

Project Development Report

Cherry Creek Wind Farm
by Shenandoah Sustainable Energy Development (SSED)

James Madison University



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1. Opportunity

Western South Dakota provides unique opportunities for innovation in renewable electricity generation and energy storage, while bolstering the reliability and resiliency on our nation's power grids. Western South Dakota lies along the "seam" where two of our nation's power grids meet; they are known as the Eastern and Western Interconnects (Bloom et al., 2020). There are four interties that connect transmission between these two large asynchronous grids (Glarus Group, 2017); thus, power generated in the east cannot be easily transmitted to the west and vice versa. Where they do exist, these connections convert the electricity from AC to DC and then back to AC for resynchronization purposes. The architecture of the power grids, as they exist at present, are the root cause of many inefficiencies and unintended consequences that plague the nation's electricity infrastructure. The lack of a unified grid in the U.S. has led to serious issues; for instance, in Texas where residents lost power for approximately two weeks during which the cost of electricity increased by as much as 25,000% in some cases (Collier et al., 2021). Such troubling impacts that relate to the lack of access to electricity can be attributed to the nature of the power grid in Texas, and could have been avoided and mitigated were the Texas Interconnect connected to neighboring grids (Lloyd, 2021). The development of additional interconnection points between grids would increase energy resiliency, provide consumers with more reliable and competitively-priced power, and reduce demand for fossil fuel power plants.

The Southwest Power Pool (SPP) recently expanded a real time (RT) market known as the Western Energy Imbalance Service (WEIS) into portions of the Western Interconnect (Farris, 2021). WEIS provides an opportunity for utilities to expand their customer base and enhance the reliability and affordability of the electricity delivered. In order to best serve customers through WEIS, additional interconnects should be developed along the seam in order to expand the currently limited capacity and accessibility.

The power infrastructure characteristics and ownership landscape of the grid in western South Dakota have motivated our company, Shenandoah Sustainable Energy Development, LLC (SSED), to pursue an innovative wind farm design that incorporates battery energy storage. SSED presents a plan for a 100-MW wind farm to be located in Meade County, SD, the business model for which includes a 32-MW battery storage farm to be located adjacent to the Rapid City Intertie in Pennington County, SD. The Rapid City Intertie, co-owned by Basin Electric (65%) and Black Hills Energy (35%), offers a 200-MW DC capacity and was constructed in 2003 (Daly, 2003). Battery storage, when combined with wind energy can reduce intermittency challenges, reduce transmission congestion, and act as a point of interconnection between power grids. SSED will offer a bundled virtual power purchase agreement (VPPA) to small data centers in the United States that have electricity loads of 5 MW or less. SSED will share with these data centers profits generated by selling a portion of wind power into the real-time balancing market in the Eastern Interconnect through SPP. The battery farm in Rapid City will be wholly owned by SSED and created as a firm subsidiary to SSED, where the firm subsidiary approach will avoid curtailment that might otherwise present a threat to the profitability of the project. The battery farm at the Rapid City location will be charged twice per day with power supplied by the *Cherry Creek Wind Farm* that we are developing. The battery farm will provide frequency regulation services for the Western Interconnect and will be sold into the RT market operated by SPP. This coupling of wind and battery farms, coupled with an innovative business model described below, has been validated by numerous industry professionals as documented.

2. Prospecting

The macro-siting analysis began with surveying of Western South Dakota, a region known for its generous wind resource, rolling hills, rich history, and pasture lands. SSED's efforts were informed by utilizing the *Wind Prospector* and the *U.S. Wind Database* to identify areas that offer (i) suitable wind resource; (ii) access to transmission; (iii) access to transportation; (iv) privately-owned lands; (v) environmentally-workable areas; and (vi) favorable terrain (NREL, n.d. & Hoen et al. 2021). Our initial analyses identified areas to avoid because of potential fatal flaws related to conflicts with Native American reservations, national parks and forests, airports, conservation districts, habitats of sensitive species, federally-owned lands, etc. Three sites were selected for more in-depth review as they appeared to be suitable for development: two located in Harding County, and the site selected for full development located in Meade County. Alternative site areas were deemed less suitable for development because of their close proximity to Cluster National Forest, greater distances to transmission, and the challenge of the greater number of landowners that would need to be involved.

Ultimately the Meade County site was selected because the criteria listed above were met. In particular, the presence of a Western Area Power Administration (WAPA)-owned 230-kV transmission line passing through the site and distance to the Rapid City Intertie being nearby strongly influenced this selection. The Rapid City Intertie is owned and operated jointly by Black Hills Energy (BHE) and Basin Electric Cooperative (BEC) both of which participate in the WEIS market along with WAPA which supported the selection of the site (Severson, 2021 & Nelson, 2021).



Figure 1. Map showing location of **Cherry Creek Wind Farm** and associated **battery farm**.

3. Siting

Detailed investigation of the Meade County site was conducted while considering key factors relative to wind farm development. SSED is confident that there are no fatal flaws associated with this site. The location of the battery farm was selected because of its close proximity to the Rapid City Intertie, and SSED does not anticipate significant risks or fatal flaws concerning this site as informed by interactions with stakeholders. The following sections investigate further each site with respect to land ownership, historical and cultural landscapes, wind farm design, and mitigation strategies.

3.1 Site Characteristics

The site selected for the *Cherry Creek Wind Farm* is located in Meade County, SD, south of highway 212, and around 54 miles northeast of Rapid City. The *Cherry Creek Wind Farm* will be located on 12,934 acres of land which comprises parcels owned by sixteen individuals and companies. The value of each parcel was estimated using an average cash rental rate of \$25.5 per acre (Davis, 2020). The cash rental rate was calculated by averaging the rates from southwest and northwest South Dakota for non-irrigated cropland and pasture/rangeland. SSED will not need to rent entire parcels, but rather will lease the acreage required to construct and maintain the wind turbines. The battery farm will be constructed on a 40-acre plot of land owned by Basin Electric Co-Op, adjacent to the existing Rapid City Intertie substation. SSED will not need to lease the entire 40 acres, but rather only the land needed to construct a 32-MW battery farm. The storage facility will upgrade the Rapid City Intertie. Leasing and developing on this property does not raise any concerns (Nelson, 2021).

