Project Development Report

Coyote Spring Wind Farm Development
by Rolling Hills Energy Development (RHED)

James Madison University

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The JMU CWC Project Development Team presents the *Coyote Spring Wind Farm*, sited in Logan County, CO by Rolling Hills Energy Development, LLC of Virginia. This 99-MW wind farm offers a levelized cost of energy of 0.021 USD/kWh and a 39% capacity factor, with minimal environmental and community impact. With hopes of entering a virtual power purchase agreement, RHED has chosen the opportunistic target market of large, energy-intensive data centers in northern Virginia (NoVA) due to their in-state proximity. Many of these firms are interested in offtaking their energy consumption to meet overarching sustainability goals, and the prime wind resource in CO provides an interesting business opportunity. The RHED project development team's efforts are driven by a diverse and democratic approach.

1.0 Opportunity

The trend toward digitalization of modern business has led to the rapid growth of data center operations in recent years. According to a data center industry report from the Washington State Department of Commerce (WSDOC), small- and hyper-scale data centers constructed between 2014 and 2018 increased the global industry footprint by 360 million square feet. As their energy-intensive server farms and processing units are in continuous operation data centers are a significant consumer of energy. In fact, a typical large-scale data center may occupy one million square feet and require at least 100 MW of dedicated power (WSDOC, 2018). As Renewable (Energy) Portfolio Standard (RPS) requirements become more widespread in the U.S. (NCSL, 2020), renewable energy will likely continue to play a critical role in the success of the rapidly-expanding data center industry.

Wind energy is growing across the U.S., and unlike solar energy, the generating capacity of wind power increases as turbines scale vertically. Therefore, wind turbines are most effective where land availability may otherwise limit solar deployment, especially as wind becomes more cost-effective. According to the 2018 Wind Technologies Market Report, the average capacity factor for wind farms built between 2014 and 2017 reached 42%, compared to an average of 31% between 2004 and 2011 (Berkeley Lab, 2019). Since 2009, wind project costs have dropped significantly as the result of technological improvements, demonstrating a 40% decrease in cost per kilowatt (EIA, 2018).

Two overarching factors prompted the selection of NoVA data centers as the target market as the offtaker of wind power generated in Colorado (CO) via a virtual power purchase agreement (VPPA): (1) the steady, but growing demand for clean energy; and (2) market attractiveness. Northern Virginia (defined as Arlington, Fairfax, Loudoun, Prince William, and Stafford county and the cities of Alexandria, Fairfax, Falls Church, Manassas, and Manassas Park) represents one of the fastest growing data center markets in the U.S. (WSDOC, 2018). And given the recent passage of the Virginia Clean Economy Act (VACEA) (H.B. 1526, 2020) establishing a mandatory state RPS, NoVA data centers will be further incentivized to steer their power procurement to non-carbon-emitting sources (Table 1).

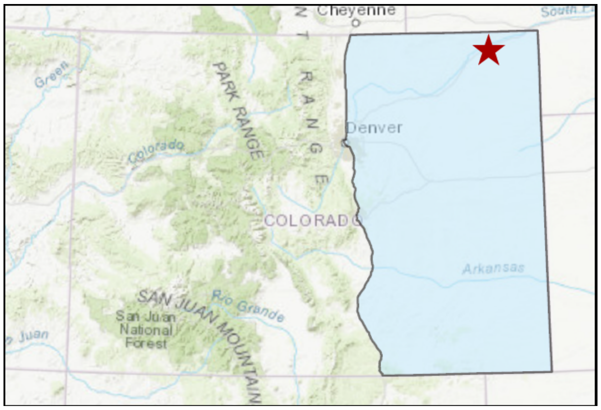
Table 1. An overview of the 2017 top data center wholesale markets in the U.S. (WSDOC, 2018).

Market	**Inventory** (MW)	**Vacancy** (%)	**H1 Net Absorption** (MW)	**Rental Rates** (USD/kW-month)
Northern Virginia	608	5.8	41.5	120-145
Dallas/Fort Worth	231	16.8	22.0	120-145
Chicago	188	2.1	4.2	130-145
Silicon Valley	169	5.3	12.0	145-165

As highlighted above, the data center market in NoVA is nearly three times that of the second largest market (Dallas/Fort Worth), and will only continue to grow as current construction projects are completed and new data centers are brought online (WSDOC, 2018). To capitalize on this rapid growth and more stringent requirements for clean power procurement in VA, a business concept was created. RHED's concept is backed by a siting effort to construct a 99-MW wind farm in eastern CO, a financial analysis that describes the economic feasibility of the project, and optimization of all factors to estimate the associated risks to support NoVA data center operations. The team utilized several decision-support tools, including Openwind®, ArcGIS® Pro, Microsoft Excel®, and NREL's System Advisor Model (SAM).

2.0 Siting Analysis

In order to best serve the target market of NoVA data centers, the site must provide the lowest cost per MWh and the highest energy output available. Siting commenced with the prospecting of eastern Colorado, a region known for competitive PPA pricing on a national scale thanks to a strong wind resource and supportive state government (CEO, 2020; Xcel Energy, 2019). This region was examined in depth using the U.S. Wind Turbine Database, Wind Prospector, etc. to identify areas that demonstrated (1) an above-average wind resource; (2) compliant local government and community; (3) low probability of fatal flaws; (4) ease of permitting; (5) access to transmission/point of interconnection; (6) likely favorable site/land control; and (7) access needed to evaluate critical environmental, community, and financial factors. Ten initial prospects were chosen as informed by the criteria outlined above.



These analyses ultimately led to the consideration of only three counties (Limon, Lamar, and Logan), and Logan County was chosen for more detailed review (Figure 1). Within Logan County, three specific sites, referenced as; I-76, N-Fleming, and E-Sterling, were selected. In accordance with the locational vetting process, the I-76 site (henceforth referenced as *Coyote Spring Wind Farm*) was identified as the optimal site as evaluated on the basis of (1) cost per MWh; (2) wind resource; and (3) anticipated risks and potential fatal flaws.

