not interfere with flight patterns and city lighting. The team also plans to have the turbines be white or light gray to reduce visual impact [13, 4]. Along with the FAA approval, the team will gain the county's approval by submitting a permit for the construction of the wind farm.

3 Financial Analysis

3.1 Initial Capital Cost

After performing a cost analysis with the final layout through NREL's System Advisor Model (SAM), the team inputted a Power Purchase Agreement (PPA) price of 0.072 $/kWh and generated a Levelized Cost of Energy (LCOE) of 0.0571 $/kWh as shown in Table 3. With these generated values, the project will generate money for the developer after 18 years. The LCOE is lower than coal's LCOE (0.09 $/kWh) [22].

Table 3

SAM Outputs	
Metric	Value
Annual Energy Output	292,183,520 kWh
Capacity Factor	29.70%
Levelized Cost of Energy (real)	0.0571$/kWh
PPA Price (Year 1)	0.072$/kWh
Levelized PPA Price (real)	0.0571$/kWh
Investor NPV Over Project Life	$6,981,328
Developer NPV Over Project Life	$8,114,202
Net Capital Cost	$169,736,176
Equity	$71,226,824
Debt	$98 509,360

Using SAM, the plant's project capital cost is expected to be around $169 million. This includes the construction of the wind farm, turbine erection, and the creation of roads.

An acceptable safe substation with a voltage class of 230kV would cost around $1,648,000 to transform and transport the energy to Western Area Power Administration(WAPA), now owned by Southwest Power Pool (SPP) customers [23]. For financial reasons, the team has decided to build an onsite substation instead of attempting to connect to nearby substations.

To help persuade the landowner, the team plans to use the property tax incentive for landowners to build renewable energy over 5MW [24]. Due to the team using parts of the land instead of the whole area, the team decided to utilize the lease incentive instead of the easement incentive. The team would not be leasing all the 5,457 acres but will abide by the county's property tax. The team would also create a contract with the landowner for lease payments during the construction of the wind farm. The team will abide by the

South Dakota Register of Deeds' Fees and file the needed county permits for the construction of the wind farm [25]. The next step is to factor in sales, use, renewable energy, and production tax.

New access roads are usually 15 feet wide, and with $25/foot, the total cost for the roads can be $35,000 or more [26]. Due to the final site having preexisting access roads, the team predicts that the upkeep of the roads would be a little higher than $35,000 but would not have to worry about full construction of a new road. To create the foundation of the wind farm, it costs from $100,00-$150,000/MW [26]. The team understands that there are different factors that can greatly influence the cost of setting up the wind farm and can easily make the price increase due to the turbine costs. If the SG5.8-155 requires a pad mount transformer to the base along with underground wiring to the substation and installation, the construction can range from $40,000-$200,00 [26]. Although the cost of the turbine is not specifically stated on the Siemens Gamesa website [2], the team decided to use the default in SAM of $1000 due to wind technology becoming more cost effective. The next step of this process is to obtain shipping fees from Siemens Gamesa. Another future step is to explore Emerson due to their background in wind energy control monitoring equipment and wind energy management [27]. The team will be going through the SPP for the transmission line system and will go through the process to get approved as shown in Appendix D: Interconnection Study Process [28].

During construction, the operation and maintenance (O&M) facilities and equipment would need to be rented and insured. The next step of this process is to reach out to local South Dakota construction facilities and a surveying company to assess the resources and survey the land for potential endangered species and/or protected environments. The project management would also be handed over to another company in future steps.

3.2 Annual Operating Expenses

Using SAM, the team generated an expense chart to display the O&M capacity-based expense, insurance expense and the total operating expenditures, Table 4.

Table 4

Operation and Maintenance Expenses			
Metric	Year 1	Year 10	End of Project Year 20
O&M Capacity-Based Expense ($)	4,712,400	5,885,142	7,533,479
Insurance Expense ($)	757,350	945,826	1,210,738
Total Operating Expenses ($)	14,763,883	15,298,258	8,744,217

By using Siemens Gamesa maintenance plan [29], the turbines would be insured for the beginning of the project life. After the maintenance plan is over, the team would keep in contact with Siemens Gamesa for opportunities to recycle and replace turbine parts as needed. Turbine technicians are needed for the entirety of the wind farm's project life. The next step in this process is to hire turbine technicians in South Dakota and to pay the average wage of $59,880/year [30].