SSED considered carefully the environmental and wildlife characteristics of the sites in Meade County and Rapid City to ensure that impacts on sensitive ecosystems and species were avoided. The battery farm site is not expected to present either environmental or wildlife impacts, given that the adjacent area was previously developed for the Intertie and does not contain sensitive species or habitats. Within the

wind farm site, land use consists mostly of pastureland, few cultivated crop plots, and natural vegetation including a mix of short perennial grasses (USBLM, 2015). Within the project boundary the average elevation is 2,698 feet with a range of 417 feet (Google, n.d.). There are no vegetative or aquatic species of concern within the site area, however SSED identified endangered and threatened avian and land-dwelling species, as shown in Table 1, that could be impacted by the project (SDGFP, 2016). Aquatic species were excluded from consideration due to the lack of adequate stream and river habitats within the project area. The site contains Red Owl Creek which has not been recognized by the South Dakota Department of Environmental and Natural Resources, is not monitored by the USGS National Water Information System, and does not possess significant recreational, ecological, or agricultural uses (SDNER, 2008 & SDWDM 2021). A larger stream, Cherry Creek, is present north of the project boundary and has been recognized as an impaired stream by the Environmental Protection Agency (EPA) (Roberts, 2020). Although Cherry Creek is impaired because of specific conductivity levels, the priority for remediation is low and development near this site will be mitigated to reduce any potential impacts (Roberts, 2020).

Table 1 indicates that only one sensitive species, the Swift Fox, may present a challenge to the development of the *Cherry Creek Wind Farm* given that the site is characterized as a short grass prairie; however, appropriate mitigation strategies will be considered to reduce potential impacts. Further, SSED considered bald and golden eagles and concluded they were not of concern given the lack of habitat present and absence of reported sightings within and near the project area (NREL, 2020).

Table 1. Threatened and endangered species identified in Meade County, South Dakota.

Species	Listing	Jurisdiction	Habitat Present
Whooping Crane	Endangered	Federal	N (USFWS, 2012)
Rufa Red Knot	Threatened	State	N (Breese, 2021)
Northern Long-Eared Bat	Threatened	Federal	N (Hansen, 2020)
Swift Fox	Threatened	State	Y (Nevison, 2018)
Least Tern (Least Tern, n.d.)	Endangered	Federal	N (Dakota Birder, 2020)
American Dipper	Threatened	State	N (Drilling, 2019)

In order to gain a better understanding of the wind resource at the site, several datasets were gathered from the Wind Integration National Dataset (WIND) toolkit and integrated into our Openwind[®] model to create a Wind Resource Grid (WRG) (Draxl et al., 2015). The selected data points reflect interpolated meteorological masts sampled at 100 meters (m). After running multiple iterations we concluded that the site presents an average annual wind speed of 8.27 m/s. Two (2) meteorological masts were incorporated into our final Openwind[®] model since very close in proximity to the site selected. The corresponding data indicate that wind direction is predominantly out of the north and northwest.

3.2 Stakeholder Analysis

We sought to gain understanding of the demographics of Meade County as that is critical to understanding who will be affected by the wind farm and how we might engage those impacted. Meade County, SD has a population of roughly 28,000 with about ~8 residents per square mile (USCB, 2019a). The low population density of the county implies that this area may be suitable for wind development. The median age of the county is 36 years of age (Data USA, 2018). Major industries include agriculture, forestry, fishing, hunting, mining, education, health, and social services (City Data, 2019). A wind project in Meade County will help to stimulate the local economy by providing jobs during construction and operations. The state of South Dakota as a whole is known to be largely in favor of wind energy development, this position is essential toward securing community support for wind power development.

3.3 Permitting

Required permits and associated regulatory frameworks are shown in Table 2. Our analyses to date suggest that the wind and battery project proposed are permissible. The Facility Permit requires a detailed Environmental Assessment (EA) that identifies any and all possible impacts in the project area as well as

any community resource impacts (USDOE WAPA, 2016). The interconnection agreement with WAPA also requires an EA to be conducted and can be used in the Facility Permit and Meade County’s Ordinance. The findings of the EA will indicate whether an Incidental Take permit is necessary and if additional conservation strategies are needed (Burns McDonnell, 2016). Under the NPDES, a Storm water Pollution Prevention Plan (SWPP) should be developed in order to minimize pollution generated during construction via runoff to nearby water bodies (USDOE WAPA, 2016). The NPDES may also require additional hazardous materials and waste management plans to maintain records of safe handling and disposal at decommissioning of either project. Finally, Ordinance 32 is specific to Meade County and includes specific guidelines for companies that develop wind energy conversion systems (WECS, 2021). According to Meade County’s ordinance, additional use permits and fees are required for the construction of a commercial wind energy facility including road use permits, building permits, construction permits, design safety certifications, etc. Since the batteries from the Rapid City battery farm will need to be replaced at least once, SSED must hold a hazardous waste permit to allow proper disposition of used batteries as they will be deemed hazardous (EPA, 2020). Also, since the battery farm resides in Pennington County, there are various other permit requirements for development with which SSED must comply (Zoning Ordinance of Pennington County, 2021).

Table 2. Permits/Regulations that apply to the Cherry Creek Wind Farm and/or battery farm.