Figure 1. The general location of the *Coyote Spring Wind Farm* within the defined CWC boundaries.

2.1 Site Characteristics

The chosen site is located in northeastern CO in Logan County, just south of I-76, north of the town of Fleming, and east of the city of Sterling. *Coyote Spring Wind Farm* was selected because of the factors detailed above, as well as its favorable topography, minimally-developed pasture land, proximity to I-76, in-state presence of Vestas as a turbine supplier, and the fact that the project site involves only four tracts of land belonging to two landowners (who are assumed to be open to development). While there is a greater risk associated with negotiating land lease agreements with multiple landowners, developers must focus on which land is most appropriate and accessible for development. Effective communication with landowners will be critical for the success of this project effort.

In order to develop a Wind Resource (Grid) Map (WRG), wind information was gathered from thirteen data sites accessed from the Wind Integration National Dataset (WIND) and then incorporated into the running Openwind models. The WIND data points served as proxies for meteorological masts at 100 meters. By using the appropriate layers, RHED generated a WRG Map in Openwind, which yielded a minimum annual wind speed of 6.92 m/s, a maximum of 8.16 m/s, and an average of 7.39 m/s (Green & Sorrells, 2020). The future *Coyote Spring Wind Farm* has been sited along the southeastern rim of the South Platte River Valley, spanning along the leeward side of the ridge away from the river. The maximum elevation of the project is 1,251 meters, with elevation change present across the project area. The terrain comprises mostly pasture grasslands, with minimal vegetation height. This works in favor of the project because when constructing on grazing land, developers do not have to consider additional costs such as crop damage, drainage tile damage repair, and irrigation disruption.

Coyote Spring will involve 5,857 acres of land (Green & Sorrells, 2020). Of the four tracts of land (Table 2), three are owned by Mr. William Condon of Sterling, while the fourth, partial tract is owned by the Ruff Family Partnership ("Sidwell's Portico," 2020). Land usage across the tracts vary, but is predominantly agricultural/pastoral with minimal development of access roads and wells for cattle. The average land value per acre is USD 24.26 ("Sidwell's Portico," 2020).

Table 2. Land usage and ownership across tracts ("Logan County Public," n.d.; "Sidwell's Portico," 2020).

Tract of Land	Value (USD)	Tract Size (acres)	Project Usage (acres)	Usage (%)	Ownership
38026727100131	34,870	916.7	47.44	5.18	William E. Condon
38026733000133	53,170	2205	973.59	44.15	William E. Condon
38048904000001	103,130	4765	4232.91	88.83	William E. Condon
38048918000011	47,120	1936	602.93	31.14	Ruff Family Partnership

The vegetation types present are common in regions of rolling pastoral lands—Conservation Reserve Program reclamation species, smaller concentrations of Shelterbelt and Playa variety, etc.—while the wildlife diversity is consistent with that found within developed pasture land—bovine, grouse, small mammals, and some protected avian species ("Interconnection Request," 2009). Additionally, sensitive wildlife species in the general vicinity of this project whose habitats have been considered in development include the silver-haired bat, bald eagle, and whooping crane (NREL, 2020). Proper mitigation strategies will help to protect native vegetation and habitats of sensitive species.

The *Coyote Spring Wind Farm* presents a few potential impacts (Table 3). The site analysis conducted by RHED represents the best possible scenario, while balancing economic performance. Precautions were taken during site selection that considered stringent limitations on noise and shadow flicker compared to state standards. The Openwind analysis revealed only three non-compliant sensors (buildings), allowing RHED to move forward with development.

Table 3. The key data from Openwind for the *Coyote Spring Wind Farm* (Green & Sorrells, 2020).

Potential Impact	Over Limit (of 541 buildings impacted)	Maximum Value	Standard Deviation
Noise > 40 dB	0	35.3	7.8
Days with SF > 30 days	0	17	1.1
Shadow Flicker > 60 min	3	99	5.9
Horizon Impact > 50%	207	131.7	27.1

Wind Farm Design

Once RHED determined the project site and quantified key parameters, attention was turned to micro-siting, overall design, and project optimization. The employed principles stressed the maximization of annualized energy power with minimal project costs, all while adhering to a predetermined set of constraints and taking advantage of economies of scale. The local presence of Vestas in CO led the team to select the Vestas V112-3.0 turbine (Table 4), featuring a rated power of 3,000 kW (Gilden, 2020; Vestas, 2020). *Coyote Spring Wind Farm* comprises 33 turbines for a total generating capacity of 99 MW. While four construction firms were considered for this project, Mortenson was ultimately selected as the general contractor due to their vast experience constructing large wind farms in CO, working alongside Xcel Energy and Vestas, and the fact they they are headquartered in NoVA ("Mortenson Wind," n.d.).

Table 4. Vestas V112-3.0 turbine specifications (SAM, 2020) and ("Openwind," 2014).

Rated Output	Rotor Diam.	Hub Height	Shear Coeff.	Cut-In Value	Peak Value
3,000 kW	112 m	105 m	0.14	3 m/s	10 m/s

Once satisfied with the site layout and projected energy output, the next phase addressed potential impacts, industry best practices, and state regulations. The constraints associated with the project offer not a comprehensive accounting, but rather inform siting decisions and the optimization routine with Openwind (Table 5).

Table 5. Constraints applied to Openwind modeling of the *Coyote Spring Wind Farm*.

