Carleton University

Integration of Microgrid in Urban Planning: An Exploration of the Potential to Replicate SPEEDIER in Alberta

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Abstract

This report aims to conduct a thorough analysis of a proposed microgrid project that integrates wind and solar energy systems as primary distributed energy resources (DERs) for the SPEEDIER Project. The objective is to evaluate the feasibility of replicating this project in Devon, Alberta, with the aim of enhancing existing ecosystems and advancing the evolution of energy systems towards sustainability. The incorporation of wind and solar energy systems as primary DERs presents a promising solution to meet the growing energy demands while reducing the carbon footprint and promoting eco-friendliness.

The SPEEDIER Project successfully built a net-zero microgrid in Ontario, but its replication is not feasible in today's policy climate due to strict laws rendering conventional net-metering practices impractical and uneconomical. Furthermore, the program was unique in that it was a grassroots solution that enjoyed strong public approval and simplified regulatory processes. Therefore, the benefits of simplified and expedited regulatory processes in conjunction with strong public approval cannot be understated.

The modernization of the grid in the Town of Devon will have several positive impacts, including reducing greenhouse gas emissions, creating job opportunities, diversifying the energy market, and promoting a shift towards a net-zero smart community. The project's lifespan is 25 years, and it will generate a profit of $2.5 million from wind energy, which will electrify 584 houses. Solar energy will produce 147 MWh and offset 160 kilo tonnes of carbon dioxide.

The report will undertake an in-depth assessment of the technical, financial, and environmental aspects of the proposed project to determine its suitability for replication in Devon, Alberta. Successful replication of the project is expected to significantly enhance existing ecosystems and promote the adoption of sustainable energy systems. The report's findings will provide a valuable knowledge base for future research and contribute to ongoing efforts towards eco-friendliness and sustainability.

The report recommends several actions for both the developer and the Town of Devon to execute the proposal successfully. These include engaging with civic actors, offering community incentives, leveraging pre-existing plans and strategies, ensuring key regulatory measures, securing a long-term power purchase agreement, and partnering with publicly owned financial institutions for low-cost financing solutions. Overall, the report concludes that the proposed microgrid project has the potential to serve as a model for future energy systems while enhancing existing ecosystems and promoting eco-friendliness and sustainability.

Administrative

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Conclusion	**Sartaj** was main pen holder for this section, but we all went in an put things for recommendation
Appendix	**Afreenish**, **Jeffrey** and **Naishadh**
Reference	Whole team contributed

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List of Abbreviations

AC	Alternate Current
AESO	Alberta Electricity System Operator
AIS	Alberta Inter-connected System grid
AMSC	Alberta Municipal Services Corporation
AMSP	Alberta Municipal Solar Program Guidebook
AUC	Alberta Utilities Commission
CAMA	Canadian Association of Municipal Administrators
CANREA	Canadian Renewable Energy Association
CF	Capacity Factor
DC	Direct Current
DER	Distributed Energy Resource
DERMS	Distributed Energy Resource Management System
DSM	demand-side management
EPCOR	Edmonton Power Corporation
EPEA	Environmental Protection and Enhancement Act
EVs	Electric Vehicles
GHG	Greenhouse Gas
HEEA	Hydro and Electricity Act
HRES	Hybrid Renewable Energy Systems
IEC	International Electrotechnical Commission
IESO	Independent Electricity System Operator
IPP	Independent Power producer
IRR	Internal rate of Return
LCA	Life Cycle Analysis
LEN	local energy networks
MCCAC	Municipal Climate Change Action Centre's
MEMS	Microgrid Energy Management System
NPV	Net Present Value
NPV	Net Present Value
NRCan	Natural Resource Canada

OPG	Ontario Power Generation
PV	Photo-Voltaic
REP	Renewable Electricity Program
REP	Renewable Electricity Program
RRO	Regulated Rate Option
SPEEDIER	Smart Proactive Enabled Energy Distribution-Intelligently Efficiently and Responsive
SSG	Small-Scale Generation Regulation
WSS	Wind, Solar and Storage

Units of Measurements

kW	Kilowatt
kWh	Kilowatt hour
kWh/yr	Kilowatt hour per year
MW	Megawatt
MWh	Megawatt hour
Sq. kms	Square kilometers
m/s	Meter per second
W/m^2	Watt per meter square

1 Introduction

It is estimated that Canada's economy will lose $14 billion in energy and utility losses over the next 30 years because of damage to power grids and production facilities, as well as lower water levels at hydro dams and nuclear plants (Rabson, 2022). In addition, the recent growth of solar photovoltaic (PV) and wind energy, as well as the climate agenda of reducing carbon emissions, have disrupted the monopoly of fossil fuel-based power plants, resulting in the transition to a new renewable energy regime (Mariam, L., Basu, M., & Conlon, M. F., 2016).

Despite the suppression of socio-economic activity caused by COVID-19, global greenhouse gas (GHG) emissions decreased by 6.4% in 2020 relative to 2019, or 2.3 billion tons (COVID Lockdown Causes Record Drop in Carbon Emissions for 2020, n.d.). However, when the pandemic ends, GHG emissions are expected to exceed previous levels. To promote a carbon-neutral community, Natural Resource Canada (NRCan) is committed to putting the consumer at the center of the energy transition (Canada, 2017). To promote energy-active citizens and a consumer-centric energy transition, many ongoing national and NRCan projects are focusing on consumer-centric local energy systems, networks, and communities. By means of collaborative R&D calls, NRCan supports projects that aim to optimize local energy networks (LEN) through the development of solutions and tools. In addition to local energy communities, renewable energy communities, and citizen energy communities, this theme (LEN) is also considered by current and future proposed projects (Canada, 2017).

1.1 Scope of the project

The objective of this report is to undertake a comprehensive analysis of the proposed microgrid project, which comprises wind and solar energy systems as the primary distributed energy resources (DERs) for the SPEEDIER Project. The report aims to explore the feasibility of replicating this project in Devon, Alberta, with a view to enhancing existing ecosystems and demonstrating the further evolution of energy systems.

Considering the growing concerns surrounding the use of traditional energy sources and the increasing demand for sustainable alternatives, the proposed microgrid project has the potential to serve as a model for future energy systems. The incorporation of wind and solar energy systems as primary DERs presents a promising solution to the growing energy demands, while simultaneously reducing the carbon footprint and promoting eco-friendliness.

Through an in-depth analysis of the feasibility of replicating the project in Devon, Alberta, this report intends to contribute to the existing knowledge base of sustainable energy systems. The study will involve an evaluation of the technical, financial, and environmental aspects of the proposed project to determine its suitability for replication in Devon, Alberta.

Upon successful replication of the project, it is expected that the existing ecosystems will be significantly enhanced, and the energy systems will further evolve towards sustainable alternatives. The outcomes of this study will not only serve as a basis for future research but will also contribute to the ongoing efforts towards promoting eco-friendliness and sustainability.

1.2 What is the SPEEDIER Project?

As a result, an initiative recognized by NRCan, Lakeland solutions, proposed the SPEEDIER project in 2018 for Parry Sound, Ontario. The SPEEDIER project addresses the issue of reducing load on a constrained transmission system. The original SPEEDIER Project aimed to create a "*Smart, Proactive, Enabled Energy Distribution - Intelligently, Efficiently and Responsive grid*" that builds towards a net zero, innovative community in the Town of Parry Sound, Ontario. (Lakeland Solution, 2022) In the final public report released by Lakeland Solutions (2022), it indicated that the Project SPEEDIER addresses the issue of reducing the load on a constrained transmission system. It is a hybrid demonstration/deployment project, deploying commercially available products while demonstrating technologies still under development. The project focused on building a seamlessly islanded microgrid incorporating renewable energy and storage, addressing the municipality’s net-zero goals. The original project aimed to update the power grid of Parry Sound's town and promote the transition towards a net-zero smart community by using existing initiatives while also net-zero smart community using existing initiatives incorporating more renewable energy and distributed energy resources (DER).

SPEEDIER accomplishes this by integrating diverse Distributed Energy Resources (DERs) a GridOS® DERMS (DER Management System) and GridOS® MEMS (Microgrid Energy Management System) to balance energy consumption and electricity generation from renewable sources (Canada, 2019). The initial project plan involved a grid-scale battery with a rating of 1.25 MW/2.5MWh and a 500 kW AC solar system that generates renewable energy while also providing storage capabilities. In addition, several integrated DERs included in the plan, such as three level-2 Electric Vehicle chargers and one level-3 Electric Vehicle DC fast charger.

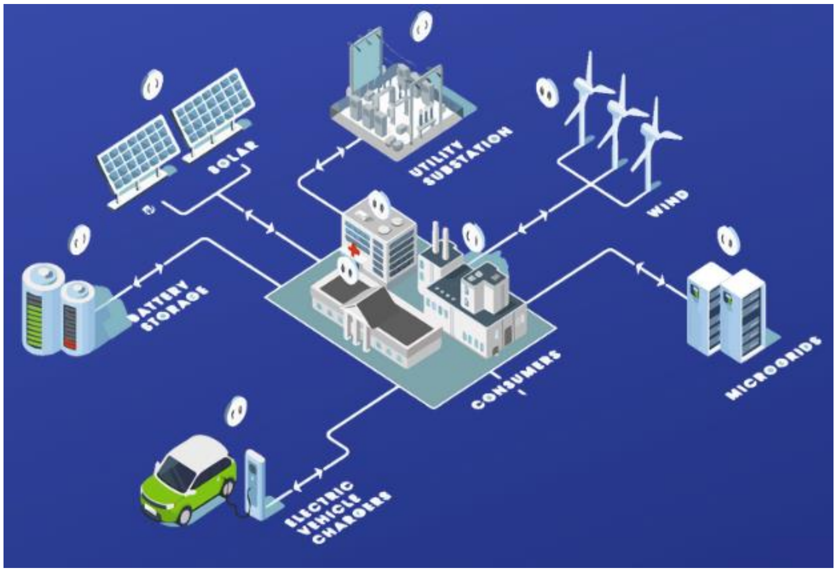

Figure 1: Structure of SPEEDIER

The project also included ten residential batteries with a combined total of 50KW/130KWh capacity and 50 hot water tank controllers. These diverse DERs are integrated using a Distributed Energy Resource Management System (DERMS), and the microgrid electricity generation and consumption is balanced by a Microgrid Energy Management System (MEMS). The DERMS and MEMS work together to manage the microgrid, allowing the microgrid to operate in either grid-connected (grid-tied) or island (off-grid) mode. This enables the microgrid to share energy with the primary grid and generate and store energy independently.

1.3 Microgrids

Microgrids, such as SPEEDIER play a vital role in remote areas where the primary power grid may be non-existent, unreliable, or over-congested. A microgrid contain distributed energy resources (DERs) can help improve the resilience of the primary grid (Lezhniuk et al., 2017), provide added flexibility to the power system (Lezhniuk et al., 2017), and integrate it into the power system. As a result, they can be critical components of the larger primary grid, levelling demand peaks and reducing the effects of capacity shortages.

In developing regions, microgrids can provide an affordable and sustainable source of electricity to communities that may not have had access to electricity before. In addition, microgrids can provide energy independence and resilience, which is particularly important in areas prone to natural disasters such as hurricanes or earthquakes. Microgrids are still in early development, yet various examples are implemented worldwide. An example of what a general microgrid looks like is seen in figure 2.

To better understand microgrid is a small-scale electricity network that can operate independently or collaboratively with other small power grids. It is a local electrical grid with defined electrical boundaries, acting as a single and controllable entity. Microgrids have distributed energy sources, storage devices, and controllable loads, and they can be operated connected to the main power network or "islanded" in a controlled, coordinated way.

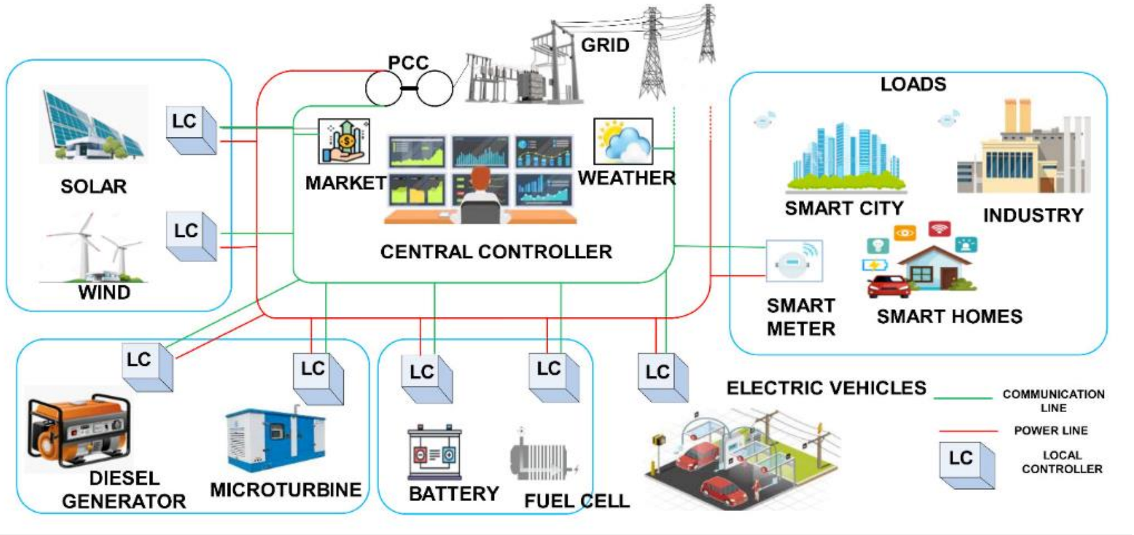

Figure 2 Structure of microgrid

In addition to improving energy efficiency and reducing transmission and distribution losses, microgrids can also increase customer reliability and resilience to grid disruptions. Microgrids can operate in grid-connected or island-based mode. If a microgrid is integrated with the primary power grid of an area, it is a hybrid system. Energy production through microgrids is distributed, dispersed, decentralized, district, or embedded. Microgrids can provide electricity to energy-deficient communities in remote areas, unreliable power grids, and urban areas. They can also improve energy efficiency and reduce carbon emissions. They can improve supply reliability and sustain renewable energy production even during significant disruptions because they can provide energy even if the superordinate grid is down. Several types of microgrids have been developed to address these reasons.