3.3 Net Annual Energy Production

Table 5 depicts the process the team underwent to optimize the annual energy production and capacity factor while also displaying the changes that were made from the previous iterations. The AEP was produced using the Eddy Viscosity Deep Array Wake Loss model in Continuum. The team plans to have two to three extra turbine sites to serve as backups that can be implemented if other sites are denied by the FAA.

Table 5

Iteration	AEP [GWh]	Number of Turbines	Capacity Factor	Installed Capacity (MW)	Changes from previous Iteration
1	559.99	28	39.34%	162.4	
2	560.71	28	39.39%	162.4	Turbine 5, 15, 18 experienced the most wake
3	561.51	28	39.44%	162.4	Turbine 5, 8, 18 experienced the most wake
4	558.51	28	39.23%	162.4	Turbine 5, 8, 18 experienced the most wake
5	354.08	17	40.97%	98.6	Too many turbines being used. Team had to redesign the whole array
6	354.85	17	41.06%	98.6	Team had to analyze the overall losses in comparison to the predominant wind direction
7	354.79	17	41.05%	98.6	Turbine 4, 5, 2, 16, 7 experienced the most wake
8	343.03	17	39.69%	98.6	Turbine 4, 5, 2, 16, 7 experienced the most wake
9	367.954	17	42.57%	98.6	Turbine 4, 5, 2 were moved due to greatly affecting other turbines

Through this final array, the wind farm has an overall wake loss of 8.89%. Since the team produces less than 100MW a year, the team does not have to notify WAPA/SPP about the wind farm energy production. Through WAPA/SPP, the team would also be integrated into the system and would go through three stages as shown in Appendix D: Interconnection Study Process [28]. By being integrated into the system, the team can then sell the produced energy to WAPA/SPP customers.

3.4 Market Conditions

Table 6 are the values that the team entered in SAM and performed an Eddy Viscosity Wake Loss model simulation.

Table 6

SAM Inputs	
Metric	Value
Target Year	20
Production Tax Credit (PTC)	0.018$/kWh
PPA price	0.072$/kWh
Rated output	6600kW
Tip-speed ratio	7

Through these different inputs, the team generated a flip year that occurs 18 years after beginning of operation with a LCOE of 0.00571$/kWh. Through SAM, the team generated a Partner After-tax Cash Flows graph to understand the cost and revenue throughout the project's lifetime (Figure 5).