Permit/Reg	Agency/Authority	Jurisdiction	Permit/Reg	Agency/Authority	Jurisdiction
Facility Permit	SDPUC (South Dakota Public Utilities Commission)	State	Incidental Take Permit	USFWS (United States Fish and Wildlife Service)	Federal
Ordinance 32	Meade County Commission	Local	Highway Access Permit & Oversize Permit	SDDOT (South Dakota Department of Transportation)	State
National Pollutant Discharge Elimination System	EPA (Environmental Protection Agency)	Federal	Aeronautical Hazard Permit	SDDOT, Aeronautics Commission	State
Hazardous Waste Permit	EPA (Environmental Protection Agency)	Federal	Zoning Ordinance	Pennington County	Local

3.4 Interconnection

It was critical for SSED to identify a point of interconnection that would support our intended offtake strategy. SSED identified two (2) such high-voltage transmission lines with capacities suitable for the interconnection and offtake strategy intended for the *Cherry Creek Wind Farm*, as pictured by the dotted line in Figure 2 (Severson, 2021). Our plan was validated throughout interactions with BEC.

WAPA was identified as the owner of the 230-kV transmission line that runs through the *Cherry Creek Wind Farm* boundary and where SSED wishes to connect via a new substation. It was understood

that an interconnection agreement would need to be developed with WAPA and SPP in order to gain grid access. SSED anticipates that interconnection is feasible given that WAPA must provide non-discriminatory access to all eligible entities wishing to connect to their transmission infrastructure given available capacity (WAPA & Harris, 2016). A substation will be constructed by WAPA to ensure that electricity generated by the *Cherry Creek Wind Farm* can be uploaded to the grid. SSED is confident that WAPA will agree to construct, own, and operate the transmission substation given the precedent established as they did the same for the *Willow Creek Wind Farm* in 2016 (USDOE WAPA, 2016). The *Willow Creek Wind Farm* is located 40 miles to the west of our site and interconnects to a WAPA transmission line, and our research shows that WAPA assumed the costs, operations, and ownership of a new interconnection substation (WAPA & Harris, 2016). For that project WAPA also agreed to incur all associated costs of upgrading any existing transmission lines that would prevent Willow Creek from successfully connecting, which gives us confidence that there will be financial support from WAPA (Burns McDonnell, 2016).

The Intertie Battery Farm will connect to incoming transmission line from the New Underwood substation and outgoing transmission to the South Rapid City substation to avoid the congested conversion line (Severson, 2021). Transmission leaving the Rapid City Intertie is four miles to the South Rapid City substation, which will likely require an upgrade in order to accept power from the *Cherry Creek Wind Farm*. It was stated in confidence that BHE, owner of the South Rapid City substation, would likely fund this upgrade since the western grid needs more capacity to meet growing demand (Nelson, 2021).

3.5 Design/Layout

Following overall site selection, SSED performed a micro-siting analyses that included numerous iterations of Openwind® modeling that were optimized for energy costs and anticipated impacts. In order to minimize environmental impacts while still maintaining optimal energy generation, larger turbines were pursued, and the Siemens-Gamesa G128 5-MW wind turbine was selected. This turbine is manufactured by an international original equipment manufacturer (OEM) headquartered in Spain and presents preferred operating characteristics that are shown in Table 3 (Bauer, 2017). Siemens-Gamesa has two (2) manufacturing facilities in the U.S., in Kansas and in Iowa, which impacted this decision given that this turbine may be manufactured at one of these facilities in the future (Siemens Gamesa, n.d.). The *Cherry Creek Wind Farm* will comprise 20 wind turbines and will offer an overall generating capacity of 100 MW.

Table 3. Specifications for the Siemens-Gamesa G128 5-MW wind turbine.

Rated Capacity	Rotor Diam.	Hub Height	Shear Coeff.	Cut-In Value	Peak Value
5000 kW	128 m	90 m	0.13	3 m/s	25m/s

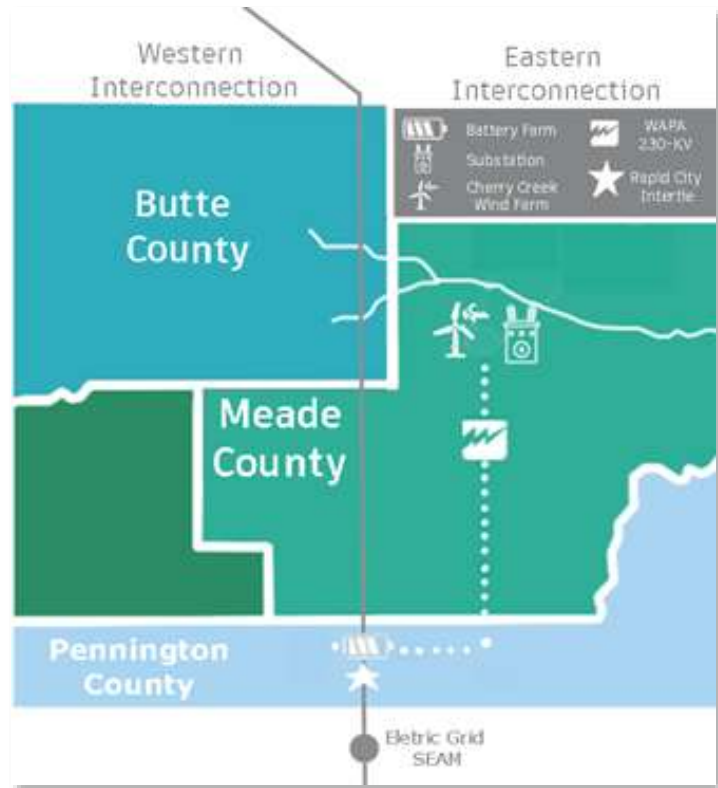


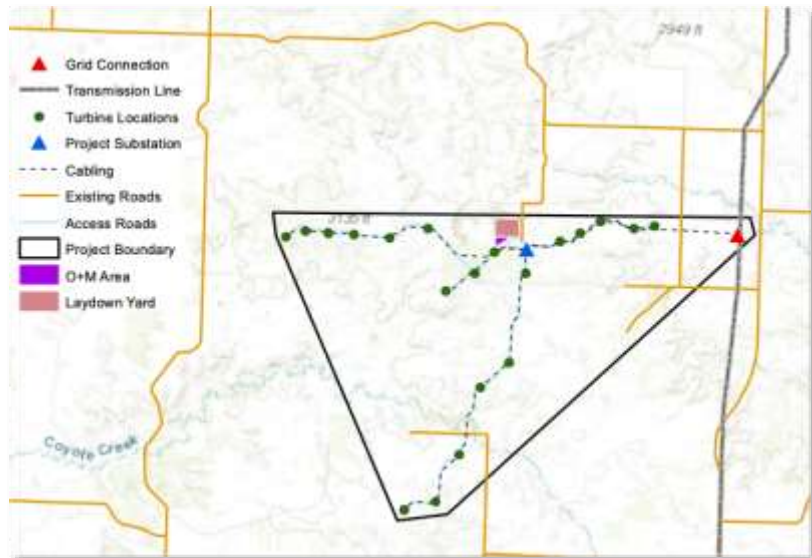
Figure 2. Map showing locations of *Cherry Creek Wind Farm* and associated *battery farm*.