There is still some productive work on microgrids (Santos et al., 2018). The role of microgrids is to provide economic value and business opportunities for smart cities, since they facilitate interaction between stakeholders. Further, energy trading is being developed in order to facilitate energy changes among microgrids (Parag & Ainspan, 2019). Due to their resilience, remote microgrids are often found in maritime, military, spaceship, hospital, and university settings (Parag & Ainspan, 2019). According to the literature, microgrids have the advantage of being able to generate and use energy (renewables) at the site, thereby increasing reliability in areas requiring greater resilience. Since a microgrid is smaller than the primary grid, less energy is lost in conversion and transportation.

1.4 Location: Devon, Alberta

Devon sits on the south bank of the North Saskatchewan River, approximately 40 km (25 mi) southwest of downtown Edmonton (See Figure 1). Devon was established shortly after the Imperial Leduc #1 well struck oil and was created by Imperial Oil to accommodate its workers.

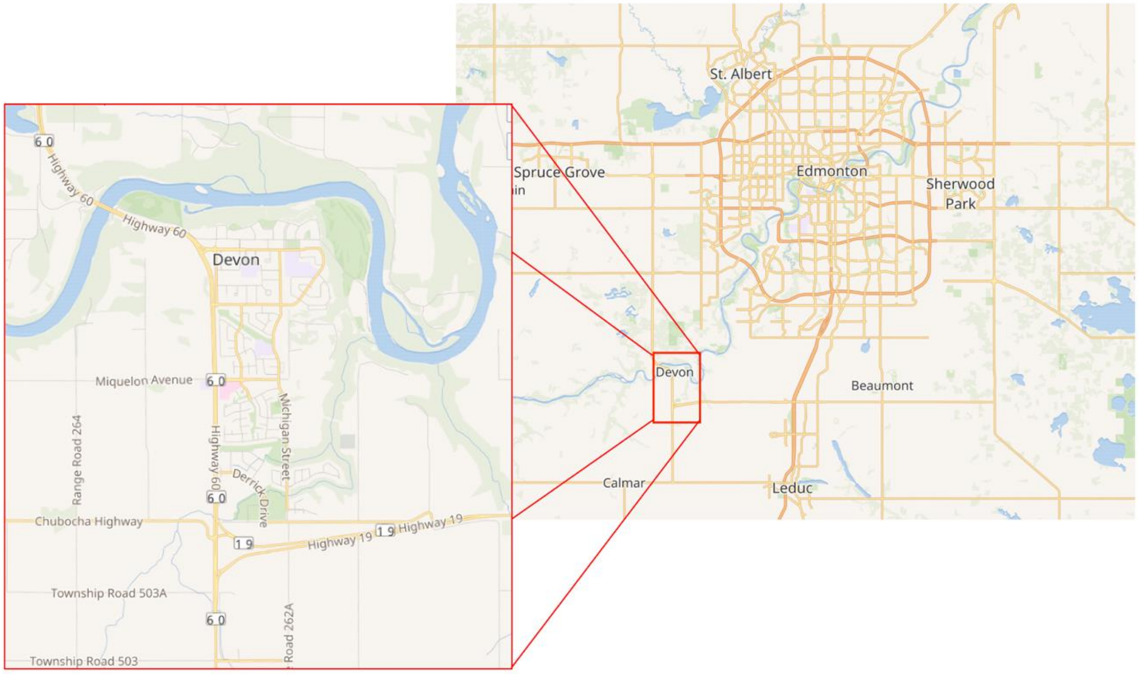

Figure 3: Map of Devon, Alberta, and its geographical location in Alberta (Created using Google Map)

In addition to its vast oil and gas reserves, the region contributes significantly to the economy. Like many other communities in Alberta, there is a growing interest in diversifying the energy mix to include more renewable energy sources, such as wind, solar, and geothermal. As a result of their dependence on non-renewable energy sources, Devon, and many other communities in Alberta face energy constraints. As a result of this dependence, communities can also suffer from fluctuations in energy prices and supplies. Access to transmission infrastructure is another energy constraint. While the region has great potential for renewable energy, a lack of transmission infrastructure can make it difficult to transport energy from remote renewable energy sources to population centers. In recent years, several initiatives have addressed these energy constraints and promoted the transition to more sustainable energy sources in Alberta.

The Alberta government, for instance, has set targets for renewable energy development and established a program to help communities develop renewable energy projects. Additionally, various initiatives aim to reduce greenhouse gas emissions from transportation and improve energy efficiency in buildings.

1.5 Why did we choose Devon, Alberta?

As a pioneering piece of legislation in 2009, Ontario's Green Energy and Green Economy Act combined solar panel production policies with generous feed-in tariffs for clean power. Despite its success in increasing renewable energy production in Ontario, which boasts the nation's largest wind energy capacity of over 4,900 MW, the act increased and politicized electricity rates, becoming a significant political liability in the 2018 provincial elections (National Energy Board, 2022). At the cost of several hundred million dollars to taxpayers, the act was repealed in 2018 (The Fair Hydro Plan: Concerns about Fiscal Transparency, Accountability, and Value for Money, 2018). Currently, Ontario manages a regulated electricity market with the Independent Electricity Systems Operator as the sole buyer of electricity. It is issuing requests-for-proposals with a greater mix of renewable energy sources. This includes emerging technologies such as small modular reactors and battery storage in a bid to focus on Ontario’s nuclear expertise (Decarbonization and Ontario’s Electricity System, 2021).

Consequently, the Independent Electricity System Operator (IESO) and Ontario Power Generation (OPG) are the only entities that purchase and generate electricity in Ontario due to its regulated electricity market. With Ontario's industrial history as a manufacturing hub, a reliable electricity generation facility is necessary to maintain a stable long-term electricity price. Only the IESO is permitted to purchase electricity in this province. In contrast to independent renewable energy providers, large utilities and power producers will benefit most from an integrated renewable energy system. The IESO has issued a long-term request for proposals that require the installation of small modular nuclear reactors and battery storage facilities as an alternative to fossil fuels. Additionally, Ontario's no legal or policy framework allows anyone to sell and produce large amounts of electricity through power purchase agreements. The SPEEDIER project was successful due to solar net-metering and other programs not being replicated. Requests for Proposals favour established power producers over independents regarding clean energy.

In contrast to Ontario, Alberta has a decentralized electricity market where all entities can generate and sell electricity, so we decided to go with Alberta. Also, as do other Independent System Operators (Midwest, Pacific, etc.), the Alberta Electricity System Operator is legally required to provide transmission infrastructure rather than delay interconnection indefinitely. The only private renewable investment has been made in Alberta due to the ease with which producers can sign power purchase agreements with buyers. Alberta is also one of Canada's highest greenhouse gas producers after Ontario, so it is a prime candidate for the project (as seen in figure 4).

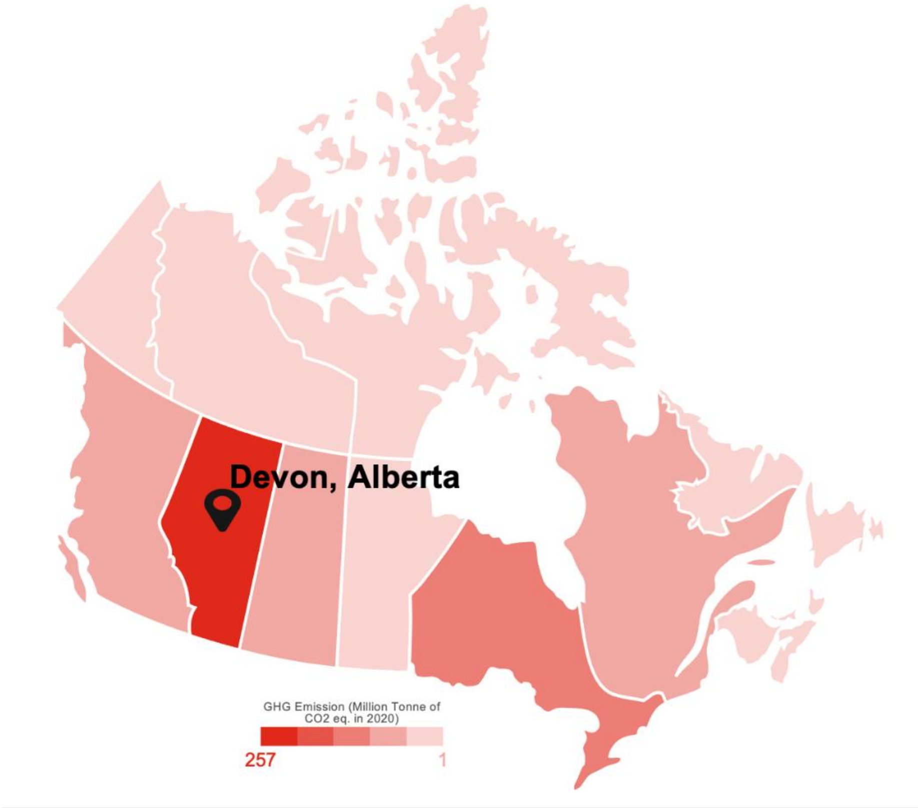

Figure 4: GHG emission map of all provinces in 2020

Due to the vast selection of cities available, to identify the ideal city in Alberta that would allow us to replicate the SPEEDIER Project, we used the following criteria to choose the optimal location/city in Alberta:

- The density of the city
- The total population in the previous year
- Temperature of area
- Limited renewable uptake

Table 1: Comparative Geographical Parameter of Parry Sound, Ontario and Devon, Alberta

Parry Sound, Ontario		Devon, Alberta	
Population	6,879[1]	Population	6,545[2]
Area of Land	13.10 km sq.	Area of land	14.26 km sq.
Population Density	524.9 km sq.	Population Density	459.1 km sq.

In addition, a comparative assessment of the parameters (as seen in table 1) shows that both cities are similar density allowing us to assess the integration of wind energy into the original SPEEDIER project, making replication more probable.

2 Technical Assessment

2.1 Solar Energy Source

Solar energy is an example of distributed energy resources (DER) that produce and supply electricity on a small scale and are spread out over a wide area. Solar panels are used in microgrids to capture, store, and distribute solar energy to a local area. (“Solutions for a Low-Carbon Future,” 2022)

2.1.1 Photovoltaic Effect

Solar panel cells are referred to as photovoltaic cells. “Photovoltaic” means that they convert sunlight into electricity. Many of these small cells link together to form a solar panel. These tiny cells are the key to how solar energy works. Each photovoltaic cell is essentially a sandwich

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[1] "Population and dwelling counts: Canada, provinces and territories, census divisions and census subdivisions (municipalities), Ontario". Statistics Canada. February 9, 2022. Retrieved November 9, 2022.

[2] "Population and dwelling counts: Canada and population centres". Statistics Canada. February 9, 2022. Retrieved November 9, 2022

composed of two segments of semi-conducting material, typically silicon. These “silicon sandwich slices” are prepared with materials that give each one a positive or negative charge. Specifically, the top silicon layer is prepped with phosphorus, adding extra electrons. The bottom layer is dosed with boron, which results in fewer electrons, creating a positive charge. This creates the ideal space for atoms to flow through, like how batteries function. (Solar Panel Orientation - Energy Education, n.d.)

The electricity produced by the solar panel is in DC (Direct Current), which is fed into inverters and changed to AC (Alternate Current) electricity. The electricity produced by the solar panel is in DC (Direct Current), which is fed into inverters and changed to AC (Alternate Current) electricity. A home's electrical panel distributes this through electrical outlets (electrical sockets/outlets). Any excess is exported to the Distribution or Grid. (See Figure 1 below) In the case of a utility size/IPP (Independent Power producer) type – all the electricity produced is exported to the grid. One thing to note is that this renewable energy source is intermittent; if there is no sunlight, then there is no electricity produced - so it is best to pair solar farms with a storage battery system for added system reliability.