Element	Distance	Constraint	Element	Distance	Constraint
Buildings	500 m (“Openwind,” 2014)	Outside	**Powerlines**	7000 m	Inside
Existing wind turbines	1600 m (Busby, 2012)	Outside	**Powerlines**	250 m (“Openwind,” 2014)	Outside
Roads	100 m (“Openwind,” 2014)	Outside	**Irrigated lands/ wells**	30 m (“Openwind,” 2014)	Outside
Interstates	1600 m (Busby, 2012)	Outside	**Elevation guide**	10 deg (“Openwind,” 2014)	Less than
BLM/State-owned land	1 m (CO BLM, 2020)	Outside	**Noise**	40 dB (NoiseFree, 2017)	Less than at all buildings
Minimizing tracts of land	1 m	Inside (set area)	**Shadow Flicker**	60 min (“Openwind,” 2014)	Less than at all buildings

During optimization, real-world percent losses in efficiency and capacity factor were considered. The Openwind model utilized the DAWM-Park Wake Model for optimization, with 12.4% in combined losses. In an “ideal” setting that ignores these losses, the model predicts a 36.8% capacity factor, while the non-ideal capacity factor is 33.3% (Green & Sorrells, 2020). The prevailing northwestern winds, topographic features such as the ridgeline, and wake effects forced the turbines in the optimized layout to be placed along two discrete lines: 16 turbines along the ridge proper, and 17 turbines along the leeward side of the ridge (Figure 2). Constraints pertaining to access roads and cabling were set within this area to minimize land use and disturbance, thus leading to the sideways “U” shape.

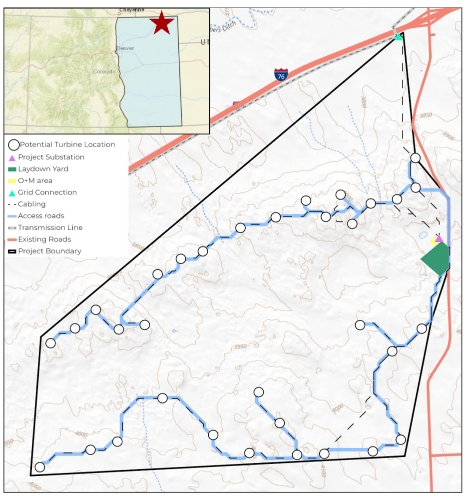


Figure 2. RHED’s *Coyote Spring* site map, created by JMU.

Given the project size (99 MW) and close proximity to transmission, the following variables yield a cost of transmission equal to USD 8.5 million (Table 9): less than 3.3 km of new, high-voltage cables (USD 495,000), one substation (USD 3 million), and one point of interconnection (USD 5 million) (Green & Sorrells, 2020). The project connects to a 115-kV transmission line owned by Highline Electric Association that runs parallel to I-76 (HIFLD, 2019), with an interconnection point found in the Sinclair truck stop parking lot (Google Maps, 2020). Accounting for the access roads (10 feet wide), radius of each turbine location (150 feet), Operations & Maintenance (O&M) building (4 acres), and laydown yard (40 acres), the total area permanently impacted by the project is 118 acres within defined boundaries.

Once the site cabling, turbine locations, and access roads were outlined, RHED determined an appropriate location for the following features near the front or east end of the project. The access point was determined based on the wide sight lines from CO Highway 55—in an effort to reduce the risk of traffic incidents and utilize an already-existing gravel access road serving an adjacent property. The current traffic density is 1,130 vehicles per day (v/d) with a capacity of 2700 v/d (CDOT, 2020). A total of 22 km of access roads will need to be installed, and 1 km of existing roads will be utilized. These new and used roads will be defined by a Road Use Agreement between RHED and Logan County officials, outlining what the county expects in return after the access roads have been utilized. The community can benefit from RHED’s plans to pave access roads that can be used by locals beyond the wind farm’s projected lifetime. RHED will hire a third-party consultant to conduct a survey before construction to study road conditions so it can be returned to its original state, if not better, after the project is finished to minimize impacts. The substation, O&M building, and laydown yard are all found at a central location, where the land is flat. The infrastructure at the front of the project will increase security via the increased perception of physical infrastructure while restricting access to the turbines. This will protect the site and workers, as well as address trespassing and occupational health and safety liabilities. Finally, the *Coyote Spring Wind Farm* is located in close proximity to the existing Colorado Highlands Project (Figure 3) which was commissioned in 2009 and expanded in 2013 (USGS et al., 2020). The project presents a potential impact on the wind resource that drives the *Colorado Highlands Wind Farm*; however, *Coyote Spring* is sited over a mile away from *Colorado Highlands*, sufficient to mitigate wake losses (Howland, 2019).

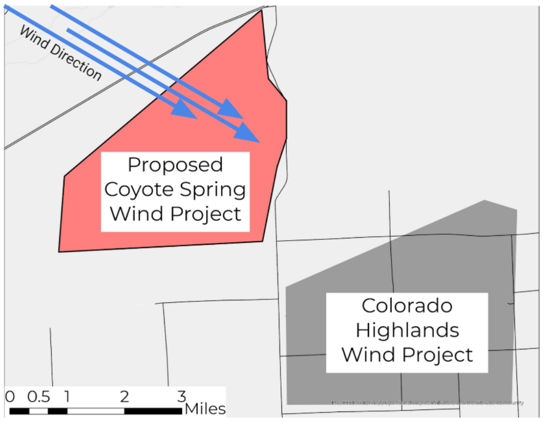


Figure 3. Coyote Spring relative to neighboring project.

2.2 Permitting

When developing a wind project, the timing and securing of permits is critically important. At the federal level, the Clean Water Act requires all wind projects to have a National Pollutant Discharge Elimination Systems' General Storm Water Permit prior to construction (U.S. EPA, 2020). And depending on the results of avian analyses, an additional Endangered Species Consultation and Incidental Take Permit may be required as well (CDOW, 2007; U.S. DOE, 2020). At the state level, the CO Public Utilities Commission (PUC) issues a certificate before the construction of new facilities, requiring local permits to be obtained (CDRA, n.d.). Most importantly, at the local level, individual special use permits and fees are required for the construction of new wind farms. These include, but are not limited to, a building permit, county permit, electrical permit, inspection fee, and grid-interconnection fee (Rice, 2020a). If a local government denies a permit, then there is an option to appeal to the PUC; but according to Policy 5.4 of their master plan, "Logan County shall support the use of wind generated energy opportunities through its rural/agricultural/large lot zoning and building regulations" (Logan County Master Plan, 2011).