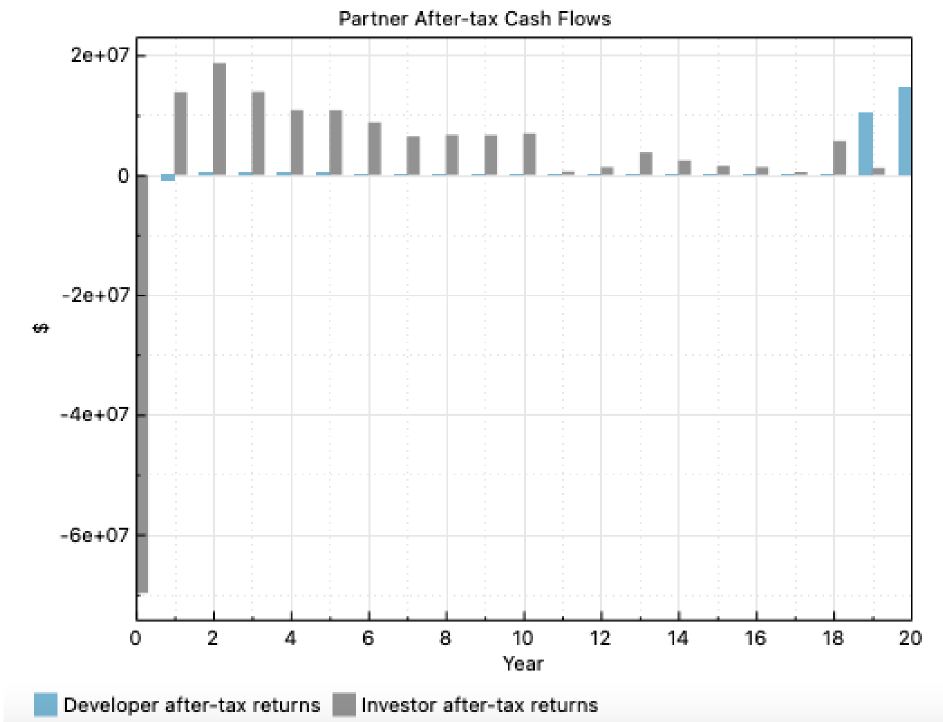


Figure 5

3.4.1 Wind Energy Technology

Lawrence Berkeley National Laboratory states that in 2018 [31]:

- South Dakota had a 23.9% wind energy generation in terms of total energy production
- SPP planned to install a higher amount of wind power capacity
- More projects are using the same type of turbine with different rotor diameters
- South Dakota has a capacity factor around 40%
- LCOE nationwide average is $38/MWh

Lawrence Berkley National Laboratory also states that within 2020 [32]:

- 100MW wind farm are around $1500/kW for construction
- Average O&M cost per unit of capacity ranges from $30-$20/kW-yr.
- LCOE has dropped to around $43/kW-yr. for a 20-year life wind farm
- Current trends show the levelized wind PPA price has decreased and is predicted to have a lower PPA price in comparison to gas

With the usage of this data, the team understands that wind technology is developing, and turbines have recently started having varying hub heights. The team is also aware that NREL is currently working on other new technologies to reduce wake losses within turbines by yawing slightly out of the wind [33].

According to the 2018 Wind Market Report, large-scale turbines' PPA after incentives is 0.05$/kWh with a capacity factor of nearly 40% [34]. The team's current LCOE is 0.0571$/kWh and is within range of the 2018 Distributed Wind Market Report. Along with the wind farm having a higher capacity factor, the team predicts that the LCOE could possibly be lower than predicted. With a debt-to-equity ratio of 1.38, having a flip year of 18 years, and with a LCOE having the same value as the PPA, the team has determined that this project is economically viable. With these values, the team would go to banks and seek out a loan or investors to start the construction of this project.

3.5 Financing Plan

Other fees include building the substation, transportation of the wind turbines, land rental, decommissioning, property tax, renewable energy tax, and production tax. Some taxes for the wind farm would also be taken care of in a negotiated contract with the landowner [35]. The team would also file taxes for the wind farm with production, sales, income, and property tax. There are no current tax exemptions for energy production in Perkins, South Dakota. Therefore, the team would have to rent out and insure the construction equipment along with its services during the wind farm construction. Through SAM, the team was also able to oversee the overall wind farm investing activities as shown in Table 7.

Table 7

Investing Activities	
Total Installed Cost ($)	151,470,000
Equity Closing Cost ($)	300,000
Development Fee ($)	4,544,000
Debt closing Cost ($)	450,000
Debt Up-Front Fee ($)	2,709,007
Total Construction Financing cost ($)	3,029,400
Purchase of Property ($)	162,502,512

3.6 Incentives

Some incentives that the team will take advantage of is the Renewable Electricity Production Tax Credit (PTC) which would give the team a $0.021/kWh for 10 years and have an escalation of 2%/year [36] or the Business Energy Investment Tax Credit (ITC) which gives 26% tax incentive for small wind farms [37]. The team is planning to go with the PTC due to having a higher capacity factor for the small-scale wind farm. Depending on how the wind farm operates within the first 10 years, the team would either renew the PTC or sign up for the ITC. The team researched incentives provided by South Dakota on the state website and did not find an in-usage incentive [38].

4 Risk Management Plan

Table 8 displays the Exceedance values that were created with Continuum using the Monte Carlo Model through the Eddy Viscosity Deep Array Model calculation.

Table 8

P Value	1yr AEP	10yr AEP	20yr AEP
P90	328.18 GWh	355.89GWh	359.75GWh
P99	277.64 GWh	323.68GWh	329.46GWh

Potential environmental risks include tornadoes, earthquakes, winter storms, and natural fires. The team is unable to control the environment but would take precautions by installing the cables underground to not only be protected from these disasters but to also reduce the visual impacts. The cabling will be marked to help determine where the cable is located and to make the process of fixing the cables easier. Due to the state being prone to fires, the team plans to mitigate this by having a watch tower installed, providing enough water to keep the land moist and clearing debris around the turbines and buildings on site with the permission of the landowner. To help mitigate these risks, the team would set aside a budget to overcome some of the financial parameters. Turbine failures will also be monitored through the wind farm system and an installed watch tower on the wind farm.