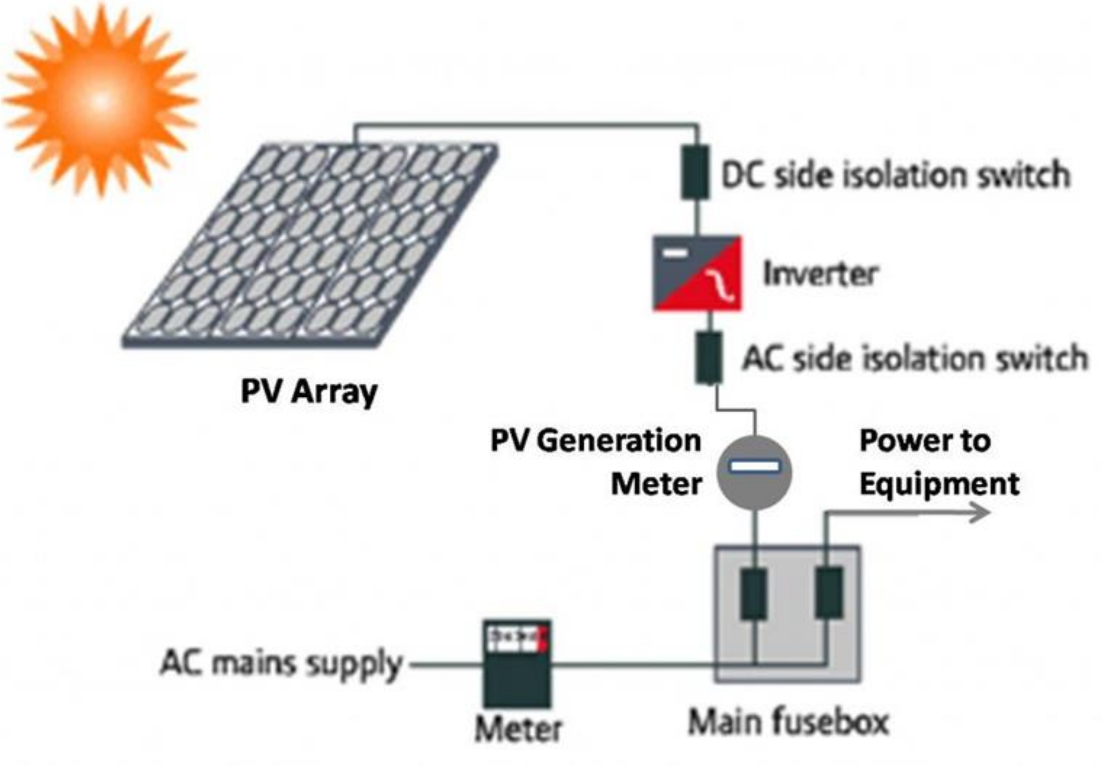


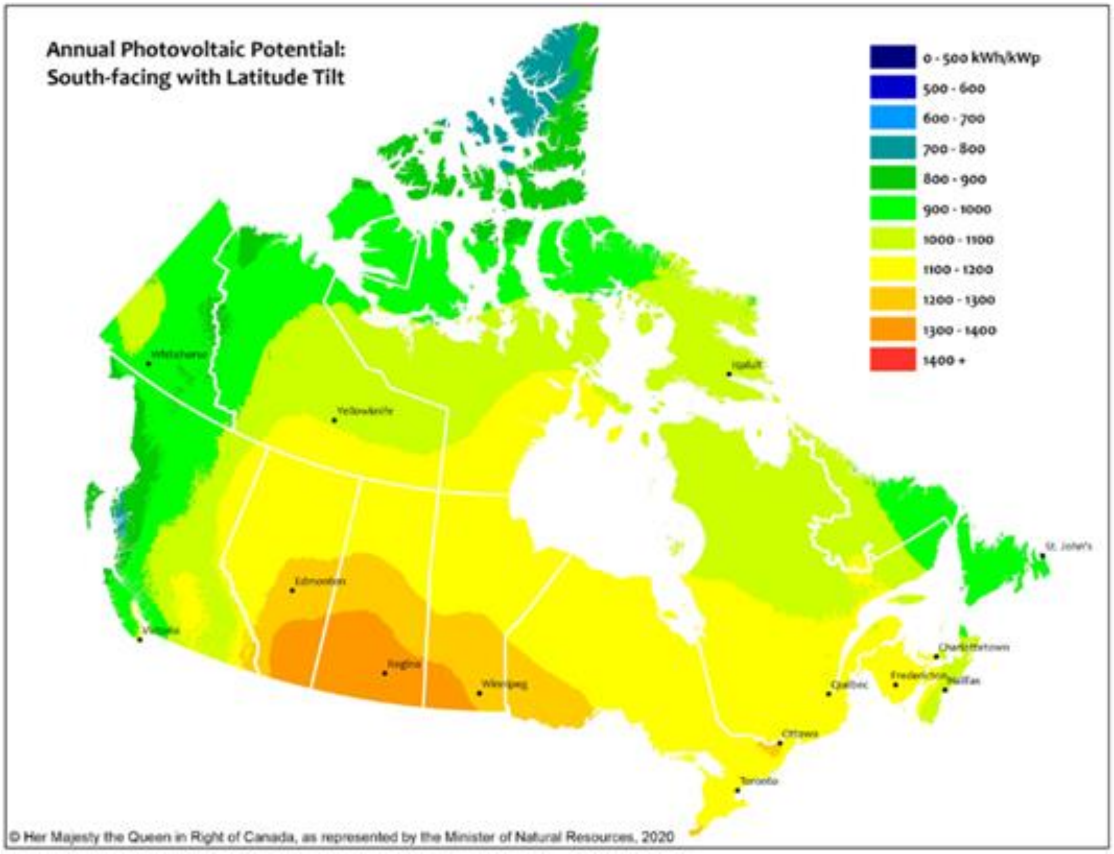
Figure 5: Systematic diagram of solar energy converted into energy

2.1.2 Solar Irradiance

The amount of energy that a photovoltaic system can produce is dependent on the amount of sunlight that the panels receive – more sunlight means more production potential. Solar panels use visible light from the sun to generate electricity. It is not heated as contrary to popular belief. The radiant power emitted by the sun per unit area arriving on a surface falling on a 1 square meter per second. Alberta is currently ranked as one of the highest in the country for installing a solar power system - scoring as one of the best provinces for sunlight levels. (energyhub.org Inc., 2021b)

According to data from Natural Resources Canada, the average solar system in Alberta can produce 1276kWh of electricity per kW of solar panels per year. (See Figure 2) We are using the data from Edmonton since Devon is just around 25 km south of Edmonton. Edmonton produces about 1,246 kWh/yr. See Figure 8 Solar Irradiance Map. (Photovoltaic Potential and Solar

Resource Maps of Canada, n.d.-b) Aside from the solar irradiance, the temperature in Devon is more remarkable than in Edmonton – this is beneficial to solar panels; the efficiency of solar panels is enhanced in colder temperatures.



Annual Photovoltaic Potential: South-facing with Latitude Tilt

© Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources, 2020

Figure 6: Solar Irradiance across Canada

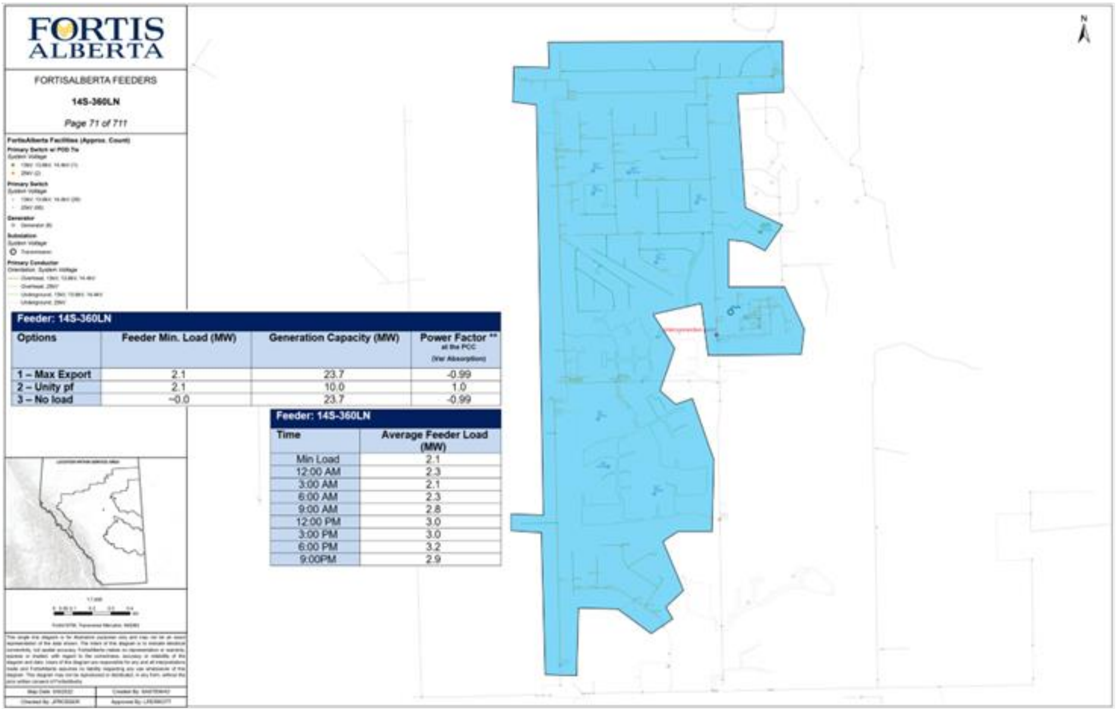
2.1.3 Resource Assessment of the Solar System

2.1.3.1 Solar Panels and Inverters

The previous project from Devon in 2015 was used as an example for choosing solar panels. The same specifications were used for the panels and inverters. As per data, solar panels from Quantum were used – specific model Q. PEAK L-G4.2 360-370, which has an array of seventy-two (72) solar cells per panel. (T. Santucci, personal communication, February 27, 2023) For the proposed panels, I considered the efficiency degradation of 0.5% for the panels in 25 years – the older the solar panels, the less efficient it becomes. (Atasu, A., Duran, S., & Van Wassenhove, L. N. 2021) This efficiency will affect the irradiance calculation in the Net Present Value calculations. Likewise,the identical inverters of Huawei – specific model SUN2000-33/36/40KTL-US, also used in the previous solar project in Devon, Alberta. (T. Santucci, personal communication, February 27, 2023)

2.1.3.2 Solar Panels Size

For the solar panels, the size was calculated based on load data from Fortis Alberta and the penetration study they have provided. Approximately 10-15 MW is needed to power the entire township of Devon. However, the Alberta Micro-Generation Regulation cap is only 5 MW.



Feeder: 14S-360LN			
Options	Feeder Min. Load (MW)	Generation Capacity (MW)	Power Factor ** at the PCC (Var Absorption)
1 – Max Export	2.1	23.7	-0.99
2 – Unity pf	2.1	10.0	1.0
3 – No load	~0.0	23.7	-0.99

Feeder: 14S-360LN	
Time	Average Feeder Load (MW)
Min Load	2.1
12:00 AM	2.3
3:00 AM	2.1
6:00 AM	2.3
9:00 AM	2.8
12:00 PM	3.0
3:00 PM	3.0
6:00 PM	3.2
9:00PM	2.9

Figure 7: Data obtained from Fortis Alberta showing the Load data, Renewable penetration data and existing infrastructure in the area. (K. Wheeler, personal communication, March 16, 2023)

As a result of Alberta's Micro-Generation Regulation, five megawatts are allowed to generate electricity via renewables. Microgeneration systems were allowed to serve adjacent sites by amending the regulation in 2016, which increased the size limit from one megawatt to five megawatts. Other changes ensured that microgeneration and the distribution grid were more reliable, stable, and safe. In light of these limitations, a 5MW solar farm has been proposed. Upon establishment, the electric distribution system owner provides metering services and net billing to micro-generators (Micro-generation, n.d.). In addition, the microgenerator's retailer or service provider will act as the supplier's representative, eliminating the need for the unit's owner to negotiate and transact directly with AESO. This will simplify interactions with the Alberta Utilities Commission (AUC) and the Alberta Electric System Operator (AESO). The previous installation's technical data (Devon Project) was also used as a reference. In light of these limitations, a 5MW solar farm has been proposed.

Onsite solar photovoltaic (PV) projects are made possible in Alberta through the Micro-generation Regulation, which governs how residents, businesses, and municipalities generate their renewable energy. This regulation also makes it possible to receive credits for any excess electricity fed to the grid from onsite generators. (Alberta Municipalities Are Ideal Solar Generators - Here’s Why | Municipal Climate Change Action Centre, n.d.)

Municipalities are especially well-positioned to become micro-generators of solar energy. That is why Alberta municipalities are ideal solar generators - and Devon benefits.

2.1.4 Location Assessment

2.1.4.1 Location of Devon

In order to assess the feasibility of the solar farm, the current land zoning of Devon is considered (*Town of Devon > Services > Town Services > Building & Development > Land Use Bylaw*, n.d.) just be some slight infrastructure change to accommodate the POI (Point of Interconnection) between the Solar Farm and the Distribution Line. A location marked “X” is shown in the map in Figure 8.