2.3 Potential Impacts and Mitigation Strategies

The following discussion regarding impact and mitigation helped to inform the site selection, from prospecting to the final optimization, of the *Coyote Spring Wind Farm*.

Environmental and Wildlife Considerations

In addition to typical environmental impacts associated with the construction and operation of wind farms, the following factors are noteworthy and pertain to a selected site: water usage, runoff (including erosion), and disruption of habitat. In order to follow regulations outlined by the PUC, Vaisala was selected to serve as environmental consultant for the project because their vision aligns with those of RHED regarding environmental conservation ("About Vaisala," n.d.). Vaisala also brings previous wind experience working with Mortenson in CO at *Rush Creek Wind Farm* (Proctor, 2019). As for wildlife and avian impacts, RHED will incorporate recommendations from the CO Division of Wildlife (CDOW, 2007) and U.S. Fish and Wildlife Service (USFWS, 2005) into mitigation planning to address the minimization of disturbances wherever possible. When constructing power lines, the standards outlined by the Avian Power Line Interaction Committee will be followed. Bird and bat concerns can be mitigated via acoustic emissions and curtailment during periods of high activity. Precautions must be taken to minimize surface disturbances to reduce erosion, promptly reclaim any disturbed land, and construct temporary silt barriers to prevent excessive runoff. Best management practices will be followed for construction and reclamation. In an effort to avoid excessive water usage and the impacts associated with depletion, the development group will participate in the South Platte River Water Related Activities Program (SPWRAP, 2019) to manage, track, and engage the local community via a water management plan. For all of these factors, key variables will be monitored to track and manage impact. As the saying goes, *what gets monitored gets managed*.

To achieve the triple bottom line (TBL) of social, environmental, and financial responsibility and performance, RHED will aid in the community's fight for water rights by ensuring that a portion of project revenue is donated annually to the SPWRAP. Members of RHED will also volunteer with the Water Quality Control Division of the CO Department of Public Health & Environment.

Historical and Cultural Considerations

There does not appear to be any sites of historical significance in the immediate vicinity of the project boundary. In Proctor, CO, however, the Powell & Blair Stone Ranch was recently nominated to the National Register because of its local importance (NRHP, 2004). Further, Downtown Sterling was listed on the register in 2013, with a total of 47 sites of historical significance identified (Logan County, n.d.). Fortunately, these landmarks are far enough away that they should not interfere with the project. Broadly speaking, this region is primarily used for crop production and grazing. Outdoor recreational activities are popular in the surrounding parks and wildlife areas situated around the South Platte River.

An additional consideration pertains to the visual and aural impact of the *Coyote Spring Wind Farm*. RHED attempted to minimize the spatial footprint of the project by siting the turbines along two roughly parallel lines instead of one long line, thus reducing the cross-sectional area of the zone of visual influence (ZVI). However, the ZVI of this area has already been compromised by the *Colorado Highlands Wind Farm* and numerous other projects across the river valley and along the Peetz Table Mesa. The additional visual impact of the project is noted; however, the potential for the turbines to obstruct the local scenery has been minimized during optimization in Openwind. This project is purposefully sited farther from development to reduce potential sound impacts.

Community and Societal Considerations

This project will positively impact the community by increasing the local tax base, creating new jobs, and providing revenues to landowners via land lease agreements. When considering social justice issues in the community, RHED also examined demographic data pertaining to Logan County (Table 6). The median household income, comparable to most other eastern CO counties, allows for development with non-excessive land values, while still containing a developed workforce (US Census, 2019).

Table 6. Select demographics for Logan County vs eastern Colorado (U.S. Census, 2019).

	Land Area (mi^2, 2010)	**Population** (2019)	**Population per mi^2** (2010)	**Housing Units** (2018)	**Median HHI** (2018 USD)	**Poverty** (%, 2018)
Logan County	1,838	22,409	12.4	9,126	48,922	14.5
Eastern CO*	1,750	120,732	228	55,628	52,681	15.7

*Denver County included

There appears to be a positive perception of wind in Logan County, with the local government boasting about their clean energy stewardship on the Sterling tourism website by listing wind turbines as a must-see attraction ("Wind Towers," n.d.). And according to the Logan County website, "Logan County is fast becoming an energy hub for the Plains" (Logan County, n.d.). However, while RHED predicts that Logan County residents are likely to support this project (Lawrence, 2007), RHED is prepared for opponents of the project as well. Some locals have expressed concerns about another proposed project (by NextEra) near Fleming, CO (Rice, 2020b). They are fearful that turbines will be constructed in their vicinity, but not on their land, such that they would not be eligible to partake in economic benefits directly by hosting turbine(s). Other impacts that may induce pushback include, but are not limited to, impacts on sightlines, sound, wildlife, and associated with the construction of access roads.

Property owners who welcome turbines onto their pastoral lands experience minimal disruption, as livestock can continue to graze. However, it is good practice to provide compensation for any loss of productive grazing land (i.e. paving and turbine bases). In addition, effective and ongoing community engagement is essential to the success of any wind project. RHED will host informational events to engage with local citizens, meet with landowners, work alongside local policy makers, and facilitate open houses for interested citizens—all intended to help educate the community about the project. The overarching goal is to remain transparent and establish trust.

As for other local considerations, such as visual impacts, there are new technologies available that can help to reduce the density of bright flashing lights on turbines that are known to disrupt views of the night sky. Aircraft Detection Lighting Systems (ADLS) are radar-based technologies that can be used to form a “geo-bubble” around the site and detect when aircraft or wildlife fly into the bubble, thus limiting how frequently aviation lighting must be activated.