The *Cherry Creek Wind Farm* was designed according to guidelines informed by the Meade County Ordinance and additional guidance associated with commercial scale wind development, where elements that provided wind farm design and modeling constraints are presented in Table 4 (WECS, 2021). Once these constraints were applied and multiple iterations were run, SSED selected the design that maximized energy yield while minimizing installed cost, while also offering a desirable turbine layout with minimal impacts as shown in Figure 2.

Table 4. Design elements listed in the Meade County Ordinance that were considered during modeling and design of the *Cherry Creek Wind Farm*.

Buildings	1000 m	Outside	Streams	152 m	Outside
Roads	310 m	Outside	Noise	55 dB	Less than at all buildings
Powerlines	310 m	Outside	Shadow Flicker	36 hours/year	Less than at all buildings

The presence of scattered valleys created from historical water flow landscapes and prevailing northwestern winds forced wind turbines to be placed at points of higher elevations which correspond to areas of high wind speed and reduced wake effects. The point of access for the development of Cherry Creek Wind Farm was placed at the end of 167 Avenue because of its connection to County Highway 20, lack of nearby residents, and its central location to the entire project (SDDOT, 2020). Access roads and cabling were constrained in order to reduce land use and disturbance, providing for a mostly shared land use footprint. Approximately 1 km of 167 Avenue will be utilized, and 16 km of new access roads will need to be constructed (USD 4.9 million). Given the interconnection agreement, project size (100 MW), and close proximity to transmission, SSED anticipates a cost of transmission equal to USD 8.4 million due to the need for installation of: 21.5 km of cabling (USD 5.4 million) and one project substation (USD 3 million). The grid connection substation was placed adjacent to the 230-kV transmission line to reduce cabling



impacts and costs. The laydown yard (39 acres) and Operations and Maintenance (O&M) facility (5 acres) were sited just west of the access point for easy transportation access, reduced disturbance to landowners, and its central location. The O&M facility and the laydown yard are placed on flat land at the entrance to the wind farm, allowing for an increased perception of security by restricting access to the wind farm. The total area permanently impacted by the project is around 116 acres, this accounts for the access roads (10 ft. wide), associated turbine area (3 acres), the O&M facility, and the laydown yard (Bauer, 2017).

For the Intertie Battery Farm, SSED will use 18 BESS shipping style containers that are 40 ft long, 8 ft wide, and 8.5 ft tall; each with a 1.8 MWh capacity. It is estimated that the area of the storage facility will be approximately 1 acre. The system will be equipped with a heating system, battery management system, and HVAC systems in order to maintain the projected 12.5year lifetime. The plan is for the battery farm to connect to the AC-DC and DC-AC inverters at the Intertie.

3.6 Risks and Mitigation Strategies

The following sections considerations pertinent to various risks and mitigation strategies that SSED has identified as critical to our triple bottom line business concept.

Environmental and Wildlife Considerations

The interconnection agreement with WAPA requires the performance of an Environmental Assessment (EA) conducted by an agency selected by WAPA (WAPA & Harris, 2016). The EA will evaluate and review potential environmental impacts of the *Cherry Creek Wind Farm* as well as addressing any potential impacts due to modifications of the transmission system deemed necessary by WAPA. Upon the completion of the EA, SSED will work with Marmot Edge Conservation (MEC) to create conservation and mitigation strategies for all potentially affected wildlife, ecosystems, and environmental resources under applicable regulatory frameworks. SSED expects a conservation and mitigation strategy to be developed for the Swift Fox if MEC's surveying analyses indicate potential impacts. MEC was chosen because of their experience in developing environmental mitigation strategies for large-scale wind farms in South Dakota and their familiarity with WAPA and pertinent regulatory agencies (Burns McDonnell, 2016). Surveying analyses of streams located within the project boundary indicate that anticipated impacts from the wind farm development are low as they do not possess significant resource uses and sensitive species (SDDENR, 2008 & Roberts, 2020). However, MEC will create Best Management Practices (BMPs) to be implemented to reduce water quality degradation and erosion, while also ensuring restoration is achieved. The development of a SWPP will supplement BMPs to ensure that Cherry Creek and Red Owl Creek are not significantly impacted by the wind farm development (USDOE WAPA, 2016).

Societal Considerations

SPP's energy generation portfolio consists mainly of coal, wind and gas (SPP Finance Department, 2021). However, in 2019 wind energy was responsible for producing 27.4% of SPP's annual energy production (SPP Finance Department, 2021). Given the development of additional wind farms, the number of coal-fired powered plants will continue to decrease, resulting in members of the South Dakota community becoming impacted (SPP Finance Department, 2021). In North Dakota, counties have enacted restrictions of wind development in efforts to save coal mining jobs (Charles, 2021). However, to mitigate the impacts of a transitioning energy economy, SSED will seek out community members who have lost their jobs in the coal mines for re-training. As of 2019, there were 7,000 wind turbine technician jobs, and the availability of these jobs is expected to increase by 61% over the next ten years (SDL, 2021). Although these jobs will not be available for the unemployed coal miners until after the *Cherry Creek Wind Farm* is operating, the jobs warrant stability for at least 20 years (Lawhorn, 2021). SSED anticipates that around 100 construction jobs will be created for both the wind and battery farm, thereby generating a generous local economic benefit (USDOE WAPA, 2016). Further, several permanent positions will be created for operations and maintenance activities at both the battery farm and wind farm, thus allowing for even more employment opportunities. Local economic benefits will also be created from permits and fees, where such revenues could be utilized for improving community and government services within affected counties. Landowners involved in the development of the *Cherry Creek Wind Farm* will receive steady lease payments from SSED for the duration of the project's life that can provide economic security in the event of adverse weather affecting ranching/farming practices (USDOE WAPA, 2016).