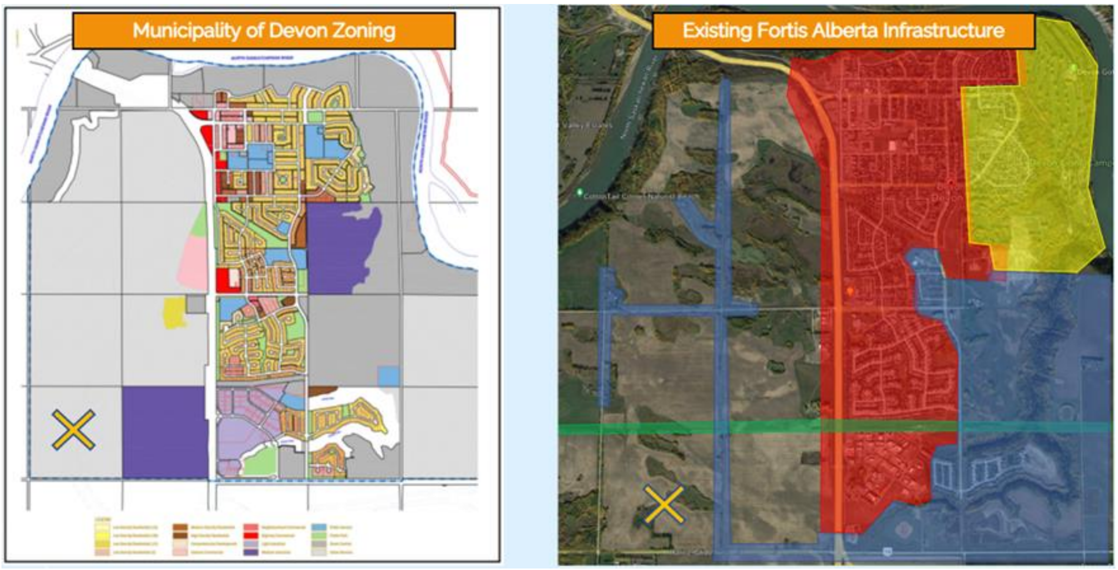
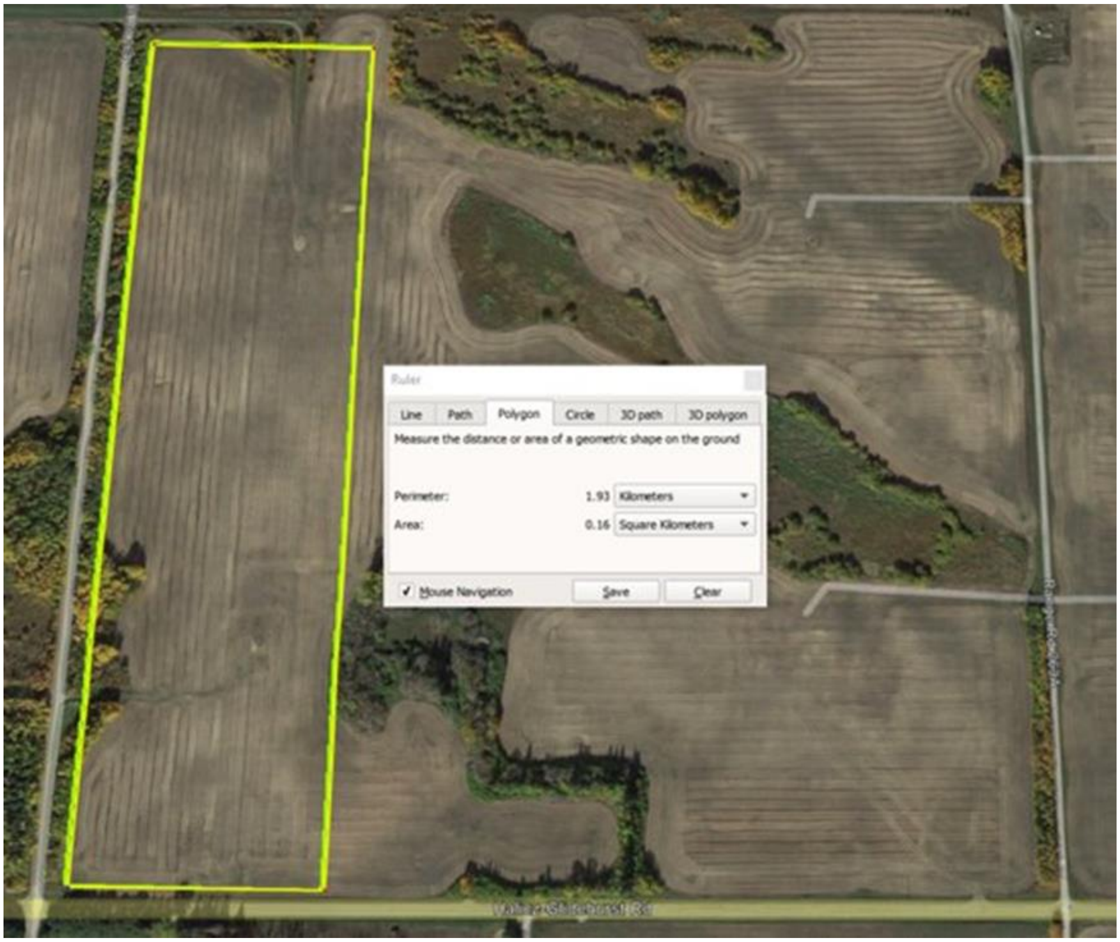


Figure 8: Potential Location of the Solar Farm based on the data from Devon and Fortis Alberta

2.1.4.2 Land Area Needed

Based on the type of installation (ground-mounted, for example), and the type of solar panels being used, the number of solar panels that can be installed per acre of land may vary. A monocrystalline solar panel with greater efficiency will produce more energy per acre, whereas a polycrystalline solar panel (more commonly used in solar farms because they are cheaper) will generate less energy per acre. All equipment on the farm that will consume space must be considered when calculating the acres per megawatt. These include the solar panels as well as the structural components (note that solar farms are generally very space efficient). (Martins, 2022) A solar power plant of this scale can generate enough electricity to power 200 households annually. (Huerta, 2022b). A 5 MW solar farm requires an area of 161,874 square meters. Figure 9 shows a map showing how much land is used or occupied for such a farm.



Measure the distance or area of a geometric shape on the ground

Perimeter: 1.93 Kilometers

Area: 0.16 Square Kilometers

☑ Mouse Navigation

Figure 9: Map showing the area for the proposed 5 MW Solar Farm.

2.1.4.3 Size for proposed solar farm site

On the basis of the renewable penetration study, the proposed project can be scaled up to a much bigger capacity of about 15 – 20 MW. It is possible to connect the generated electricity directly to Alberta's grid – there is an existing 138 kV line (Altalink) in Devon, which can be used to transfer energy. (See Figure 10)

Figure 10: A map shows where a direct grid can be connected on the exiting 138 kV Grid line

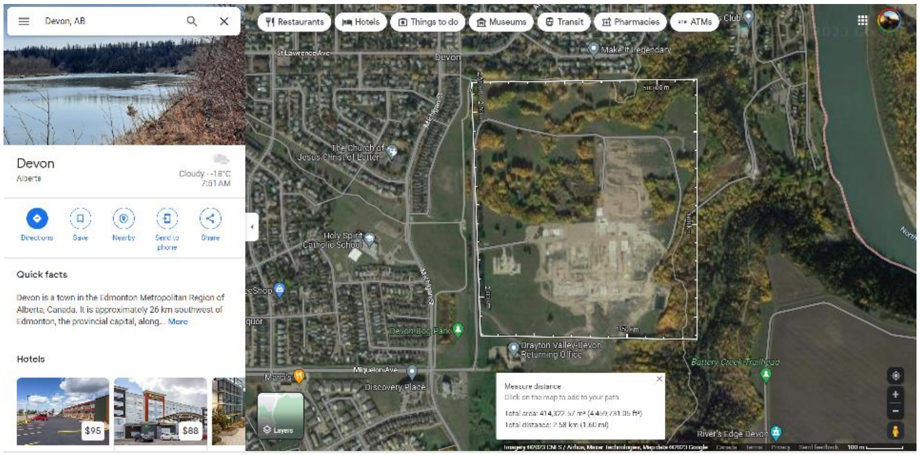
However, with this huge project, zoning might be needed, since it needs four times the area of the 5 MW Solar. The one big challenge would be finding the funding for this large-scale project.

2.2 Wind Energy Source

The Alberta government established a Renewable Electricity Program (REP) in 2016, with the goal of ensuring that 30% of Alberta's electricity comes from renewable sources by 2030, as well as plans to add 5,000 MW of renewable energy capacity by 2030 (Alberta, n.d.). According to industry experts, wind energy projects could account for up to 95% of the new capacity in Alberta.

2.2.1 Location Assessment

Devon, Aberta is in the Southern-Eastern part of Alberta, comprising the maximum potential for Wind Energy generation. The number of wind turbines depends on the size of the site. Wind turbines must be spaced at least '5 rotor diameters' apart to avoid turbulence from affecting one another. This equates to 250 meters for a 500-kW wind turbine and 410 meters for a 2.5 MW wind turbine (renewables first, n.d.).



Devon is a town in the Edmonton Metropolitan Region of Alberta, Canada. It is approximately 26 km southwest of Edmonton, the provincial capital, along... More

Total area: 414,322.57 m² (4,459,731.05 ft²)
Total distance: 2.58 km (1.60 mi)

Figure 11: Proposed Area for implementation of Distributed Energy Resources (Screenshot from google map)

The Figure above portrays our proposed site of wind turbine installation, the area is 0.414 km² on the outskirts of Devon, Alberta, The reason behind choosing this site depends on two reason specifically, sufficient separation from noise-sensitive neighbors and secondly during our virtual meeting with Town of Devon Head of Infrastructure, he suggested that this particular patch of land is dedicated for industrial purpose. There is no plan for now nor in future to integrate infrastructure. Because wind turbines are large and heavy, the access roads and tracks to the site must be capable of carrying heavy loads with no weak bridges, excessively tight corners, or steep gradients. Obviously, as the proposed turbine grows, the size of the constituent parts that must be delivered grows in size, and the access requirements become more stringent. The Endurance 55 kW turbine is delivered on standard articulated lorries, while the others are delivered on special oversize trailers (renewablesfirst, n.d.). The wind rose diagram below is acquired from the nearest weather station, which is Edmonton International Airport, it depicts that strong wind flows from the South-West direction. This weather station is located very near to our proposed site.

The area of region above is 0.414 km² which is equal to 102.38 Acres. According to approximate rule if a wind turbine producing 2 MW is installed it requires 60 acres of land, therefore in 102.38 acres of land we can implement 2 large wind turbines which are enough to provide electricity to 70% of Town of Devon. (Landgate resources, 2021).

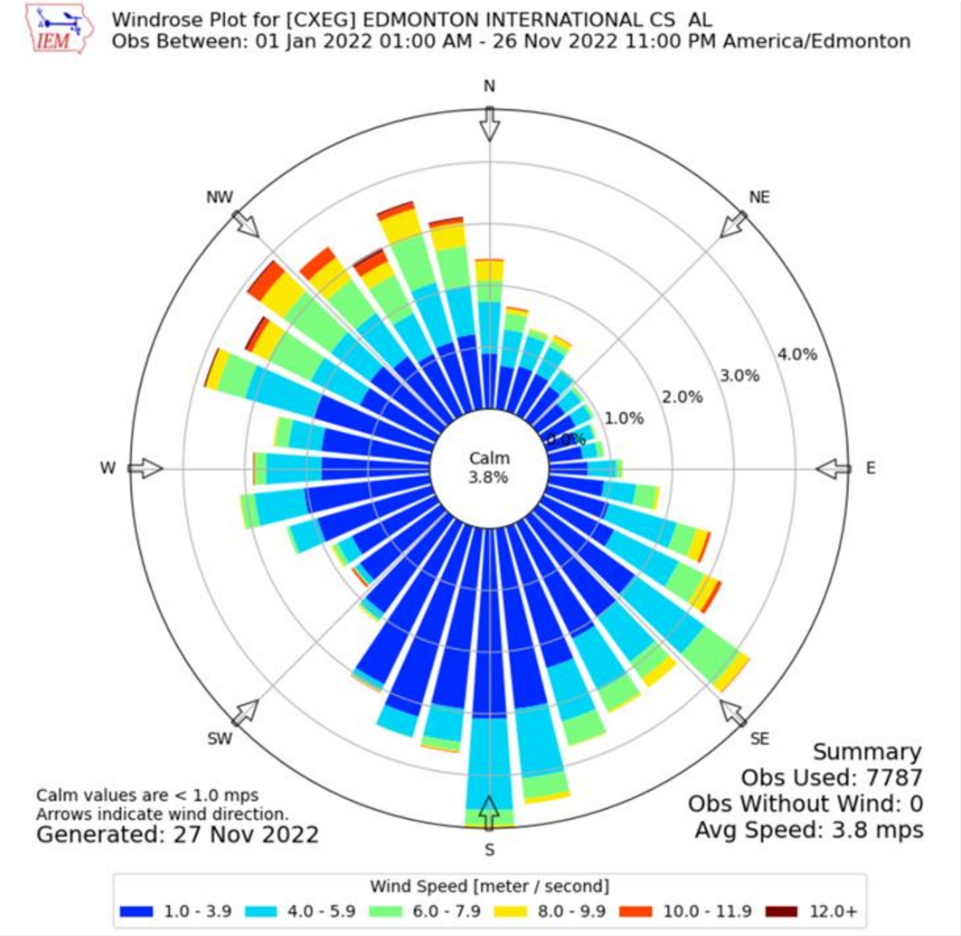


Figure 12: Wind Rose Diagram (Edmonton International Weather Station) (University, n.d.)

2.2.2 Resource Assessment for Wind System

According to Pembina Institute, one of the finest provinces in Canada for wind resource potential is Alberta, which Rystad Energy predicts will take the lead in solar and wind capacity by 2025 (Chen, 2020). In Alberta, wind energy is currently the least expensive source of new electricity, according to the Canadian Wind Energy Association. Experts have also noted that during the transition to renewable energy, there are significant economic opportunities which can be recognized through outside investment, community economic development, and local employment (Jeyakumar, 2020).

For finding the mean annual wind speed of the Devon region, we used the data of Wind Atlas Canada which is the official website of the Government of Canada and comprises the wind data on a yearly and seasonal basis. Devon is situated in the South-Eastern part of Alberta which is gifted with wind speed speeds which are above 5 m/s. One of the key issues with wind energy production is whether wind resources are constantly available during periods of peak energy demand, which typically happen in the winter because of the requirement for interior heating (Farris, 2017).

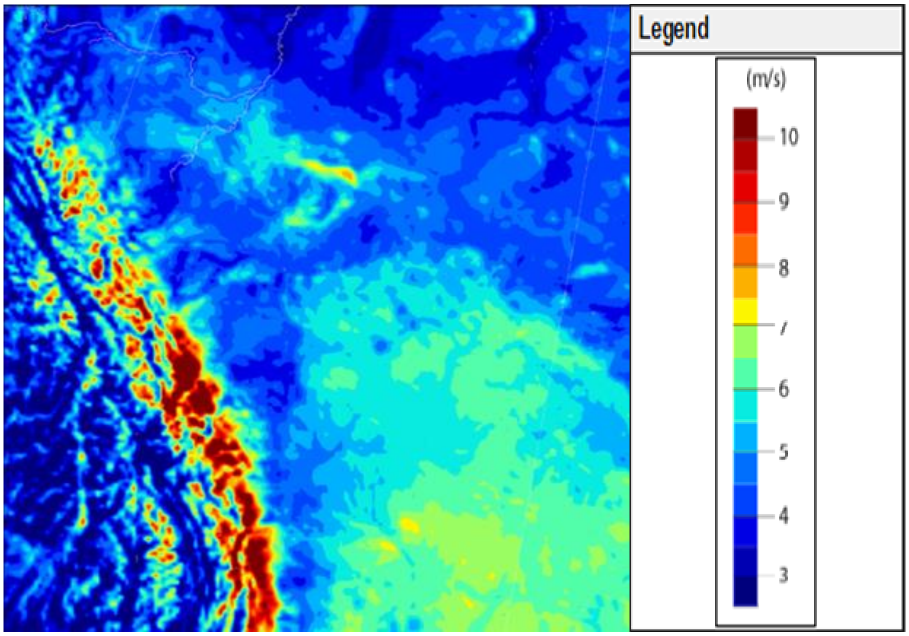


Figure 13 Annual Wind Speed Data of Devon, Alberta at 10m (Canada, Wind atlas, n.d.)