When considering further TBL opportunities, RHED will help fight for social justice by offering yearly donations to the local school system(s). RHED hopes this will advance sustainability initiatives in education while forming a deeper relationship with local citizens. RHED also intends to hire and train, to the greatest extent possible, local workers to provide operational support for the project within Logan County. Such efforts are expected to offset any NIMBY-related sentiments and reinforce the intention for RHED to serve as good stewards within the community.

2.4 Plan for End of Project Life

Another crucial component of siting is how to handle the end of *Coyote Spring*’s expected twenty-year lifetime. In this section, the restoration of the site and asset recycling will be discussed.

Restoring the Site

When the *Coyote Spring Wind Farm* is to be decommissioned, temporary work areas will be graded to match the pre-disturbance contours, and affected areas will be seeded with an appropriate native seed blend in accordance with the local Natural Resources Conservation Service (NRCS) to match or enhance the vegetative cover. These efforts will be informed by in-depth surveys taken prior to construction to return the project site to its original state. RHED will obtain approval from the landowners to implement these recommended practices (“Interconnection Request,” 2009; NRCS, 2020).

Asset Recycling and Disposal

Despite having a recycle rate of 85-90% (WindEurope, 2020), wind turbines present a logistical end-of-life challenge. A multi-faceted approach was established to address disposal challenges by addressing the following questions in turn: 1) Have more advanced wind technologies made repowering financially obsolete?; 2) Is there a market for second-hand wind turbine components?; and 3) Has a firm in the U.S. solved the disposal problem and are there appropriate options for disposal? These questions will steer RHED toward either a repowering strategy, or to consider other cradle-to-cradle solutions. These could include selling intact components and/or selling scrap metal for recycling with third-party companies like Belson Steel Center Scrap, Inc. outside of Chicago, Illinois (“Wind Farm Scrap,” n.d.).

3.0 Financial Analysis

The siting analysis presented in the previous section informs the financial analysis described below and vice versa; neither process is completed in a vacuum. RHED utilized SAM, Openwind®, and Excel®, to develop the financial analysis and its various elements.

3.1 Market Research and Analysis

In identifying and pursuance of the target market of NoVA data centers further details are needed to practically and successfully start up and operate a successful business plan. This section will explore and document the information regarding how RHED’s business concept fits into the market.

Market Size and Trend

In 2018, the technology sector consumed approximately 7% of all global electricity (Cook, 2017). As the presence of data centers continues to expand to meet rising demand in internet traffic, their energy demand will continue to grow as well. Large data companies have begun recognizing their high levels of energy usage (U.S. SEC, 2020), and are seeking opportunities to incorporate more renewable energy into their portfolios to reduce their carbon footprint. In 2011, twenty-four of the largest, most energy-intensive technology firms made a commitment to use 100% renewable energy, thereby demonstrating social responsibility with their intentions to create a cleaner data sector (U.S. EPA, 2019).

Data centers represent a multi-billion dollar industry with the capital to make wholesale clean energy purchases outright (U.S. EPA, 2019). Not only do these firms possess the will and the capital to purchase, they also have a need as the industry is projected to grow through at least 2023, driving even further demand for clean energy projects (Table 7). It is worth noting that there is overlap associated with the definition of such closely-related industries, but the sentiment stands.

Table 7. IBIS World Industry in the U.S. (IBIS World, 2018).

IBIS World Industry	Total Revenue (2018 USD)	Annual Growth (2018-2023)	Profit Margin (2018)
Colocation Facilities	13.5 billion	6.5%	18.3%
Data Processing & Hosting Services	162.2 billion	2.2%	8.8%
Internet Publishing & Broadcasting	141.1 billion	9.9%	21.2%
Internet Hosting Services	31.6 billion	9.6%	7.4%

Market Segmentation and Targeting

The definition of 'clean energy' amongst data centers is quite intriguing. *For the most part*, data center operators aggregate their total energy demand and their purchased clean energy (or rights to it), then procure clean energy to meet their total demand, which they allocate across their various facilities (Alphabet Inc., 2020; Digital Reality, 2020). This practice has the curious effect of resulting in "100% clean" data centers still operating and receiving energy from a grid dominated by fossil fuels. Therefore, when RHED proposes to enter into a VPPA with a Virginia-based data center, RHED intends to sell the energy and/or the rights to that energy to a firm with an exceptional concentration of data centers located in VA. There are still small, independent data center operators that could constitute a "NoVA data center," but the industry trend toward consolidation and the upfront capital of small operators is not sufficient to carry the business model intended by RHED (IBIS World, 2020). Thus, large data center operators are the primary target, such as Equinix and Digital Reality, or other large companies with a massive data center presence in NoVA such as Amazon and Facebook (Table 8).

Table 8. A cross-sectional look at VA data centers, total energy need, and clean energy fulfillment.

	VA Data Centers	Total Energy (MWh)	Proportion Clean Energy (MWh)	Sources
Digital Reality	18+	6,601,549	1,188,278	*(Digital Reality, 2020)* *(U.S. SEC, 2020)*
Equinix	13+	~6,000,000	5,520,000	*(Equinix, 2020)*
Amazon Web Services	29	1,436 MW	718 MW	*(DataCenters.com, 2020)* *(AWS & Sustainability, 2020)*
Facebook	1*, Distributed	5,140,000	4,420,400	*(Data Center Knowledge, 2019)* *(Facebook, 2020)*

*Largest sole-leaser, 97 MW *(Data Center Knowledge, 2019)*

RHED will negotiate with data center operators to commit to 100% of the project or a lesser portion. If the latter were to occur, then the balance of the offtake will likely be distributed among local co-ops and merchants. RHED anticipates the VPPA to survive the twenty-year estimated lifetime of the project. However, if the project is still operational after twenty years, then RHED would consider either renewing the data center deal or pursuing a new deal. While there is a significant geographic distance between VA and CO, the wind resource and associated financials of energy procurement are much better in CO than in VA, thus presenting the unique business opportunity for a data center in NoVA to procure its power virtually from a wind farm in CO for the best available price.