The turbines would have to travel through one state to reach the site location. Due to the roads not being paved, the team plans to have 15 feet access roads to mitigate delivery issues [26]. Due to the elevation changes from Iowa to South Dakota, the team plans to order the turbine parts ahead of time to give Siemens Gamesa more time to deliver the parts to the wind farm site.

Along with environmental risks, the team would also need to consider performance risks, project development risks, construction risk, and regulatory risks. Since the PTC is solely based on the amount of power produced, the power plant would need to produce the same amount of energy throughout its lifespan and if the power plant does not produce the anticipated amount of energy, then the team would need to switch to the ITC [36]. Other risks include the project not reaching commercial operations, developers choosing to construct a different project, having site control difficulties, no access to transmission lines, poor wind resources, and an unfavorable market [39]. Other construction risks include impacts on generating revenue. To mitigate this, the team would have guarantees, extra funds, and punitive payments [39]. The regulatory risks would include tax incentives and contracts expiring during the wind farm's operation. With regulatory schemes being subject to change, the team would have to adjust to the new regulations.

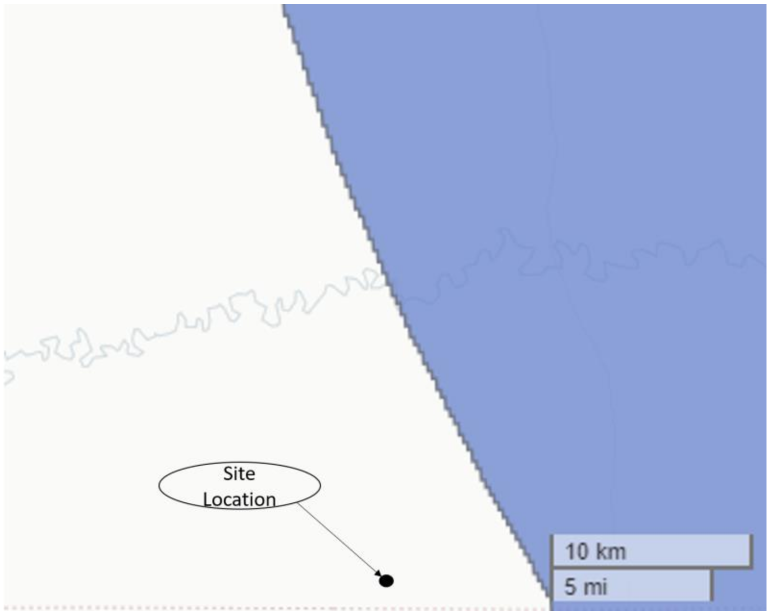
Due to COVID-19, multiple wind farms have been experiencing problems including not being able to obtain turbine parts, implementing COVID-19 safety regulations, and securing money/capital for the wind farm. With supply chains being forced to shut down factories, project developers would have orders be deferred/cancelled [40, 22]. World Health Organization Regulation and Safety work would limit the amount of people who can work on site [41]. Developers also have had problems securing money for project development due to COVID-19 [42]. To mitigate some of these issues, the team would need to have strong management throughout the wind farm operations.

5 Conclusion

The 2021 team has created a viable wind project that is located in the south western part of Perkins, South Dakota that is accessible, not near existing wind farms/under development, has a high wind resource, level terrain, one land owner, accessibility to transmission line and environmentally friendly. The team also went through the process of researching site characteristics, permitting, ordinances, sensitive species, impacts on wildlife, capital costs, current market conditions, and creating a financing plan. The team has also developed a risk management plan that also considers COVID-19 delays.