The map below shows a clear perspective of wind speed data in Alberta. As we can see on the map the mean annual wind speed is certainly higher in the southeastern part of Alberta, the area circled black is where our site is situated (Devon, Alberta). The wind of any given region is highly dependent on the topography and other factors. The average hourly wind speed in Devon tends to vary seasonally throughout the year. From September 16 to June 1, the windier season lasts 8.5 months, with average wind speeds of more than 4.7 kilometers per hour. January is the windiest month in Devon, with an average hourly wind speed of 16.5 kilometers (about 10.25 miles) per hour. The calmer season lasts 3.5 months, from June 1 to September 16. August is the calmest month in Devon, with an average hourly wind speed of 12.9 kilometers (about 8.02 mi) per hour (Spark, n.d.).

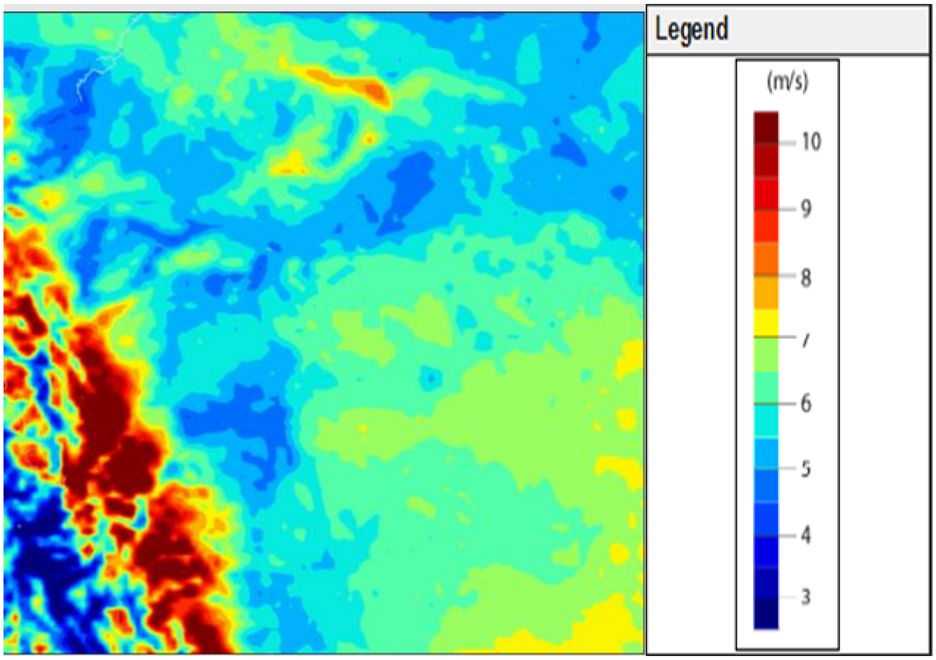


Figure 14 Mean Annual Speed at 80 m in Devon, Alberta

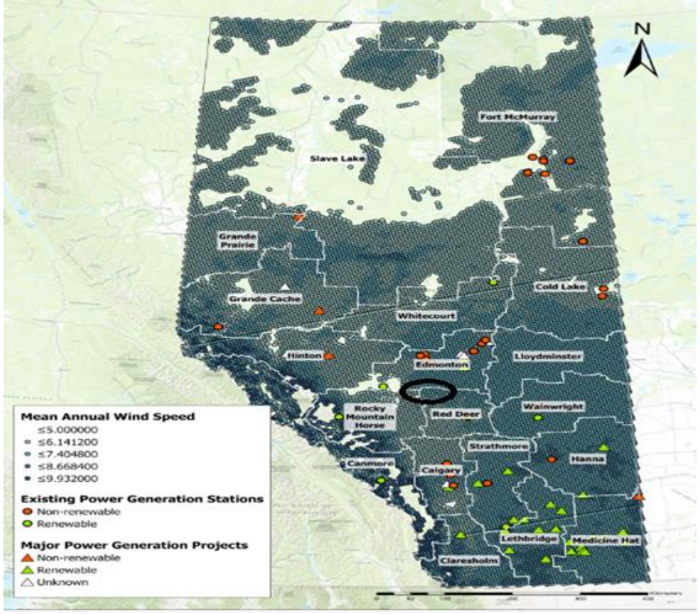


Figure 15: Map of mean annual wind speed >5 m/s to determine suitable regional site (Chen, 2020)

2.2.2.1 Turbine Selection

We propose the installation of two Enercon E-82 turbines at the proposed wind farm in Devon, Alberta. The Enercon E-82 turbine is a high-efficiency wind turbine designed for low to medium wind speeds. The turbine has an 82-meter-diameter rotor, a 78-meter-high hub, and a rated power output of 2.0 MW (Enercon, n.d.). The Enercon E-82 turbine is specifically designed for wind conditions in North America and is well-suited to Devon, Alberta's wind resource potential. The turbine has a high-power output and is extremely efficient, making it ideal for the site.

The reliability and sturdiness of the Enercon E-82 turbine are key factors that underpin its selection. Enercon is an established wind energy enterprise with an impressive track record, boasting more than three decades of experience in the industry and a global installation count of over 31,000 wind turbines (Enercon, n.d.). The Enercon E-82 turbine has consistently demonstrated its dependability and durability, rendering it a top-tier choice for Devon, Alberta's severe weather conditions.

Another reason to choose the Enercon E-82 turbine is its low noise level. The turbine is designed to be quiet, with a noise level of only 104 dB(A) at a 10-meter distance (Enercon, n.d.). This is well below the Alberta government's maximum noise level of 40 dB(A) during the day and 35 dB(A) at night (Alberta, n.d.). The Enercon E-82 turbine's low noise level makes it ideal for the proposed site, which is located near noise-sensitive neighbors.

The Enercon E-82 turbine boasts exceptional operational efficiency and a noteworthy capacity factor. The capacity factor metric represents the ratio of the actual power generated by the turbine to its rated power output. With a capacity factor surpassing 40%, the Enercon E-82 turbine is among the most efficient and productive wind turbines available in the market (Enercon, n.d.). Thus, the turbine's remarkable capacity factor renders it an optimal match for the wind resource potential in Devon, Alberta, where wind speeds exceed 5 m/s.In conclusion, the Enercon E-82 turbine is a perfect fit for the proposed wind farm in Devon, Alberta. The turbine is highly efficient, reliable, and designed for the wind conditions in North America. Its low noise level and high-capacity factor make it a perfect fit for the proposed site, which is located near noise-sensitive neighbors and has high wind resource potential. Installing two Enercon E-82 turbines in the proposed site will be enough to provide electricity to 70% of the Town of Devon. Now, let’s talk about winter-climate considerations for the project.

2.2.2.2 Winter Climate Considerations

Wind turbine operation in a cold climate, such as Canada's, delivers additional challenges not encountered in warmer climates, such as ice accumulation on wind turbine blades, which results in reduced power output and increased rotor loads, freezing weather shutdown to prevent equipment failure, and limited or reduced access for maintenance tasks (Canada, Wind energy in cold climates, n.d.). From November 19 to March 4, the cold season lasts 3.5 months, with an average daily elevated temperature of less than -1 °C. January is the coldest month in Devon, with an average low of -15 °C and a high of -6 °C (Spark, n.d.). Wind turbine manufacturers have become more aware of the ramifications of cold climate operation and are designing turbines that are better suited to winter conditions. Some turbines can operate in temperatures as low as -30 degrees Celsius by installing "cold weather packages" that would provide heating to turbine components such as the gearbox, yaw and pitch motors, and battery. Various de-icing and anti-icing mechanisms, such as heating and water-resistant coatings, are currently being used, as are operational strategies to limit ice accumulation (Canada, Wind energy in cold climates, n.d.).

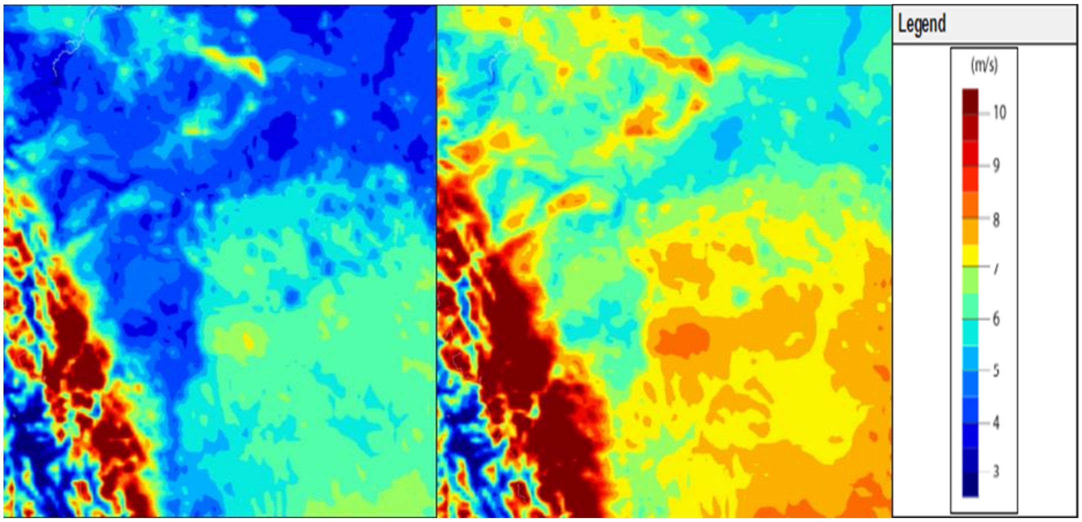


Figure 16. Mean Annual Wind Speed in winter at heights 30 m and 80 m respectively (Canada, Wind atlas, n.d.)

We received the above data for the mean wind speed in Winter which is December, January, and February from the Wind Atlas Canada. Analyzing the data, we found that wind is comparatively low at 30 m height while it is high at 80 m. Production loss is bound to occur in winters if the turbine is placed at 30 m height, but relatively as you increase the height temperature also decreases which results in freezing of wind blades and damage to the turbine.

The wind turbine selected for this project in Devon, Alberta is an Enercon E-82. All ENERCON wind energy converters include a standard ice detection system based on a specially developed and patented characteristic curve analysis method. During operation, the ice detection system compares current operating data such as wind, power, and blade angle to long-term mean values that have been recorded. Ice buildup on the wind energy converter alters its aerodynamic properties, causing the turbine to shut down. The outside temperature determines the thawing time. The wind turbine is restarted after this time period has passed. Automatic restart after icing can be deactivated if required by the specific site. In this case, the operator/owner manually restarts the machine after performing a visual inspection (ENERCON TECHNOLOGY FOR SITES AT RISK OF ICE FORMATION).

Enercon also provides Blade Heating System, this system is known to shorten thawing time period. A fan heater installed in the blade root is activated, and air recirculation is used to heat the air inside the rotor blade. The temperature of the blade surface rises above 0°C, melting the ice build-up (ENERCON TECHNOLOGY FOR SITES AT RISK OF ICE FORMATION).

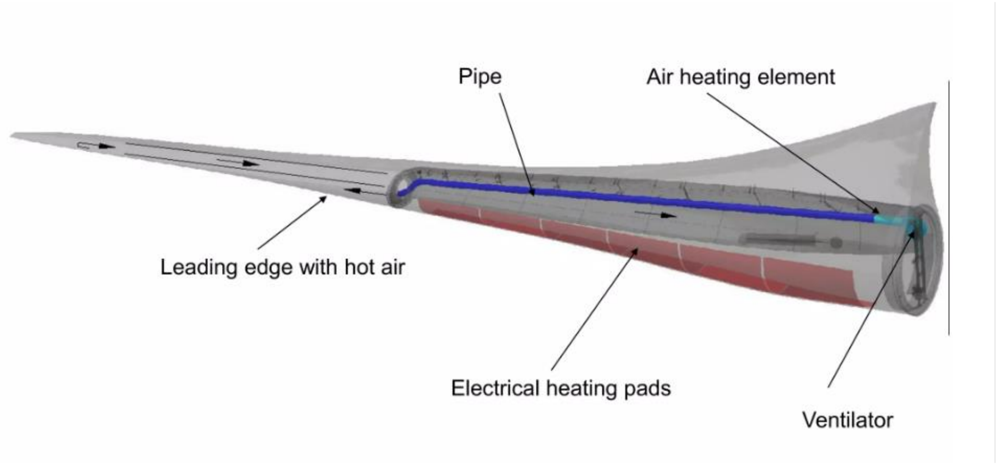


Figure 17 Inner structure of blade including winter climate package.

2.0 Wind Turbine Power Generation Calculations

In Devon, Alberta, an estimate was made of the amount of energy required for the maintenance and operation of the residential community. As of 2020, Devon is estimated to have 2415 households and a population of 6698 people, according to the Point1Home real estate website. As a result of the annual mean wind speed of 8.5 m/s (Lee, Tarek, P.K., & Malmedal), the wind speed in Devon falls into Class 2 winds and IEC 2 (International Electrotechnical Commission) according to European Standards. (International Electrotechnical Commission).

Table 2 Site Classification based on annual wind velocity and density at 10m.

Wind Power Class	**Average Annual Wind Velocity (m/s) at 10m**	**Average Annual Wind Density (W/m^2) at 10m**
1	0-4.4	0-100
2	4.4-5.1	100-150
3	5.1-5.6	150-200
4	5.6-6.0	200-250
5	6.0-6.4	250-300
6	6.4-7.0	300-400
7	7.0-9.5	400-1000

The values in the table are site classification according to the average wind speed at 10 m. According to our resource analysis Devon lies under Wind Power Class 2 which has average wind velocity of 4.4-5.1 m/s at 10 m. Assuming the power density 175 W/m² is available at the site, this can be multiplied by the number of hours per year (8760hrs./yr) to get the energy in Watt-hours that are available at site. Shown below is the calculation:

$$\frac{(175 \cdot 8760)}{1000} = 1533kWh\, per\, m^2$$

This indicates that every m² area swept by a wind blade it produces 1533 kWh energy at 10 m height. If a turbine with blade of 82 m diameter is used (area of 5281.01 m²) the amount of energy generated by wind flowing would be:

$$1533 \times 5281.01 = 8{,}095{,}788 \cdot 33\ kWh\ /\ yr$$

Now for a wind farm it does not work on its full efficiency, therefore the most common assumption is taking 30% as the efficiency. Therefore, the wind farm would deliver from each turbine-generator would be approximately 2,428,736.499 kWh/year.