Competition and Competitive Edge

This project's attractiveness derives from three factors: (1) Currently, utility-scale wind is cheaper than utility-scale solar (Berkeley Lab, 2019); (2) Wind yields a superior cost of energy compared to other renewable sources (Berkeley Lab, 2019); and (3) NoVA data center growth is anticipated to be consistent and significant during the coming years (WSDOC, 2018). By siting in CO, the cost is minimized, yielding a competitive price within Virginia, the PJM Interconnection (Pennsylvania-New Jersey-Maryland), and the nation. Additionally, NoVA data centers are often engaging in voluntary procurement of clean energy well beyond RPS requirements (U.S. EPA, 2019). Thus, RHED has determined that utilizing a superior clean energy resource to support a competitive industry presents a win-win proposition; however, there remains one additional factor that is critical—timing.

Given the recent VACEA (H.B. 1526, 2020), which mandates a state-wide RPS for Virginia's two leading power producers with provisions for 100% clean power by 2045 and 2050, respectively, the VA clean energy market appears to be transitioning (Schneider, 2020). This project responds to this transition by providing a clean energy source, within the service territory of Dominion Energy, to offset variable costs of constructing new clean energy projects while facilitating the phasing out of fossil fuels. Data centers in NoVA demand reliable power at a competitive price, and the competitive pricing offered by the out-of-state *Coyote Spring Wind Farm* will be particularly attractive to data center operators during this period of transition of Virginia's energy market.

Result of the Market Research

Virginia is a hub for companies such as Amazon, Google, and Digital Reality. Furthermore, VA is home to more than 700 firms that support data processing, hosting, and related tasks (Dominion Energy, n.d.; Data Center Map, 2020). Data centers are involved in heavy virtue signaling, yet drive a hard bargain for procurement of clean energy (Murray, 2020). Given the high volume of internet traffic in this area, it is vital to provide opportunities for these companies to choose greener solutions while reducing the well-documented impact that data centers impose on the environment (Pearce et al., 2018; GreenPeace, 2020). The impending age of the Third Industrial Revolution serves as evidence that *everything moved to a digital platform must be stored somewhere*.

3.2 Business Economics

Once the *Coyote Spring* site was determined and the business opportunity identified, the financials for the project were relatively simple to assess.

Initial Capital Cost

Utility-scale wind development is a highly-complex undertaking—one for which planning and logistics must be carefully managed. Developers must consider the transport of turbines to the site, installation of temporary meteorological towers, delivery of cranes needed to erect and install turbines, and many other factors. A combination of background research and SAM simulations were conducted to determine that the *initial* cost of capital would be USD 183,385,520. This accounts for the acquisition and installation of thirty-three 3-MW V112-3.0 Vestas wind turbines, as well as the engineering, project management, construction of access roads, site improvements, land leases, and legal fees.

Annual Operating Expense

In addition to the initial cost (capital expenses) of construction, the annual costs associated with O&M must be determined. A fixed annual amount of USD 5 million was determined, which will cover the salaries of 11 employees (U.S. Bureau of Labor, 2019), site and equipment maintenance, repair, land leases, and insurance. The variable cost of USD 100/MWh which accounts blade and hub repair, electrical maintenance and overall operation of the site ; and the fixed capacity cost of USD 44/kW-year.

Net Annual Energy Production

After determining the project expenditures, RHED ran numerous simulations to estimate annual energy production. RHED determined that *Coyote Spring* project, assuming a realistic 2% constant loss, will nominally produce an annual energy output of 340.4 million kWh with a net capacity factor of 39%.

3.3 Financial Plan

This financial plan assumes a combination of debt and equity financing. The SAM model slightly favors debt financing, with an estimated USD 115 million of debt, while maintaining an equity value of nearly USD 68 million. RHED will maintain internal control over finances, and will not need to rely on an external equity firm. A Production Tax Credit (PTC) of 60% was assumed, with the remainder of financing derived from debt financing (Heck, 2020).

Highlights of the Financial Statements

The model developed by RHED predicts that all debt will be paid by Year 17. This will allow for operation during three debt-free years with associated profits, and a spike in profits in Year 20. An internal rate of return (IRR) of 7% is predicted by the model.

Desired Financing and Investor's Return

Investors can expect to realize a net present value (NPV) greater than USD 11 million at the end of the twenty-year project term. Using the average EBITDA over the project's twenty-year period and the average business valuation multiplier for the industry, the *Coyote Spring Wind Farm* is valued at USD 251.6 million. A 15% valuation was used to determine the company's value at Year 1 as USD 37.74 million. Therefore, the company is seeking USD 3.77 million, equating to a 10% stake in the company. This investment will support the startup and maintenance of the project, as well as provide an economic cushion should the market experience an unexpected downturn. RHED also seeks investors to participate on the board of directors, to offer insight by virtue of their expertise in the field. Investors can expect a return of 110% over a four-year span, valued at USD 4.15 million, two seats on the board, and the option to reinvest or to sell their returns back to the company after Year 5. RHED will also seek loans from lending institutions to cover debt financing needed to support start-up costs and the long-term operation of the project until Year 17 of the project, at which time the debt will be paid in full.

Incentives

It was recently announced that the PTC will be extended beyond 2020 (WindExchange, n.d.). For wind facilities initiating construction between 2022 and 2024, a PTC of 60% will be available (Brown, 2020). All necessary permitting for *Coyote Spring* will be completed in time to qualify for the PTC, and the VPPA will certify operation beginning in 2024 to provide RHED sufficient lead time in anticipation of possible delays related to the COVID-19 pandemic.