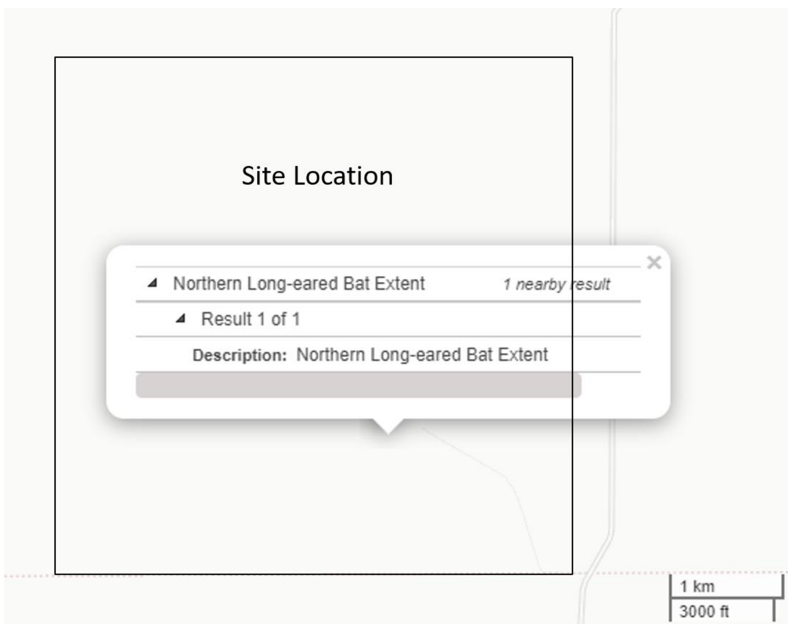
Appendix A: Whooping Crane Migration

Displayed in Appendix A is a map of the Whooping Crane migration path [9] with respective to site location.



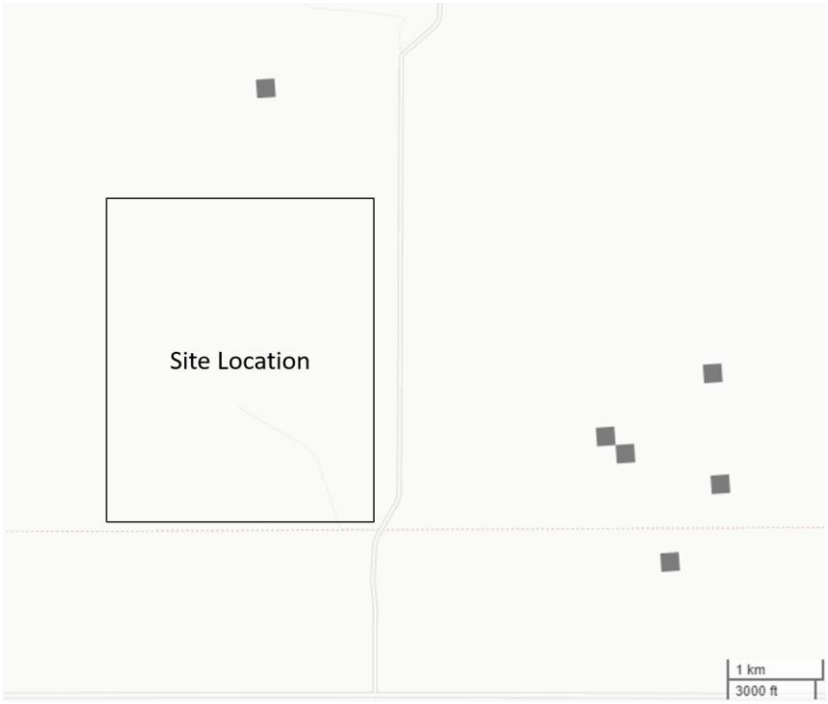
Appendix B: Northern Long-eared Bat Sighting

Displayed in Appendix B is a map of the Northern Long-eared bat sighting [9] with respect to the wind farm. Due to not finding the specific location of the Northern Long-eared bat, a perspective map was taken.