Now, let us assume the proposed hub height of the tower will be 84 meters and the proposed generator rating will be 2000 kW. We already found the energy generated at 10 m with a wind velocity of 5.1 m/s, to find the wind velocity at 85 meters hub height corrected wind velocity should be found by the following formula:

$$\frac{v}{v_0} = \left(\frac{H}{H_0}\right)^{\propto}$$

Table 3 :Roughness index of the land proposed in Devon, Alberta

Coefficient	**Type or region**
0.10	Smooth ground or water
0.20	High crop on level ground
0.25	Wooded countryside

0.30	Small town with trees and shrubs
0.40	Large city with tall buildings

According to the location analysis Devon falls under smooth ground roughness index ratio. Now using the equation and assuming the terrain farmland as 0.10, the corrected average velocity at 85 meters will be:

$$\frac{v}{5.1} = \left(\frac{84}{10}\right)^{0.10}$$

V = 6.30 m/s

Next step will be finding the blade diameter which will give the largest amount of energy. This can be found out by the equation, where is the proposed generator rating which is 2000 kW

$$2000 = 0.0435D^2(6.30)$$

D = 85.42 m

D ≈ 82 m

The Rotar diameter for the turbine will be 82 meters. If we match a large blade to a smaller generator at a specific location, we may cause the generator to produce more output for much of the year, resulting in a high-capacity factor.

If the blade is made small and the generator is made large, the turbine may be capable of producing enough energy for the generator to produce its full output during high wind speeds, but at slower wind speeds, the generator will be running far below its ratings because the turbine cannot produce enough power for most of the year. As a result, the capacity factor will be low, and total energy output will be less

than optimal. Therefore, to find the capacity factor (CF) by the following equation:

$$CF \approx 0.087v - \frac{P_r}{D^2}$$

$$CF \approx 0.087(6.30) - \frac{2000}{82^2} = 0.25$$

Therefore, the amount of energy the turbine is expected to produce at the site is approximately:

$$E = 0.25\ (8760)\ (2000) = 4380\ \text{MWh/year}$$

In this project we are proposing two wind turbines each of 2MW rated output. Generally array efficiency can range from 95% for a 2x2 array of turbines with 10 blade diameters between each tower to 85% for a 10x10 array with only 4 blade diameters between towers and less than 50% for a 10x10 array with only 4 blade diameters between towers. As we are implementing only two turbines side by side at 8 rotor diameter spacing which is equal to 650 meters apart, we can assume 80% array efficiency for each turbine. Each turbine by factoring in the 80% efficiency on overall generation of a turbine comes to 3504 MWh/year, for two turbine it equals to 7008 MWh/year.

The total number of households in Devon are 2415 residential units, Edmonton uses on an average 1200 kWh per month, therefore assuming monthly electricity usage for each household per month in Devon as 1000 kWh which equals to 12000 kWh per year. From the above equation the energy turbines will generate each year will be 7008 MWh which equals to 7,008,000 kWh/year. Now, dividing the energy generated by the total consumption by each house per year will give us 584 houses.

2.3 Battery Storage

Energy storage technologies have the potential to reduce the impact of wind power variability and solar power variability on the financial performance of a wind and solar farm as well as the security and reliability of the electricity system (Reily, et al., 2022). Combining wind and solar with battery storage provides benefits over using either system alone. These hybrid systems can generate energy essentially anywhere. When the sun shines, it can generate solar power; when the sun is not as bright in the winter, it can generate wind energy and store it for later use . (Peter, 2022)

The project will make use of the EVLO 1000 battery storage option, which was specifically designed for Devon's unique weather conditions (EVLOenergy, n.d.). The battery storage system will ensure consistent and reliable energy supply, reduce carbon emissions, and help the region achieve energy independence. The EVLO 1000 battery option has a 1 MW storage capacity and can supply power for up to four hours. The batteries use lithium-ion chemistry, which provides high energy density, a longer lifespan, and superior cold weather performance. To achieve the desired storage capacity of 5 MW, the batteries will be arranged in a series and parallel configuration (EVLOenergy, n.d.). A microgrid system will connect the battery storage system to the solar and wind farms. When production exceeds demand, the microgrid will be equipped with a power management system that will ensure that energy generated by the solar and wind farms is stored in batteries. During periods of low production, the stored energy will be made available, ensuring a consistent and reliable energy supply.

Figure 18 EVLO 1000 – Battery Storage

The battery storage system will also include a control and monitoring system, allowing for remote control and monitoring of the system's performance. The control and monitoring system will provide real-time data on the status of the battery, including its charge and health, allowing for timely maintenance and replacement of faulty batteries.

In Devon, Alberta, the integration of a battery storage system with a solar farm and wind farm is a step towards achieving sustainable and reliable energy supply in the region. The EVLO 1000 battery storage option ensures the system's performance and durability, making it suitable for Devon's harsh winter conditions. The project will help the region achieve energy independence and reduce carbon emissions, making it both environmentally and financially sustainable. To ensure the successful integration of the solar and wind farms with the battery storage system, the project's implementation will necessitate careful planning and coordination.

2.4 EV charger

The transportation sector accounts for approximately 12% of Alberta's annual greenhouse gas emissions (GHGs), placing it third after oil and gas and electricity (Alberta.ca, n.d.). Electronic

Vehicle Charging stations can be the viable option for the future as Plug in Hybrid Vehicles and fully electric vehicles are increasing in the market. The PHEV technology is emerging quickly because of it more efficient transportation vehicles are introduced in the market every year. EVs are two to three times more efficient than conventional gasoline-powered vehicles and emit no tailpipe emissions; however, the reduction in GHG emissions and overall air quality benefits they bring are dependent on the mix of generation sources on the grid used to charge them. If charged primarily with fossil fuel-based generators, EVs could result in significant GHG emissions or even help extend the life of fossil fuels in some cases. Due to the country's reliance on a coal-fired grid, one study found that EVs can contribute two to five times more smog than gasoline-powered vehicles in China (Bird & Hutchinson, 2019).

Therefore, by connecting the EV Chargers with the Distributed Energy Resources in our case it is the Wind Turbines and Solar Farm will efficiently provide charging capabilities. During the day time Solar Power will be used for powering the chargers and at night in absence of sunlight wind power will be taking over the power supply of the EV Chargers.

Although only a few programmes have allowed customers to charge EVs with renewables to date, in the few programmes where data was available, a third or more of customers chose to use renewable sources. Pricing of renewable energy options and charging time constraints are two factors that can influence participant interest. With EV adoption expected to increase in the coming years, investigating methods of charging EVs with clean energy sources is critical for reducing transportation sector GHG emissions. Although EV adoption is still in its early stages, rapid growth is underway and is expected to accelerate over the next decade. To encourage charging at advantageous times and to integrate renewable energy sources into the grid cost effectively, new solutions for meeting EV demand by commercial customers are required (Bird & Hutchinson, 2019).

2.5 Co-Location of the SPEEDIER system

Co-locating a solar farm with wind turbine, energy storage and other source of renewable energies has several benefits, from future proofing schemes, maximizing land usage and grid capacity and minimize operational costs.

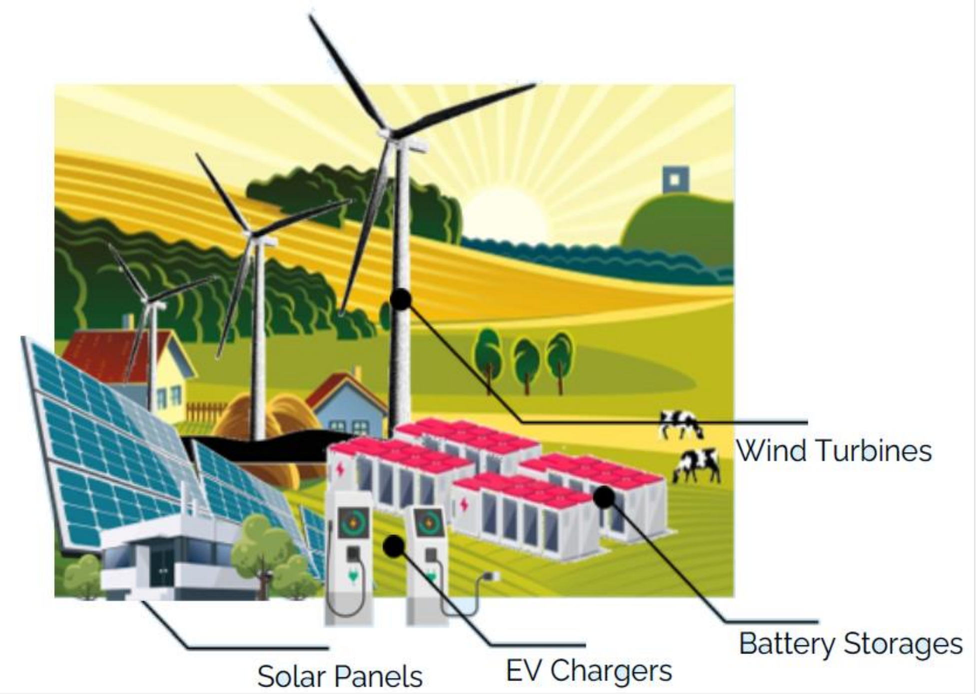


Figure 19 Typical Co-Location of several renewable sources and farming.

There are opportunities for large-scale solar energy installations to reduce environmental impacts and environmental mitigation costs through co-location with vegetation. Vegetation production might occur under or around energy infrastructure(Macknick et al., 2013).

Currently, there is no existing co-located microgrid that shares farmland in Canada as this is still a novel proposal due to not being done anywhere else yet. Though active research is being conducted. However, an article published by Scale grid mentions that vertical farms provide a fertile ground for the same distributed energy and microgrid propositions being explored across North America (Scale Microgrids, n.d.). The article highlights that plant factories require a staggering amount of energy, and microgrids can help to provide a reliable and sustainable source of electricity (Golden, 2020). The article does not mention microgrids sharing farmland. The article mentions that microgrid systems can be co-located on-site and share the same utility interconnect, but it does not provide any specific examples of microgrids sharing farmland.

3 Policy & Political Assessment

With more than 80% of its electricity derived from renewable energy (Canada 2022 Energy Policy Review, 2022), Canada is a leader among industrialized countries in the use of renewable energy in electricity generation. Due to its fragmented electricity sector, Canada has a long way to go before it can achieve total decarbonization. Regulatory frameworks for energy and natural resources are unique to each province, resulting in a wide range of regulations. As previously mentioned, the deregulated electricity markets make Alberta the leader in Canada for clean energy deployment. It is possible for the province to support corporate power purchase agreements (Canada Renewable Power Landscape, 2017), rather than mandating sales to a central buyer, in this case, the Alberta Electric System Operator.

3.1 Alberta Energy Market

In contrast to a restrictive regulatory climate where planning is directed by the provincially owned utilities and other bodies, Alberta’s pioneering decentralized electricity market enables community-led solutions to be executed swiftly. The province has experienced an upsurge in wind power use over the last two decades. In 2016, the Government of Alberta established a Renewable Electricity Program (REP) that sets a target to ensure 30% of Alberta’s electricity will come from renewable sources by 2030 and established plans to add 5,000 MW of renewable energy capacity by 2030 (Delphi Group, 2017). While the first commercial wind farm was installed at Cowley Ridge in southern Alberta in 1993, community-based solar farms have long faced odds to immediate uptake (Nadkarni & Hastings-Simon, 2017). Recent technological changes over the past decade have drove down costs so aggressively that previously ignored projects are much more economical. Past barriers such as lack of roof space or available land, zoning ordinances, market regulations, budgets, financing, or navigating demands of utility companies are resolved much more easily when development is community-led as opposed to utility-led projects which have the tendency to inflame antagonism between rural residents and corporate interests (Nadkarni & Hastings-Simon, 2017).

Alberta’s electricity market has been fully deregulated since 2001 for power generation and retail suppliers. Any qualified generator can participate in the wholesale market by selling to a spot-market where hourly prices are determined by a supply and demand balance overseen by the AESO. Independent power producers participate in the wholesale power pool by submitting bids to sell their electricity. As a result, the hourly pool price is an aggregate of the AESO-regulated bulk supply and demand. Electricity retailers purchase electricity from the wholesale market at the spot price based on their customers' projected demand. This wholesale electricity is transported via high-voltage transmission lines from centralized generation facilities to local substations. Electricity is then repackaged by retailers into their own retail bundles that end-customers pay (Alberta Electric System Operator, 2021).

Non-centralized generation of electricity through behind-the-meter solar systems as proposed by the project will enable the municipality-owned utility to directly participate in power generation and revenue collection that isn’t possible with the traditional centralized generation schemes such as those in Ontario. By producing their own electricity and selling excess to the grid, the citizens of Devon can reduce electricity expenses (Alberta Electric System Operator, 2021).

3.2 Alberta's Policies and Regulations Consideration

Canadian wind and solar projects require several permits and approvals. This is no exception to Alberta's SPEEDIER Project requirements. The following provides a summary of legislation and regulations that may need to be considered for the project deployment.

3.2.1 The Renewable Energy Act

In this province, the Renewable Electricity Act encourages the use of renewable energy. As defined by the Act, renewable energy resources are those that occur naturally and can be renewed within a person's lifetime, including but not limited to (i) moving water (ii) wind (iii) earth heat (iv) sunshine and (v) sustainable biomass. Despite the lack of enforcement methods, the plan sets a target for renewable energy to account for 30% of the province's electrical energy supply by 2030.