Key Financial Assumptions

A financial analysis of the site was conducted using SAM. Due to challenges in identifying exact values related to wind development, and given that so many variables are proprietary and unpublished, some values were estimated through primary research. This included speaking to industry professionals and/or assuming default values based on data found online. Many values found involved projects of varying sizes, so adjusted the values accordingly to match this 99-MW wind farm. It is also very challenging to account for every variable involved in a project such as this. Many major variables such as operation and turbine related costs were given priority, and then minor costs were extrapolated from these values (Figure 4).

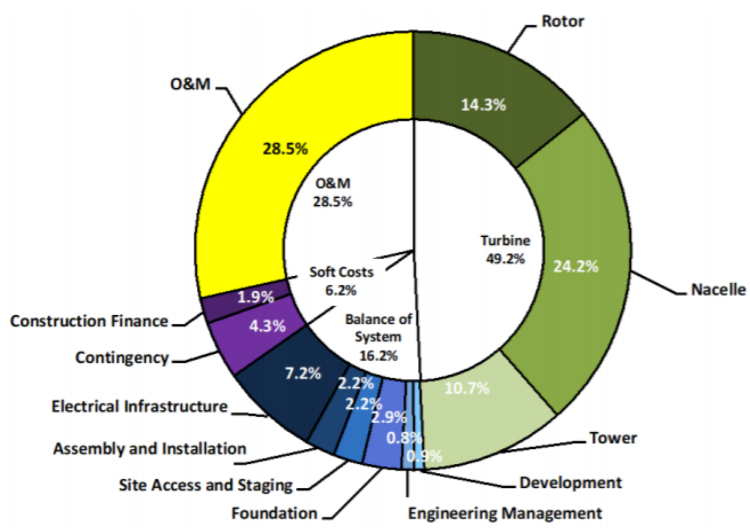


Figure 4. Levelized cost of energy for land-based wind development in the U.S. (Stehly & Beiter, 2019).

Some assumptions are easier to derive from published values, such as the inflation rate or federal income tax rate, while others such as fixed cost capacity or variable cost were more challenging to estimate (Table 9).

Table 9. Key assumptions and results associated with the SAM modeling simulation.

ASSUMPTIONS		RESULTS	
IRR Target	7% (Alalouch et al., 2019)	**IRR**	7%
Project Term Debt	60%	**Annual Energy Prod.**	340,479.963 kWh
Installation Costs	40% per million dollars	**Capacity Factor**	39%
O&M Costs	1.5 million USD/year	**Levelized PPA**	21.27 ¢/kWh
PPA Price Escalation	1%	**Levelized COE**	20.83 ¢/kWh
Federal Income Tax	21%	**Net Present Value**	USD 11,515,796
CO State Income Tax	4.63% (SmartAsset, 2020)	**Net Capital Cost**	USD 183,385,520
Sales Tax	3.90% (Colorado Sales, 2020)	**Equity**	USD 68,165,704
Inflation Rate	2.30%, U.S. rate	**Size of Debt**	USD 115,219,816
Fixed Annual Cost	5 million USD/year		
Variable Cost	100 USD/MWh (Casten, 2008)		
Fixed Cost Capacity	44 USD/kW-year		
Cost of Transmission	USD 8.5 million		

Given these assumptions, SAM was used to generate a projected annual cash flow for the *Coyote Spring Wind Farm* during the twenty-year expected lifetime of the project (Figure 5). During Years 1-10, the greater cash flow is a byproduct of the 60% PTC. Cash flow then decreases until Year 17, at which time debt is fully paid off. This is manifested through the modest cash flow increase in Years 18-19, and then the large increase in revenue in Year 20.

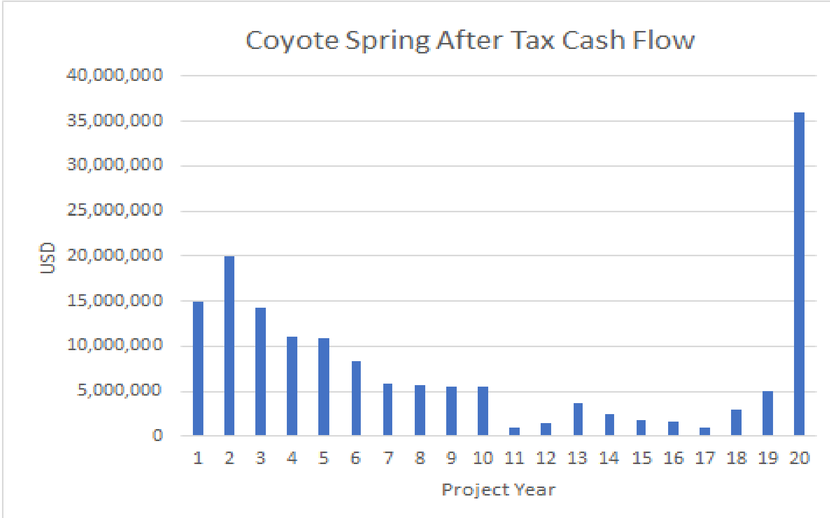


Figure 5. Coyote Spring Wind Farm after-tax Cash Flow for twenty-year expected lifetime.

While Openwind provides the more robust functionality for micro-siting a wind project and estimating performance, SAM enables a deeper dive into financial performance. Once SAM analyses were completed, the results were reconciled with those derived from Openwind by making adjustments to key assumptions. As the Openwind model was further refined, the net capacity factor varied between 28.0% and 33.3% (Table 10) and the projected cost per MWh between USD 11.24 and USD 43.34 (Table 11). This range of costs is competitive and below industry averages, as NREL estimates onshore costs at approximately USD 42/MWh (Stehly & Beiter, 2019).

Table 10. Openwind range of modeling outcomes for the *Coyote Spring Wind Farm*.