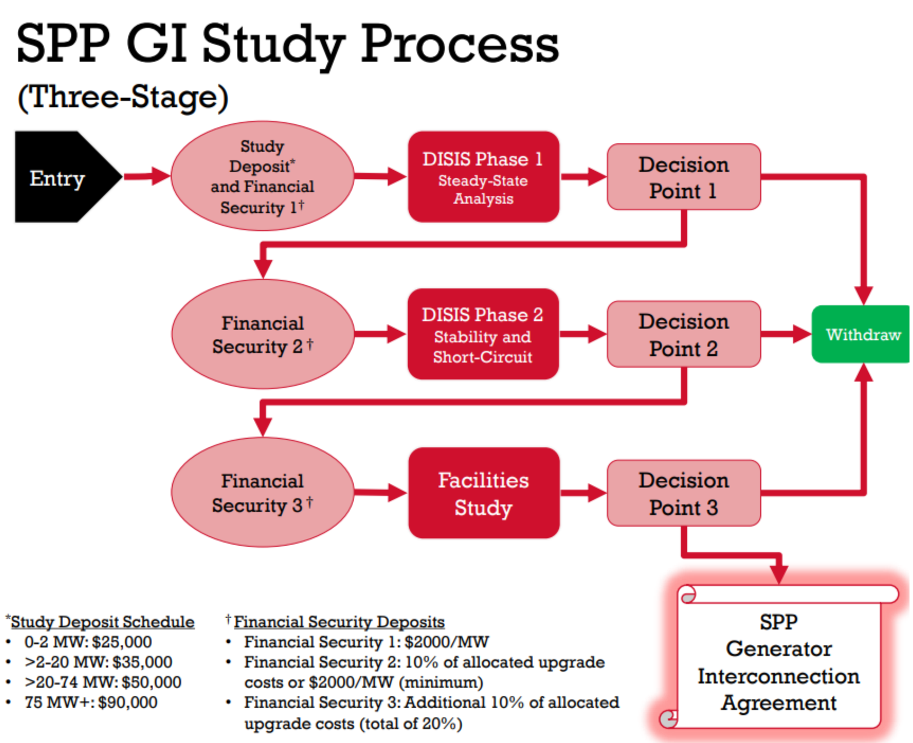


Appendix C: Bald Eagle Sightings

Appendix C is a map of the Bald Eagle sightings [9] with respect to the site location.



Appendix D: Interconnection Study Process



6 References

[1] Office of Energy Efficiency & Renewable Energy: WindExchange, "WINDExchange: South Dakota 80-Meter Wind Resource Map," 2020. [Online]. Available: https://windexchange.energy.gov/maps-data/116. [Accessed August 2020].

[2] Siemens Gamesa, "Siemens Gamesa Onshore Wind," 2021. [Online]. Available: https://www.siemensgamesa.com/-/media/siemensgamesa/downloads/en/products-and-services/onshore/brochures/siemens-gamesa-onshore-wind-sg-5-x-platform-en.pdf. [Accessed 2021].

[3] Siemens Gamesa Renewable Energy, "Siemens Gamesa Renewable Energy Location Finder," Siemens Gamesa, 2021. [Online]. Available: https://www.siemensgamesa.com/about-us/location-finder. [Accessed 2020-2021].

[4] Federal Aviation Administration, "Obstruction Evaluation/Airport Airspace Analysis," Federal Aviation Administration, 02 March 2021. [Online]. Available: https://oeaaa.faa.gov/oeaaa/external/portal.jsp. [Accessed 2020-2021].

[5] USGS, "USGS Science for a Changing World," United State Geological Survey, 2020. [Online]. Available: https://apps.nationalmap.gov/downloader/#/. [Accessed 2020-2021].

[6] QGIS, "QGIS: A Free and Open Source Georgraphic Information System," QGIS, 2020. [Online]. Available: qgis.org. [Accessed 2020-2021].

[7] L. Walls, "Continuum Wind Energy Software," Continuum, 2020. [Online]. Available: https://www.continuumwind.com/about. [Accessed 2020-2021].

[8] QGIS MRLC, "MRLC: Multi-Resoluation Land Characteristics Consortium," QGIS MRLC, 2021. [Online]. Available: https://www.mrlc.gov/viewer/. [Accessed 2020-2021].

[9] NREL, "NREL Wind Prospector," NREL, 2016. [Online]. Available: https://maps.nrel.gov/wind-prospector/?aL=MlB4Hk%255Bv%255D%3Dt%26VMGtY3%255Bv%255D%3Dt%26VMGtY3%255Bd%255D%3D1&bL=clight&cE=0&lR=0&mC=40.212440718286466%2C-74.619140625&zL=4. [Accessed 2020-2021].