3.2.2 Hydro and Electric Energy Act

Hydro and Electric Energy Act stipulates the approval process for power plants, which are classified as "facilities for the generation and collection of electric energy from any source." According to the Alberta Utilities Commission (AUC), anyone cannot construct or operate a power plant without their approval (*Hydro and Electric Energy Act - Open Government*, n.d.). Utility-scale solar and wind developers should pay special attention to four AUC guidelines in particular:

- As part of Rule 007, power plants, substations, transmission lines, industrial system designations, and hydro development applications must be submitted. As part of Rule 007, operators must also determine how to ensure that the project has sufficient cash at the end of its life cycle to pay for decommissioning and reclamation. A Renewable Energy Referral Report from Alberta Environment and Parks is also required, along with a list of any other government offices that must approve the project (*Hydro and Electric Energy Act - Open Government*, n.d.).
- According to Rule 012: Noise Control ("Rule 012"), a project's overall permissible sound levels are calculated separately for night and daytime. Noise Impact Assessments are required by the AUC before a project can be approved to make sure that permissible sound levels are calculated and respected. They also ensure that the project doesn't exceed the permissible decibel levels (*Hydro and Electric Energy Act - Open Government*, n.d.).
- Rule 033 requires wind and solar power plants to be monitored post-approval.
- "Rule 024" describes the rules regarding micro-generation.

3.2.3 Environmental Protection and Enhancement Act

As part of the Environmental Protection and Enhancement Act (EPEA), there are certain approval criteria in addition to the AUC clearance process. As part of the EPEA's Schedule of Activities, the Alberta government incorporated wind and solar energy in 2017. Under the EPEA, larger solar projects are not listed as either mandatory or exempt. These changes widened regulatory oversight of activities related to their development, operation, and reclamation. According to the Activities Designation Regulation, “power plants that produce thermal electrical power (greater than 1 MW)” may be required by the Director(*Environmental*

Protection and Enhancement Act - Open Government, n.d.). The AUC published a new Rule 007 in 2021 for renewable energy and community projects, which includes requirements for small-scale CGU applications. Solar projects, particularly concentrated solar power and thermal power plants could be included in this definition .

In Alberta, two regulators have complementary jurisdictions when it comes to environmental approvals. As a result, Alberta Environment and Alberta Utilities Commission (AUC) would be the regulators that approve renewable energy referral reports (required by AUC), environmental assessment screening, reclamation certificate, water act approvals, and construction and operation of the power plant as well as permits and licences (Bryanskiy N., Salsman J., Ridge S., 2018).

3.2.4 Electric Utilities Ac-Micro-generation Regulation

Under the Electric Utilities Act, Micro-Generation Regulations govern generating units whose sole source of energy is renewable or alternative; the unit is designed to meet all or part of the customer's total energy needs; the total nameplate capacity does not exceed 5 megawatts or the rating of the customer's site; and the customer's electricity is only provided to a site on its own or leased property (Government of Alberta, n.d.-b). Net-metering is another feature of this rule, which allows consumers to be credited for any excess electricity they generate and send back to the grid. The AUC approves most micro-generation projects, except when there are party disputes. The activation of a micro-generating unit is determined by an agreement between the project proponent and the wire service provider. AUC decisions cannot be appealed. The Regulation was amended in 2017 to allow small micro-generators to be credited for the electricity they deliver to the grid at retail rates. Larger projects would not have qualified before.

For electricity generated by large micro generators, 150 kW and above, the hourly wholesale price is credited to the grid. In addition to being able to serve two or more sites on one customer's property, the size of applicable microgenerators has increased from 1 MW to 5 MW. In conjunction with this regulation, AUC Rule 024 applies to micro-generators, allowing more people to generate their own renewable energy (Government of Alberta, n.d.-b).

3.2.5 Small Scale Generation Regulation

To bridge the gap between microgeneration and utility-scale projects, the Small-Scale Generation Regulation (SSG Regulation) was created. Its purpose is to allow partnerships on small-scale renewable energy projects between neighbors, community groups, municipalities, agricultural societies, rural and urban cooperatives, universities, schools, Indigenous communities, and others. Among the sources of renewable energy, the following are defined: "Electricity generated from EcoLogo-certified products, solar, wind, hydro, fuel cells, geothermal, biomass, or other sources if the total amount of energy produced by electrical and thermal energy is less than 418 kg of CO2e per MWh." The regulation allows proponents to apply for either small-scale or community generating units (Government of Alberta, n.d.-b).

3.2.6 Land Use Regulation

Alberta's Municipal Government Act governs municipal zoning policies. While municipalities are responsible for local land use, the Alberta Utilities Commission can override them. As the Alberta government defines its land use regulations for renewable energy in Alberta, it protects wildlife corridors. To develop and maintain conservation and reclamation plans for renewable energy operations (REOs), the guidelines for REOs guide those who run renewable energy operations. If projects exceed 1 MW, they do not require environmental assessments, enabling rapid implementation. An AUC policy affirms that development approval can be more contentious for areas with "agricultural value" as defined by the local municipality (Government of Alberta- Guidelines for Renewable Energy Operations, n.d.).

3.2.7 Growth of Renewable Regulations in Alberta

As a result of Bill 10: An Act to Enable Clean Energy Improvements in 2018, the Municipal Government Act was amended to make it possible for an Alberta Clean Energy Improvement Program (PACE-like program) (Government of Alberta, n.d.-a). In Alberta, energy systems are paid for by municipalities and property taxes are repaid. Loans run with the property in the Alberta program. MGA allows municipalities to create clean energy improvement tax bylaws that outline the programs. Property owners can apply for a clean energy improvement project on their property if a municipality passes a clean energy improvement tax bylaw. Municipalities and property owners can enter into clean energy improvement agreements after the program administrator approves an improvement. In the Clean Energy Improvements Regulation, details on how property owners will repay a loan through property taxes. As part of this regulation, the Minister can designate a program administrator who will develop a list of renovations, adaptations, and installations that may be covered by clean energy improvement agreements.

Additionally, they oversee creating a list of Qualified Contractors who are eligible to perform the work. The Alberta government disbanded Energy Efficiency Alberta (the original program administrator) in June 2020. Alberta Municipal Services Corporation ("AMSC"), a subsidiary of the Alberta Urban Municipalities Association, has taken over the administration of the Clean Energy Improvement Program since then (French, 2022). Municipalities will receive assistance from the AMSC for passing necessary bylaws, ensuring proper installation of projects, and paying Qualified Contractors for their work. By spring 2021, Devon, Rocky Mountain

House, and Canmore will all have passed bylaws for the Clean Energy Improvement Program. Rocky Mountain House and Devon launched their programs in summer 2021.

This assessment is not exhaustive to any upcoming regulatory changes within Alberta and Canadian Regulations. Further in-depth assessment of this may be needed to better understand the exact barriers that might need to be crossed to implement SPEEDIER.

3.3 Tax Incentives & Regulatory Climate

In response to American climate legislation and tax incentives announced in the US Inflation Reduction Act of 2022, Canada also unveiled a slate of new fiscal incentives to expedite clean energy investment in Budget 2023 (Government of Canada, 2023). These measures include the Smart Renewables and Electrification Pathways Program to support local regional programs in rural areas to support electrification and power generation and the recapitalization of the Canada Infrastructure Bank to support projects under its Clean Power and Green Infrastructure mandates with $20 billion in financial support (Government of Canada, 2023). The most promising of the new budgetary measures however would be the Clean Electricity Investment Tax Credit, which would reimburse 15% of the project investment costs (Government of Canada, 2023). These incentives, alongside regulatory reform to expedite future development by easing permitting barriers, illustrates the prime investment opportunity that local governments have to rapidly invest in their decarbonization.Financial incentives have also been buttressed by stringent environmental legislation to promote comprehensive economic industrialization. Ambitious proposals by both the federal and provincial governments exhibit momentum towards a firm cap on emissions. This is further supplemented by key corporate actors in the electricity sector such as the AESO itself publishing their own decarbonization frameworks with a target of 2035

(AESO, 2022). Therefore, first-mover success is critical for municipalities to stay relevant as investment flows shift to regions that can promise investors affordable, reliable and clean electricity to power operations. That was a major factor in provinces such as Ontario landing contracts serve as a hub for EV manufacturing or Quebec for clean fuels refining, a theme recognized by the AESO in its decarbonization report as it seeks not only to increase clean electricity generation but also serve as a hub for future industrial projects as they become electrified (AESO, 2022). Under the Technology Roadmap report published by Emissions Reduction Alberta, a provincial Crown corporation created in 2009 to help the province deliver on its environmental and economic goals; the national and sub-national governments are committed to rapidly bridging the financing gap that exists for rural communities, particularly for emerging technologies (Emissions Reduction Alberta, 2022). This is critical because should Devon choose to expand into more novel energy solutions like battery storage in the future, it can expect significant financial and political support from government institutions.

While institutional investors have been pouring capital into utility-scale projects, local development is more challenging. Recognizing the need to bridge this deficit, federal and provincial grants alongside economic partnerships that invest capital rather than distribute funds offers reflect the political priority governments are placing on decarbonization. It is against this policy backdrop that municipalities like Devon can tap into a melange of incentives from federal grants, investment tax credits, affordable financing from Crown corporations and a regulatory landscape eager to attract investment into clean energy.

3.4 Case Study: Box Springs Wind by WindRiver Power

Community-led renewable power projects are not new entrants to the Alberta electricity market. A comparative analysis of the Box Springs Wind project, a 6 MW windfarm located in Medicine Hat, Alberta, illustrates the commercial viability and political salience of such a model.

Box Springs Wind is considered an unparalleled success and pioneer in in the field of community-led development (Pembina Institute, 2016). The city of Medicine Hat, Alberta, was facing a power deficit in the event of completing an expansion to its local school board and wanted to diversify into clean power sources. Rather than simply sourcing additional electricity from the Alberta grid, it proposed an innovative policy model where it partnered with a local independent power producer, WindRiver Power. It offers the firm a long-term contract to purchase wind power, which in turn allowed the company to finance a $12-million, 6 MW wind farm within the municipal boundaries, a feat that would be legally and politically impossible in Ontario. Medicine Hat relied on a myriad of critical strategies to facilitate this partnership (Pembina Institute, 2016). Firstly, it relied on members of its city council to act as local partners and ease the political tensions that often plague utility-scale renewable power projects. WindRiver also engaged with civic organizations to extol the merits of the project, a step often skipped by utilities that often results in hostile public consultation events. The early mobilization of political support was able to assuage investors, a critical step in overcoming the risk of construction completion. WindRiver and Medicine Hat then turned to ATB Financial, a provincial Crown corporation and the only publicly-owned bank in Canada with retail and commercial operations. Community engagement was a critical factor in securing more attractive financing for the project as it eliminated the significant risk that comes with development major construction projects (Pembina Institute, 2017). Thus, it is imperative to secure early political support to streamline the regulatory approvals process. Furthermore, municipalities can also adopt a development framework to bolster future projects and scale community-led renewable power initiatives. Covenants for expedited regulatory approvals could include Indigenous or community ownership, a model that has been aggressively deployed in the EU to quickly develop renewable power facilities for local use rather than directly uploading electricity to the grid (Pembina Institute, 2017). Other project developers have used such features as a form of inclusive development and a major mitigating factor to regulatory risk. The act of mobilizing key stakeholders at the local level can act as a major disincentive to governments to cancel construction permits, a problem that has plagued pipeline construction and offshore wind projects in Canada and the United States (Pembina Institute, 2017).

4 Financial Assessment

Funding community-driven electricity capital projects can no doubt be expensive. Limited public coffers, particularly for smaller townships, can be a challenge especially in contrast to investor-owned or provincially owned utilities with deep pockets or taxpayer guarantees. Given the economic imperative towards building a decarbonized electricity grid, multiple low-cost financing avenues exist.

Solar PV generation costs have dropped dramatically in recent decades when compared to other forms of electricity generation, such as natural gas or coal. The average levelized cost of electricity for community-scale solar in the United States ranges from $76-150/MWh, compared to $42-$78/MWh for combined cycle natural gas, $156-$210 for natural gas Peaker plants, and $60-$143/MWh for coal (Lazard & Frères Perspectives, 2017).

Figure 20 :Unsubsidized Levelized Cost of Energy Comparison of alternative and conventional energy

Fuel is the greatest cost driver and given its volatility, is a major factor in the cost of producing natural gas which is the backbone of most North American power systems. The long-term outlook indicates that solar PV prices will continue to fall, while natural gas prices may rise. This is further reinforced by the increasing competition for natural gas as supply chains reorient from Russia towards imported LNG from the United States. In addition to limited investment into greenfield natural gas plays in Canada and a pernicious regulatory and political climate needed to build out the requisite infrastructure, natural gas is only poised to become more expensive, particularly for rural communities (Hastings-Simmon, 2016).

A transition towards a solar energy grid offers both financial and environmental benefits. The electricity produced by the solar PV system generates a revenue stream over the lifetime of the system. This is critical because financing partners assess the commercial viability of a project through sustainable and economically resilient cash flows. Renewable generation is much easier to finance because developers' scope for site suitability and rely on climate data over the past 2-5 years, assessing factors such as solar radiation exposure and intensity or wind speeds and topography. These inputs are much easier to forecast than volatile fuel inputs such as coal or natural gas that rely on complex supply chains and geopolitical factors. Returns are thus not only realized through reduced costs when solar-generated electricity offsets additional demand from the grid but also through surplus electricity exports to the grid (Pembina Institute, 2017). Given that Devon and its surround municipalities have no major industrial operations, such as factories or power plants that are more common in rural Ontario townships, solar PV electricity generation is likely to meet more than its daytime needs.

An alternative to wholesale electricity sales is the increasingly popular power purchase agreement. This mechanism entails the signing of a long-term contract with a customer to sell electricity at a favourable fixed cents-per-kilowatt-hour rate. This can apply to customers who have their solar PV array connected behind the metre, or to distribution-connected solar PV systems, where electricity is sold to the wholesale market and the contract is set up as a virtual PPA (Nadkarni & Hastings-Simon, 2017).