Assumptions	**Cost per MWh**	**Capacity Factor (%)**
Best Case Assumptions	36.58	33.3
Average Case Assumptions	40.31	30.51
Worst Case Assumptions	43.34	27.95

The wide range of energy costs generated across thirteen different iterations of optimization was impacted by the presence and duration of the PTC. According to the Openwind model, the *Coyote Spring Wind Farm* is expected to yield a capacity factor of 33.3% and a cost of energy equal to USD 20.10/MWh. Without the benefit of the PTC, the project will present much less favorable metrics (Table 11).

Table 11. Coyote Spring Wind Farm's Openwind economic outcomes of PTC iterations.

Cost of Energy (USD/MWh)	**0 years**	**5 years**	**10 years**	**20 years**
100% PTC = 24 USD/MWh	36.58	25.35	18.84	11.24
62.5% PTC = 15 USD/MWh	36.58	29.00	24.85	20.10
50% PTC = 12 USD/MWh	36.58	30.23	26.91	23.11
0% PTC	36.58	36.58	36.58	36.58

3.4 Expected Cost of Energy and Capacity Factor

Once the Openwind and SAM models were reconciled, final capacity factor and associated cost estimations were derived from the Openwind model, while key financial figures were provided by the

SAM model. This was especially true for the projected cash flow over time. The projected cost of energy derived from the Openwind model is USD 20.10/MWh, and from the SAM model is USD 20.83/MWh.

> The *Coyote Spring Wind Farm* is projected to yield a cost of energy of USD 20.46 per megawatt-hour while operating with a capacity factor of 39%. This projected cost of energy equates to USD 0.020 per kilowatt-hour.

Thus, the *Coyote Spring* project offers a competitive price among wind projects within the Interior distinction (Berkeley Lab, 2019) and compared to clean energy projects nationwide (excluding natural gas, where applicable). This price point will allow *Coyote Spring* support data center operations in NoVA.

3.5 Anticipated Risks and Mitigation Strategies

In addition to the analysis and metrics provided above, it is vital for RHED to acknowledge and plan for risks and uncertainty. In this section we look at multiple issues that extend beyond the normal anticipated risks for wind project development.

The recent emergence and impact of COVID-19 has affected the global economy, in addition to providing mass uncertainty for companies and individuals alike; which is why its widespread impacts on both the wind and data center industries must be considered. In speaking with industry professionals, two key trends were identified: (1) Impacts are variable, but present, i.e. supply chains shutting down (Proctor, 2020) or orders are being deferred (Parnell, 2020), which has halted or delayed a significant number of projects; and (2) Capital is difficult to secure at present, and seeking investments, loans, and capital is nearly impossible (Murray, 2020). While the value of oil and the U.S. dollar have fallen dramatically, and despite anticipation of an eventual rebound, the economy has certainly taken a hit. Projects continue, but with additional hurdles associated with social distancing for in-person operations and capital delays. Therefore, developers must be cautious of uncertainties related to not only the PTC (projected to push up clean energy projects), but the COVID-19 pandemic as well (pushing back project development). Management of these factors is key to successfully balancing a financial plan given the current market. The pandemic caused pent-up demand of economic growth and spending (Smith, 2020), and with appropriate timing, there is an opportunity to exploit current volatility and emerge ahead of other clean energy developers eager to engage in the growing green economy.

Another important risk is the ‘Catch-22’ of data center energy usage. The current market conditions show that there are more data centers being built, but they are also becoming more efficient. As a result, the net energy usage of data centers ranges from flat to slow growth. Even so, the share of data centers sourcing green energy is growing, and is anticipated to continue (Shehabi et al, 2016). Data centers like to flaunt clean energy, and with their ability to self-develop, fulfilling energy needs requires good project timing and competitive national pricing.

Keeping the benefits of the project local will allow RHED to achieve the financial responsibility of the TBL. As previously mentioned, this utility-scale project will bring many economic benefits, including jobs, land lease payments for farmers and ranchers, and an increased local tax base. Project construction adds jobs in manufacturing, transportation, and project construction, especially within the local community (Stefek et al., 2019). The development and construction phases of building a wind farm, especially, bring local construction and supply chain jobs (direct) as well as an increase in local business at hotels and restaurants in the community (indirect and induced). Land lease payments to farmers and ranchers who host wind turbines on their private lands allow them to profit from a new “cash crop” (Lawrence, 2007). In 2018, energy developers spent USD 280 million on land lease payments to private landowners, which is becoming an increasingly important element of wind development and financing.

Finally, utility-scale wind projects pay property taxes, thus generating added revenues for local communities to support new roads, bridges, schools, etc. (WINDExchange, n.d.).

4.0 Optimization Procedures

The development of the *Coyote Spring Wind Farm* was viewed with a problem-centric approach, defined by rational system behavior and the ability to intervene within this system behavior (Meadows, 1999; Waddell et al, 2004). Once a final site was selected, the process shifted from siting to optimization. The optimization was characterized by four non-discrete steps: (1) pursue individual work, directed and supported by existing research and group support within various decision support systems; (2) undergo rapid prototyping and build more than needed; (3) work aggressively and conduct additional research as needed; (4) synthesize the results of siting and financial analyses, then reconcile, adjust, and iterate as needed. In the first three steps, the process involved modifying one assumption at a time, plotting a matrix of the various outcomes of iterations of the single changed variable (an example of this can be seen above in Table 11), determining the ideal value associated with the given assumption, then moving to the next variable and repeating as needed until the optimal solution set was achieved (i.e. lowest cost per MWh). This iterative process was employed to address any discrepancies between competition-related constraints and the realities of wind development.

JMU
CWC

The James Madison University Collegiate Wind Competition Project Development Team thanks you in advance for your time, your insights, and your commitment serving as competition judges. We thank you for your kind consideration and dedication to the field.

COYOTE SPRING
Wind Farm Development

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