Despite some negative feedback from some landowners unwilling to participate in the *Willow Creek Wind Farm*, a project developed by Ørsted in Butte County, the project was successful regardless. Ørsted worked with 14 private landowners to satisfy the acreage needed for their wind farm (Peterson, 2019). SSED's project will directly impact only nine private landowners, thus simplifying land access. Other potential impacts to community members includes shadow flicker, noise, and aesthetic degradation, although our Openwind[®] simulations suggest that such impacts do not exceed ordinance specifications as outlined in Table 5.

SSED's Road Use Agreement with Meade and Pennington Counties will ensure that county roads utilized for construction purposes will be returned to their original state or improved beyond that (WECS, 2021). SSED will hire a third-party engineering company to evaluate the road conditions prior to and after construction, where SSED will assume responsibility for upgrades as directed. The presence of existing

gravel roads within the project boundary allows for SSED to utilize and develop them to the extent practical, where community members can benefit from paved access roads beyond the project’s life.

Table 5. Modeled impacts from Cherry Creek Wind Farm.

Potential Impact	Over Limit (of 19 houses impacted)	Maximum Value	St. Dev
Noise > 55 dB	0	40	6.7
Shadow Flicker > 60 min	1	240	55
Shadow Flicker > 30 Days	0	30	6.8
Horizontal Impact > 50%	14	197.5	45.7

Historical and Cultural Considerations

South Dakota has an extensive Native American history and the eastern part of the state contains five Indian Reservations (USBLM, 2015). Black Hills Reservation is closest to both project areas and is home to the Oglala Sioux Tribe. It is possible that the *Cherry Creek Wind Farm* will be built on land that is or was once considered sacred Native American land. In the Treaty of Fort Laramie, signed on 29th April 29th 1868 between the United States government and the Sioux Tribe, the United States promised the Black Hills region for exclusive use by the Sioux Tribe (Clark, 2016). At present the Sioux Tribe views the entire Black Hills region as their land. SSED will approach the Oglala Sioux tribal leadership to provide details of the project and to seek their support. The sustainable nature of this project may appeal to their core values and the meeting could establish a future partnership with the tribe. Ultimately, the cultural importance of these sites is determined by the tribes and SSED will work to maintain positive relations. In addition our company will seek to provide training and employment opportunities for members of the tribe.

3.7 End of Life Strategy

The production of sustainable energy is only one single component that comprises a fully sustainable process, thus the entire life cycle of the wind and battery farms must be considered. Turbine blades degrade over time due to the extreme loads endured over their lifetime, and they will be decommissioned after around 20 years of operation. At present, the two primary methods of disposal of wind turbines are to bury them in landfills or burn their parts. In order to avoid the emissions of toxins into the environment, the team is proposing an approach to recycle and repurpose all wind turbine components, as 85-90% of wind turbines total mass can be recycled. The blades present a unique challenge due to their composite material, but we are exploring the possibility to grind old blades to produce material that can be used to construct road beds. For all wind turbine components not including the blades the team will consult with Belson Steel Center Scrap Inc. to sell the decommissioned parts. Belson supplies the necessary labor, equipment, and transportation required for decommissioning a wind farm project. The team will also consult with GeoCycle, a global company that specializes in the co-processing of waste materials. The potential sales of decommissioned blades to GeoCycle and Belson could also improve our efforts toward more environmentally sustainable project development and decommissioning.

4. Offtake

System Advisory Model (SAM) modeling software was used to calculate costs and revenues associated with the wind and battery farms; UL's Openwind[®] software to estimate energy output; and Excel[®] to calculate revenues from the ancillary markets.

4.1 Transmission Market Analysis

Our offtake strategy strives to improve society, enhance the environment, and provide a generous rate of return. SSED will develop a 100-MW wind farm in Meade County and a 32-MW battery farm adjacent to the 200-MW capacity Rapid City Intertie.

SPP supports three separate markets: *transmission service*, the *integrated marketplace consisting of a day-ahead (DA) market and a real-time (RT) balancing market*; and the *Western Energy Imbalance Service Market (WEIS)*³. The WEIS market, launched 1st February 2021, operates in the western electric grid, and SPP was compelled to expand their resources to “enhance the reliability and affordability of electricity delivery from utilities to their customers (Farris, n.d.). Given the high levels of wind generation in the SPP portfolio, wholesale power prices are dropping (Farris, n.d.). Power grids must have equal electricity generation and demand. A key obstacle to a wind farm's business model is grid congestion, and subsequent curtailment due to limited transmission resources in western South Dakota, resources that have been strained as a result of the previously mentioned increase in wind energy in the area. While it poses an immediate challenge, it also leads to the potential for a decrease in revenue realized as related to forecast potential over the life of projects due to curtailment. The wind industry has seen a long-term trend toward lower profit margins which presents a threat to the long-term viability of the traditional wind business model in this region (Berkley Lab, 2020). Battery Energy Storage Systems (BESSs) can mitigate the volatility of wind farms by peak shaving and time shifting, the transference of energy output to times of higher demand. Initially, we evaluated a BESS connected on site to the wind farm. SSED confirmed with Basin Electric Power Co-op that the 230-kV transmission line owned by WAPA next to our proposed wind farm has enough capacity for to support 100 MW. However, as a result of congestion on transmission lines at the Rapid City Intertie, it is likely that the *Cherry Creek Wind Farm* would be curtailed. SSED thus decided to mitigate the risk of curtailment by adding a 32-MW BESS adjacent to the Intertie. The BESS will provide increased energy resiliency, frequency regulation, and black-start ancillary services to the western grid.