[10] South Dakota Government, "State and Federally Listed Threatened, Endangered and Candidate Species Documented in South Dakota by County," 19 July 2016. [Online]. Available: https://gfp.sd.gov/userdocs/docs/ThreatenedCountyList.pdf. [Accessed 2021].

[11] South Dakota Game, Fish & Parks, "Hunting and Fishing Licenses," 2021. [Online]. Available: http://gfp.sd.gov/hunt-fish-license/. [Accessed 2021].

[12] Fish and Wildlife Service and the National Oceanic and Atmospheric Administration, "Endangered and Threatened Wildlife and Plants; Regulations for listing Endangered and Threatened Species and Designating Critical Habitat," 16 December 2020. [Online]. Available: https://www.federalregister.gov/documents/2020/12/16/2020-27693/endangered-and-threatened-wildlife-and-plants-regulations-for-listing-endangered-and-threatened.

[13] Federal Aviation Administration, "Notice of Proposed Cosntruction or Alteration," 25 September 2020. [Online]. Available: https://www.faa.gov/documentLibrary/media/Form/FAA_Form_7460-1_042023.pdf. [Accessed 2021].

[14] U.S. Fish & Wildlife Service, "U.S. Fish and Wildlife Service Land-Based wind Energy Guidelines," 23 March 2012. [Online]. Available: https://www.fws.gov/ecological-services/es-library/pdfs/WEG_final.pdf. [Accessed 2021].

[15] Fish and Wildlife Service, "Removing Regulations Implementing the Fish and Wildlife Conservation Act," 20 August 2010. [Online]. Available: https://www.federalregister.gov/documents/2010/08/20/2010-20634/removing-regulations-

implementing-the-fish-and-wildlife-conservation-act#:~:text=The%20regulations%20at%20part%2083,programs%20to%20benefit%20nongame%20species. [Accessed 2021].

[16] South Dakota Government, "Siting Guidelines for Wind Power Projects in South Dakota," 2021. [Online]. Available: https://gfp.sd.gov/userdocs/docs/wind-energy-guidelines.pdf. [Accessed 2021].

[17] South Dakota Legislature Legislative Reserach Council, "Codified Laws 49-41B-25.1," 2021. [Online]. Available: https://sdlegislature.gov/Statutes/Codified_Laws/2070995. [Accessed 2021].

[18] Perkins County, "Govoffice," 2021. [Online]. Available: https://denr.sd.gov/des/gw/Sourcewater/countycontacts/Perkins.pdf. [Accessed 2021].

[19] W. Abbassi, Interviewee, *Project Manager*. [Interview]. 2021.

[20] B. Conner, "Wind Energy Prospects in Japan," Flagstaff, 2020.

[21] U.S. Department of Transportation: Federal Aviataion Administraction, "Advisory Circular: Obstruction Marking and Lighting," 16 November 2020. [Online]. Available: www.faa.gov/documentLibrary/media/Advisory_Circular/Advisory_Circular_70_7460_1M.pdf. [Accessed 2021].

[22] IEA, "Covid-19 and the resilience of renewables," 2020. [Online]. Available: https://www.iea.org/reports/renewables-2020/covid-19-and-the-resilience-of-renewables. [Accessed 2021].

[23] T. C. D. W. Tim Mason, "Captial Costs for Transmission and Substations: Recommendations for WECC Transmissino Expanision Planning," October 2012. [Online]. Available: https://www.wecc.org/reliability/1210_bv_wecc_transcostreport_final.pdf. [Accessed 2021].

[24] DSIRE: NC Clean Energy Technology Center, "Program," March 2021. [Online]. Available: https://programs.dsireusa.org/system/program/detail/2879/large-commercial-wind-and-solar-alternative-taxes. [Accessed 2021].

[25] Perkins County, SD, "Register of Deeds," 2020. [Online]. Available: https://www.perkinscounty.org/register-of-deeds. [Accessed 2021].

[26] L. Daniels, "Windustry: Chaper 8: Costs," 5 December 2007. [Online]. Available: https://www.windustry.org/community_wind_toolbox_8_costs. [Accessed 2021].

[27] Ovation, "SCADA for Wind Energy Management," 2020. [Online]. Available: https://www.emerson.com/documents/automation/wind-farm-scada-using-ovation-technology-en-67436.pdf. [Accessed 2021].