Transmission Offtake

The WEIS market is operated by SPP which serves as the regional transmission operator (RTO) for the region of South Dakota where the *Cherry Creek Wind Farm* is located. Basin Electric Co-op and Black Hills Energy share ownership of the Rapid City Intertie. SSED will create a firm subsidiary company that owns the battery farm located at the Intertie and will enter into a physical PPA with their subsidiary company in order to charge the batteries directly with electricity derived from the *Cherry Creek Wind Farm*. The firm subsidiary company will guarantee that electricity from the *Cherry Creek Wind Farm* will charge the battery farm without curtailment through firm capacity. This design will protect SSED from any financial risks resulting from congested transmission at the Intertie and subsequent curtailment. The RT market is based off the difference between the actual electricity load for an area and the forecasted electricity load (Mazzi and Pinson, 2017). The WEIS market balances electricity generation and load in real-time, dispatching energy every five minutes into the western electric grid (Farris, n.d.). Thus the RT market is relatively small and experiences higher volatility and larger ranges for pricing (Farris, 2021). The utilization of batteries in the RT market will result in the same price volatility mentioned above. Participating in a volatile market presents price risks. For example, charging the battery when the RT market prices are low will increase the price of electricity during the low demand hours, due to the small size of the market (Mazzi and Pinson, 2017). However, arbitrage services will enable charging of the BESS during hours of low demand and discharging during hours of high demand. Our analysis of the WEIS RT market mean pricing suggest that selling energy would be profitable, details are provided below.

SSED will also participate in the SPP RT market on the eastern side directly from the wind farm. SSED will sell electricity into the real-time market when prices are high in order to maximize revenues. A downside to selling wind energy in the real-time market is covariance risk which implies the possibility

that wind power is sold at lower rates. The loss in revenue associated with covariance risk will be overshadowed by the lack of curtailment losses.

Customer Market Analysis and Offtake

In order to hedge the risks associated with the real-time markets, SSED will offer a *flexible, bundled, virtual* PPA (FBVPPA) to small data centers throughout the country who will be subscribed to this service. Since this manifest strictly as a financial transaction, the data centers do not need to be located in the Eastern Interconnect. The bundling strategy reduces the financial risk by guaranteeing a favorable offtake price for 100% of the electricity by choosing a customer niche that is highly sensitive to energy prices. Smaller data centers seek lower energy rates, but at the same time lack the bargaining power needed to negotiate lower rates. Further, the strategy to use a flexible VPPA allows SSED to divert a portion of energy away from the customers to trade in the RT market that will offer higher returns, where SSED will share the profits from RT sales with the data centers when they do not receive 100% of the capacity from the *Cherry Creek Wind Farm*. In effect, SSED will “borrow” electricity from the data centers to trade in the real-time markets on the eastern and western grids, and then share 33% of their profit with the data centers. The strategy decreases the Basis Risk, or risk of a customer defaulting on energy payments; due to the presence of multiple customers, it allows other companies to absorb the offtake of a subscriber in the case of buyer default.

In 2016, American data centers were responsible for 2% of total electricity consumed that year (Sverdlik, 2020). The data centers that would be considered for our wind project are smaller data centers with electricity loads between 2 and 5 MW. For example, Cavern Technologies is a data center located in Kansas City, Kansas that has an electricity load of ~ 4 MW, as company president and COO, Sean Khurana, explained to the SSED team. By engaging smaller data centers, SSED will have a competitive advantage because these companies will not have the power to otherwise negotiate lower electricity rates. These smaller data centers typically pay retail industrial rates for electricity. As of February 2021, the average industrial electricity price for the West North Central States was USD 76.80 per kWh (U.S. Energy Information Administration, n.d.). SSED is able to offer these data center subscribers electricity at a more competitive cost of USD 67.73 per MWh. Electricity purchases account for 40% of data centers’ annual operating expenses (USTEC, 2017). Since data centers must purchase electricity in large quantities, they will likely be inclined to subscribe to SSED’s flexible VPPA which will save them 11–13% on their electricity bills annually. By targeting these smaller data centers, SSED can provide electricity that is just below what they would normally pay, thus enabling these data centers to be more competitive with larger ones.

Figure 4 provides a visual representation of our business model that shows that SSED will trade into the real-time balancing market operated by SPP in the Eastern and Western Interconnects.

SSED will utilize the battery farm to access the WEIS market on the western grid. The lines in blue represent where electricity from the *Cherry Creek Wind Farm* will flow. The variable portion of the offtake strategy using the VPPA is seen in green, which represent revenue streams.

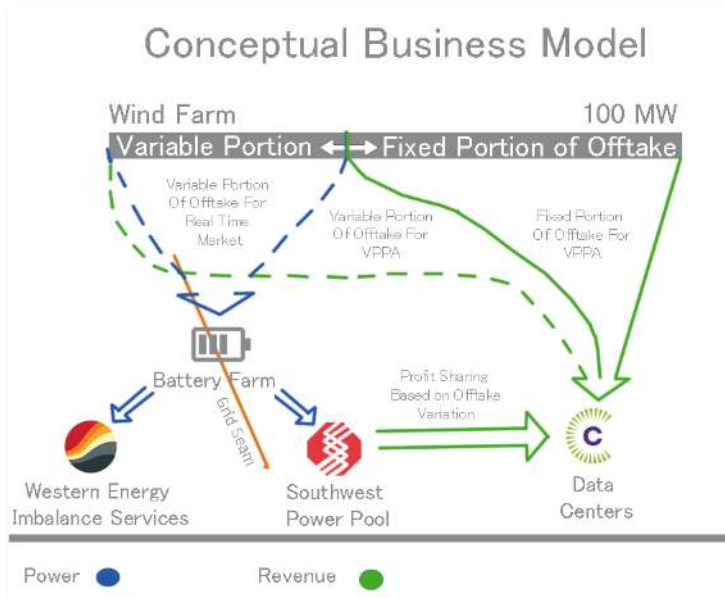


Figure 4. Cash and energy flows of business model.

4.2 Financial Parameters

Our SAM model assumed no debt financing due to the customer market of data centers participating in the PPA. SSED will maintain internal control over finances.

Energy Production

SSED utilized Openwind® to simulate estimated annual energy production. The *Cherry Creek Wind Farm* is predicted to produce 356.5 MWh annually with a capacity factor of 40.7 %. This annual energy production value was calculated while assuming values listed in *Table 6*. These values were applied to both our Openwind® and SAM analyses as we reconciled both models to validate assumptions and methodologies.

Initial Capital Cost

In order to calculate the initial capital cost of the *Cherry Creek Wind Farm* as well as the Intertie Battery Farm, SSED utilized SAM software to generate two separate models. SSED determined the total capital costs of the windfarm and battery farms to be USD 153,468,769. The *Cherry Creek Wind Farm* has 20 turbines with total capacity of 100 MW. Turbine costs are the highest as there are large costs for turbine foundations, site preparations, and transportation. Battery farm costs are based on average industry cost of \$293/kWh and \$263.12/kW respectively.

Annual Operating Expenses

Annual operating expenses include additional costs for operations and maintenance that were determined for both the *Cherry Creek Wind Farm* and the battery farm. A fixed annual cost of \$20,000 per year was added for the wind farm. The *Cherry Creek Wind Farm* has a fixed cost by capacity of \$41 per kW-year, and the battery farm has a fixed cost by capacity of \$13per kW-year.

4.3 Financial Model

SSED created an integrated financial model using an Excel® spreadsheet that was informed by each of the offtake elements. The financial model used parameters from the SAM software such as net capital costs and energy production from the *Cherry Creek Wind Farm* and the accompanying battery farm. The values provided from SAM accounted for expenses including taxes, construction, maintenance, etc. Further, the combined financial model incorporates PPA parameters and real-time market parameters for the eastern SPP market, the western SPP market, and WEIS. By utilizing an Excel spreadsheet SSED was able to generate revenue estimates corresponding to our business model.



Figure 5. Displays the flow of software's used to generate a financial model.

Key Features

The combined financial model created by SSED applies a Monte Carlo approach to simulate the real-time balancing markets and WEIS markets in the Eastern and Western Interconnects respectively. Since the WEIS market was recently launched, the only available data is bidding data from the past three months (Electric power monthly, 2021). The average market price of 44.76 \$/MWh for the WEIS market was used in a Monte Carlo method of generating random price data. While a standard deviation would have

provided a reasonable assumption, to be extra conservative in the revenue estimation SSED assumed a 1/10th of a standard deviation from the mean for the calculated accepted bid range. While alternative data were available for SPP’s RTBM, SSED used the same statistical model to predict revenue since it had already been constructed. By using the modeled revenue data from the two real time markets as well as the FBVPPA simulation, SSED was able to combine these with expense data from SAM. The combined model estimated a project Net Present Value (NPV) of 42.4 million USD. The *Cherry Creek Wind Farm* in addition to the battery farm models an IRR of 21%. Given that the revenue simulations for the ancillary markets are overly conservative, it is reasonable to assume that the IRR actualized by such a project may be meaningfully higher.

Incentives

One of the major incentives created by the federal government is the Production Tax Credit (PTC). This includes a \$0.018/kWh credit (EIA, 2021a). This was extended for projects beginning by 31st December 2021. At the state level in South Dakota there is a Property Tax Incentive for wind energy projects with nameplate capacity greater than 5 MW. The incentive has two components – the first part is a \$3 per kW of capacity of the wind facility for the first calendar year (Proudlove, 2021), the second part is that wind farms producing power for the first time after 31st March 2015 pay an annual tax of USD 0.00045 per kWh of electricity produced (Proudlove, 2021).

Assumptions and Results Chart

Given the assumptions gathered through research and stated below, SAM was applied to model the cash flow for the *Cherry Creek Wind Farm* over a 25-year life cycle. We made several assumptions based on Real Time Market data acquired from WEIS and SPP. The data applied were all bid offers and no accepted bids. We then conducted statistical analyses on the bids that were within a standard deviation of 0.15 of the average bids. The RT market data is what informs the parameters presented below including IRR, PPA, and COE.

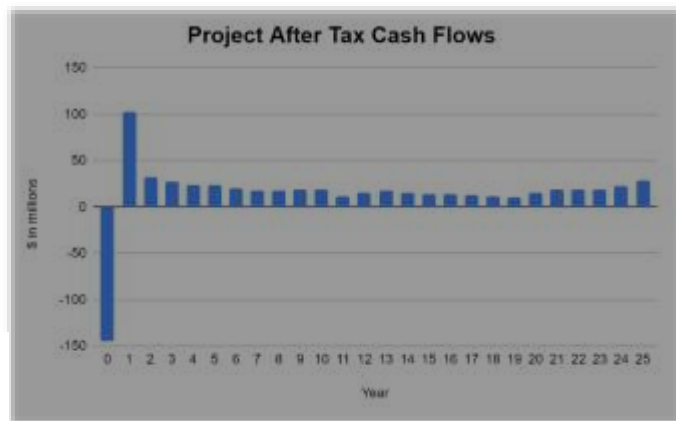
Table 7. Assumptions and results associated with financial modeling.