[28] Southwest Power Pool, "Three-Stage GI Study Process Overview," March 2019. [Online]. [Accessed 2021].

[29] Siemens Gamesa Renewable Energy Group of Companies, "General Pruchasing Conditions," June 2018. [Online]. Available: https://www.siemensgamesa.com/en-int/-/media/siemensgamesa/downloads/en/sustainability/purchase-conditions/siemens-gamesa-general-purchasing-conditions-us-gpc-003-2018-06-en.pdf?la=en-bz&hash=A33FF4AA231E73304696C5930DD25464F4A08A38. [Accessed 2021].

[30] Sokanu, "Wind Turbine Services Technician Salary in South Dakota," 2021. [Online]. Available: https://www.careerexplorer.com/careers/wind-turbine-services-technician/salary/south-dakota/#:~:text=Wages%20typically%20start%20from%20%2443%2C440%20and%20go%20up%20to%20%2477%2C140. [Accessed 2020].

[31] Lawrence Berkley National Laboratory, "2018 Wund Technologies Market Report Summary," 6 August 2019. [Online]. Available: https://www.energy.gov/eere/wind/downloads/2018-wind-technologies-market-report. [Accessed 2020-2021].

[32] M. B. B. H. D. M. J. R. G. B. N. D. W. G. S. J. A. M. B. P. Ryan Wiser, "Wind Energy Technology Data Update: 2020 Edition," August 2020. [Online]. Available:

https://emp.lbl.gov/sites/default/files/2020_wind_energy_technology_data_update.pdf. [Accessed 2020-2021].

[33] M. Sinner, Interviewee, *Reseracher at NREL.* [Interview]. 2021.

[34] U.S. Department of Energy: Office of Energy Efficiency & Renewable Energy, "2018 Distributed Wind Market Report," U.S. Department of Energy, 2018.

[35] Tax-Rates, "Perkins County Assessor," 2020. [Online]. Available: http://www.tax-rates.org/south_dakota/property-tax/perkins-county-assessor. [Accessed 2021].

[36] R. W. K. C. T. J. Mark Bolinger, "PTC, ITC, or Cash Grant?," NREL, 2009.

[37] DSIRE NC Clean Energy Technology Center, "Business Energy Investment Tax Credit (ITC)," 24 February 2021. [Online]. Available: https://programs.dsireusa.org/system/program/detail/658. [Accessed 2021].

[38] South Dakota Public Utilites Commission, "Energy Efficiency Tax Incentives," 30 May 2014. [Online]. Available: https://puc.sd.gov/energyefficiency/#:~:text=South%20Dakota%20state%20law%20SDCL,are%20considered%20renewable%20resource%20systems. [Accessed 2021].

[39] D. F. J. F. E. S. Paul Schwabe, "Wind Energy Finance in the United States: Current Practice and Opportunities," NREL, 2017.

[40] Y. Rack, "Wind-Turbine makers wobble under COVID-19 impacts," S&P Global Market Intelligence, 14 August 2020. [Online]. Available: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/wind-turbine-makers-wobble-under-covid-19-impacts-59913851. [Accessed 2021].

[41] World Health Organization, "Coronavirus idseas (COVID-19) advice for the public," May 2021. [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public. [Accessed 2021].

[42] D. Proctor, "Wind Energy Group Says $43 Billion at Risk from COVID-19," POWER, 19 March 2020. [Online]. Available: https://www.powermag.com/wind-energy-group-says-43-billion-at-risk-from-covid-19/. [Accessed 2021].

[43] Fish and Wildlife Service and the National Oceanic and Atmospheric Administration, "Endangered and Threatedned Wildlife and Plants; Regulations for Listing Endangered and Threatened Species and Designating Cricital Habitat," 16 December 2020. [Online]. Available: https://www.federalregister.gov/documents/2020/12/16/2020-27693/endangered-and-threatened-wildlife-and-plants-regulations-for-listing-endangered-and-threatened. [Accessed 2021].

[44] Independent Staistics & Analysis U.S. Energy Information Administration, "Levelized Costs of New Generation Resources in teh Annual Energy Outlook 2021," eia, 2021.