Assumptions		Results	
IRR Target	8-12%	IRR*	21.00%
Fixed Cost by Capacity*	\$41/kW-yr	Capacity Factor*	40.70%
Federal Income Tax	37%	Annual net revenue for battery*	USD 350,101.64
SD Sales Tax	4.50%	Annual Energy Prod.*	353,640.032 MW
PPA Escalation	2%	Net Capital Cost*	USD 175,258,896
Discount rate	4%	Net Present Value*	USD 74,414,588.83
Inflation Rate	4.20%	Levelized COE *	\$37.70/ MW
Average Annual Expense*	USD 9,500,000	Size of Debt*	USD 75,606,216
WEIS RT Projected Max. Bid*	\$37.16	Levelized PPA*	75.25c/ kWh
SPP RT Projected Max. Bid*	\$39.50	Equity*	USD 99,652,688
Projected Escalation of RT Market*	.15%/yr	Maximum annual gross revenue for PPA*	USD 23,950,271.17

Cash flow

This graph of projected cash flow shows that our project has a strong and positive cash flow throughout its life. The graph shown in Figure 6 shows a negative \$144,765,565 revenue at year zero. This negative revenue accounts for the net capital costs of the *Cherry Creek Wind Farm* and subsidiary battery farm.

Figure 6. Projected cash flow for the *Cherry Creek Wind Farm* and battery farm over twenty-five years.



4.4 Economic Risks and Mitigation Strategies

A SWOT analysis was conducted to understand the *Strengths, Weaknesses, Opportunities, and Threats* specific to our business model. Economic risks associated with the *Cherry Creek Wind Farm* include the volatility of the real-time markets in the eastern and western grids operated by SPP. The volatility could be beneficial for SSED if the RT market rates are high, or detrimental to profit if rates drop. However, to combat this SSED is using a bundled flexible virtual power purchase agreement with up to eighteen data centers in the United States. The bundled VPPA approach is based around a profit-sharing strategy, where SSED will borrow a fraction of the capacity being sold to the data centers to trade into the real-time markets on the eastern and western electric grids. Any profit made by SSED in the real-time markets will then be shared evenly among the eighteen data centers. The flexible nature of this bundled VPPA is what mitigates economic risks from the volatility of the real-time markets. If the real-time market rates drop below a profitable margin for an extended period, SSED has guaranteed customers who will buy the electricity generated at the *Cherry Creek Wind Farm* for a fixed and favorable price. For example, If SSED were to sell 100% of the electricity to the participants in the bundled VPPA, they would save 2% on their electricity costs; whereas if SSED were to “borrow” 30% of the 100 MW, VPPA subscribers could save as much as 10% on electricity costs, making both mitigation options favorable to all parties involved. In addition, by having a bundled flexible VPPA, the *Cherry Creek Wind Farm* and the subsidiary battery farm is mitigating the risk of not being able to secure financing.

Table 7 presents all the factors considered by SSED during our SWOT analysis. This analysis describes the weaknesses and threats of our business model that need to be addressed.

Table 7. Factors considered during SWOT analysis.

SWOT Analysis	
Strength	Weakness
Reliable wind resource	Limited transmission capacity in western South Dakota
Available land	Rapid City substation is at capacity
Minimal environmental and sociocultural risks	
Opportunity	Threat
Sites are in close proximity to the electric grid SEAM	Increased congestion and curtailments due to wind development in Western South Dakota
Rapid City intertie can be avoided	
WAPA 230-kV line has available capacity leading to the intertie	Decreasing margins for the wind power industry
Black Hills Energy owned 230-kV transmission line leaving the intertie has capacity	

The last economic threat identified by SSED was the location of the turbine manufacturer that was selected. SSED modeled the wind farm using a Siemens-Gamesa G-128 5-MW turbine. While there are two Gamesa manufacturing facilities in the United States, neither one of them manufactures the specific turbine used for modeling by the SSED team. The SSED team is optimistic that Siemens-Gamesa will begin manufacturing this turbine in the United States in the future as the wind industry continues to expand. However, if Gamesa does not expand their manufacturing within the United States then SSED will consider shifting to a GE turbine which is manufactured in Arizona and North Dakota (GE Renewable Energy, n.d.).

SSED has completed extensive due diligence during the development of our business model. While there are risks present, SSED is confident that this project will be profitable and will stimulate similar projects along the seam. SSED team members have spoken with numerous industry leaders who have validated the business model presented. The innovative idea of using a battery farm to provide a means to avoid transmission congestion and to provide a less risky means to participate in the real-time markets has been validated throughout conversation with multiple wind industry experts.

5. Optimization

In order to effectively achieve SSED's triple bottom line approach, many iterations occurred between initial wind farm designs and business and financial model development. Openwind® models were first developed to determine optimal energy output at the site selected without considering key fatal flaws. Detailed research, analyses, and data synthesis were performed by SSED to ensure that all likely fatal flaws were identified within the site boundary while considering residences, land parcels, water bodies, roadways, and transmission lines. Upon successfully identifying all potential fatal flaws and inputting them into the Openwind® model, the layout was optimized for maximum energy production at the lowest cost while still minimizing the environmental and community impacts. We limited access roads and reduced cabling to reduce their costs and minimize land disturbances, while considering real-world energy losses that reduced capacity factor from an initial 47% to 40.7%. Our financial model was optimized through an iterative process beginning with modeling the wind farm and battery farm separately using SAM software. SAM was used to factor in the various expenses associated with each design feature. Finally, an excel model was created to combine both our financial models and apply the offtake strategy. Using Excel®, SSED changed specific variables such as the percentage of electricity that would be "borrowed" from subscribers to the VPPA, in order to find the scenario that generated the highest revenue. The SSED financial model was optimized upon the final modeling of the WEIS market in February 2021 at which time the financial model was expanded to include a battery storage farm that would allow for penetration into the western real-time market (Farris, 2021).

6. Conclusion

SSED has developed a 100-MW wind farm, the *Cherry Creek Wind Farm*, in addition to a wholly owned subsidiary 32-MW battery farm. An intricate business model was developed that allows SSED to participate in the real-time balancing market in the eastern electric grid and the western real-time market, while securing financing and 100% offtake. SSED created a profitable wind farm and battery farm design. The combination of wind energy and battery storage has allowed for SSED to fulfill their triple bottom line strategy by creating a new point of interconnection between the largest electric grids in the nation, therefore improving reliability and resiliency on both grids. This in turn enables consumers to access clean, reliable, and affordable electricity on both sides of the seam.

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