Lastly, solar PV systems can act as a long-term electricity price hedge which itself is a financial return in an era of extreme price volatility in electricity spot markets. Because a renewables-based electricity is primarily based around upfront development costs (and often regulatory uncertainty), the deviation in long-term costs is modest as solar panels require far less technical expertise and upkeep to maintain than nuclear reactors or gas turbines. As a result, the cost of electricity is relatively stable. This contrasts with other forms of fossil-fuel based electricity generation where future prices are determined by the price of the fuel inputs. Procuring renewable energy thus creates a natural hedge on future electricity prices.

4.1 Net Present Value Analysis for DERs within this system

4.1.1 Solar system

The net present value (NPV) is the difference between cash inflows and cash outflows over a period. Capital budgeting and investment planning use NPV to analyze the profitability of an investment or project under consideration. By using the appropriate discount rate, NPV determines the current value of a future stream of payments. Projects with a positive NPV are generally worth pursuing, while those with a negative one is not (Fernando, 2022).

The estimated kWH production from solar panels is the following (see Figure 8) – solar panels degrade by about 5% a year. This affects the value of benefits – in this case, benefits on the 25-year are 12% lower than the original year. Solar panels have a lifecycle of 25-30 years, so we chose 25 years in this example.

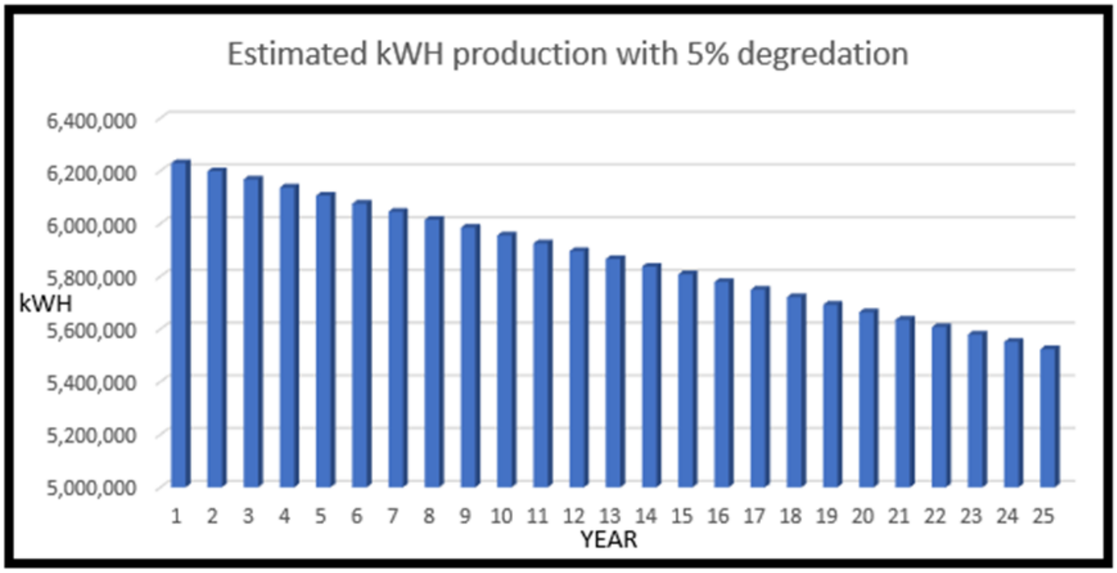


Figure 20 : Yearly energy (kWh) produced for a 5MW System.

To determine the NPV results for each scenario, the fixed values in table 4 were used. For this project, the social assessment is conducted based on theoretical information available as no survey or data was available for the town of Devon, Alberta to identify social needs. These social considerations range from being widespread and pertaining to the public of Alberta, to more specific impacts to neighboring communities.

Table 3: A summary of the key values used to calculate the scenarios.

Fixed Values			
Initial Costs	$6.3 Million (without rebates)	$4.41 Million (with rebates)	
Rebates	$1.89 Million		
Fixed Yearly Cost	$125,000		
Lifetime of project	25 years		
Variables used			
Interest Rate	6%	7%	8%
Variable for Price per kWh at $0.20	60%	70%	80%

As shown in Table 1, NPV results have been calculated for each scenario. The full results can also be found in Appendix 9.1 and 9.2.

Table 4: NPV results with different scenarios identifying the breakeven year.

Scenario	Rebate	Interest Rate	Power Purchase	Breakeven Year	NPV Results
1	No	8%	0.12 cents	25	$27,937.73
2	No	6%	0.12 cents	18	$1,239,407.45
3	No	6%	0.18 cents	9	$5,808,070.94
4	Yes	6%	0.18 cents	6	$7,698,070.94

Using a worst-case scenario, no rebates, an interest rate of 8%, and an electricity purchase of 12 cents per kWH, the solar panels would require approximately 25 years to break even. NPV analysis indicates that the greatest takeaway is the rebates available. If rebates are offered, a 6% interest rate is applied, and electricity purchase is made at 18 cents per kWH, it will take approximately six years to recover the investment. It is recommended that the rebate amount be at least a third of the cost.

4.1.2 Wind system

Report evaluates two wind turbines with a capacity of 4 MW, with a focus on the project's net present value (NPV). Over a 25-year period, the analysis considers capital costs, operating costs, and revenue generated. The capital cost of the project is $5,600,000, with a 6% interest rate used to discount future cash flows. The wind turbines produce 7008.00 MWh per year at a variable cost of $109.90 per MWh, resulting in an annual revenue of $1,401,600.00 at a sales price of $200.00 per MWh.

Table 5 : Results of net present value over a fixed 25 year lifetime

Scenario	**Interest Rate (%)**	**Price per MWh ($)**	**Breakeven Year**	**NPV ($)**
Current Market Price	6	200	13th	2,324,556.79
Best	8	250	8th	4,880,717.30
Worst	8	190	21st	392,000

The NPV of the project is calculated using a cash flow model in the analysis. The model considers the cash inflows and outflows for each year of the project's lifespan. The annual net cash flow is discounted using the interest rate to calculate the discounted cash flow, and the cumulative NPV is calculated by adding the discounted cash flow for each year.

The NPV analysis results show that the project has a positive NPV of $2,324,556.79 over 25 years, indicating that it is financially viable and adds value to the company. The analysis also reveals that the project generates positive net cash flows in all but one year, with the exception of year 0, which a significant capital has cost.

Sensitivity analysis was performed using variable interest rates such as 8% and 7% along with variable rate of selling price. Different scenarios were calculated with the help of variable values of interest rates and selling price by which the worst-case scenario and best scenario are presented in the report.

In Worst-Case scenario the projects cumulative NPV is negative for 21 years of project. The project's total discounted cash flow over the decision horizon of 25 years is only $392,000, which is positive. This does not make sense because for 21 years the project remains in negative cash flow and the project’s life span is maximum 25 years, after that it needs to be decommissioned. In worst-case scenario the interest rate of whopping 8% and sale price of electricity of $ 190 per MWh was used.

As a result of this analysis, it is not recommended to invest in the project because it will not be financially viable. Investors may need to re-evaluate project assumptions or consider other investment options.

In Best-Case scenario, based on the data provided, this report evaluates a proposed project. The project has a $5,600,000 capital cost and a 25-year decision horizon. The annual output is 7008.00 MWh, with a variable cost of $109.90 per MWh, for a total variable cost of $770,179.20 per year. The sales price is $250.00 per MWh, for a total annual revenue of $1,752,000.00. The discount rate used to calculate future cash flows is 8%.

The report depicts the project's annual cash flows, discounted cash flows, and cumulative net present value (NPV) using a cash flow model. The results show that the project has a positive NPV of $2,982,129.16 over the decision horizon, indicating that it will generate a positive return on investment. Furthermore, the analysis shows that while the annual cash flow of the project decreases over time, the discounted cash flow and cumulative NPV increase. The sum of the discounted cash flows over the decision horizon is the cumulative NPV.

It should be noted that the data provided does not include the internal rate of return (IRR) for the project. However, if the IRR exceeds the 8% discount rate, the project becomes even more appealing. If other factors not included in the data have no effect on the project's feasibility, it is recommended that the project proceed based on the positive NPV results.

Finally, this report provides a thorough analysis of the project, demonstrating that it is financially viable and adds value to the company. It is recommended that the company proceed with the project based on the positive NPV results and assuming that other relevant factors do not affect the project's feasibility.

4.2 Regional Market Challenges

The Alberta electricity market can be tricky for power supply agreements. As a merchant market, pricing is established by hourly supply and demand data. Thus, the principal challenge for clean power producers is price certainty. Because of Devon’s community-oriented potential power purchase framework, pricing risk can be significantly mitigated because of a much deeper understanding of local electricity markets through better synchronization with customer demand profiles. According to Kipp Horton, President and CEO of Wind River Power, a Calgary-based IPP, the price of electricity in Alberta averaged 3.3 cents a kilowatt-hour in 2015 yet wind power producers received on average only 2.2 cents per kilowatt-hour almost exclusively due to disparities in production profiles. The deciding factor for commercial success can almost exclusively be attributed to revenue confidence through fixed-pricing via power purchase agreements. Wind River Power illustrates a novel public-private partnership framework that could be emulated by Devon. When the city of Medicine Hat in Alberta wanted to diversify its electricity mix, it partnered with local IPP Winder River Power and the provincial crown corporation ATB Financial to devise a solution (Pembina Institute, 2016). Medicine Hat offered Wind River Power a long-term PPA to buy wind power, which in turn allowed the IPP to secure financing from ATB Financial to build a small $12-million, 6-megawatt wind farm right within the city limits of Medicine Hat. Medicine Hat facilitated the process by expediting permitting and easing zoning regulations, enabling a quicker development timeline relative to utility scale projects ((Pembina Institute, 2017). These incentives in concert with Medicine Hat's AAA credit rating offered significant confidence to investors and enabled them to underwrite the requisite project finance loans at favourable terms (Pembina Institute, 2016).

If the municipality of Devon were to replicate the SPEEDIER model in partnership other local municipalities, it would likely find significant investor interest and would be a valuable policy instrument in achieving a net-zero emissions grid.

4.3 Financing Solutions

The proposed framework towards implementing a net-zero electricity model in Devon calls for a mix of private and quasi-public financing. The primary anchor would be the Canada Infrastructure Bank, a federal Crown Corporation of Canada supports revenue-generating infrastructure projects that are aligned with public policy objectives such as decarbonization or Canadian industrialization through public-private financing.

CIB recently anchored a hydroelectricity expansion project in Atlin, BC to sell power to the Yukon microgrid. Through its $80M capital financing, the project will enable the Taku River Tlingit First Nation community in the Yukon to own the distribution line and construct a small hydroelectric power facility on the Atlin River in British Columbia. This electricity generated from the project will be used to power seven municipalities that mainly serve the Taku River Tlingit First Nation community in the Yukon, directly reducing the consumption of emission-intensive diesel fuel as is common in the Arctic. The loan will be paid back over a 25-year fixed sub-market rate of 2.33% (Canada Infrastructure Bank, 2022).

Bespoke financing solutions like this illustrate how public capital can bolster market solutions to clean energy targets. Because the proposed municipality-led regional utility framework would serve Devon and surrounding towns, the CIB funding could also serve an anchor to public market partners when raising capital, thereby bolstering investor confidence and keeping rates low. Alternatively, the municipality of Devon could also tap into commercial financing options through private-sector banks. While project finance costs would be higher than public options, the Medicine Hat-Wind River model illustrates how upfront PPAs can significantly defray project risks and enable more affordable financing solutions.

5 Economic Assessment

Wind turbine installation and Solar Installations can have a significant impact on the local economy in terms of job creation and income generation. The direct job opportunities created by wind turbine installation can benefit the local community in a variety of ways.

5.1 Opportunities

5.1.1 Job opportunities

A large workforce will be required during the wind farm's construction phase. Project managers, engineers, construction workers, and support staff will be among those employed. These workers will oversee installing the turbines, constructing the necessary infrastructure, and completing the project on time and within budget (Lee & Zhao, 2021).

The construction phase can help the local economy by creating many job opportunities. This is especially useful in areas with high unemployment or few job opportunities. The influx of workers has the potential to increase demand for local goods and services, resulting in increased economic activity.

Maintenance and operation personnel will be required once the wind farm is operational. These employees will oversee ensuring that the turbines are operating properly and dealing with any problems that arise. This ongoing need for personnel can provide long-term job opportunities for members of the local community.

The employment opportunities created by wind turbine installation can also have a positive impact on the area's standard of living. The additional income generated by these jobs can increase disposable income levels, allowing people to purchase goods and services that they previously could not afford. Individuals and families in the local community may benefit from a higher quality of life because of this (NREL.gov, n.d.).

The installation of wind turbines can provide significant direct employment benefits to the local community. The construction phase can generate many job opportunities, while the ongoing need for maintenance and operation personnel can provide long-term employment opportunities. These job opportunities can help the local economy and people's standard of living.

5.1.2 Tourism sector growth

Wind farms, solar parks, and hydroelectric plants, for example, are increasingly being recognized as potential tourist attractions that allow visitors to learn about clean energy technology and sustainability. These installations can not only provide clean energy but also provide tourists with unique educational and interactive experiences. By allowing visitors to interact with renewable energy technology, these installations can raise awareness and understanding of the importance of sustainability and clean energy, while also contributing to local economies by attracting tourists and creating jobs in the tourism industry.

Wind farms, for example, allow visitors to get a close look at wind turbines and learn about the process of generating electricity from wind power. These facilities also provide guided tours, interpretive centers, and educational exhibits that highlight the benefits of renewable energy. Notable examples of wind farms with integrated educational exhibits and interpretive centers include the Altamont Pass Wind Farm in California and the Vestas Wind Turbine Park in Denmark.

Solar parks, in the same way, have the potential to be appealing tourist destinations for those interested in sustainable technology and innovation. Visitors can learn how solar panels work, see them in action, and discover the potential benefits of solar power for lowering carbon emissions and combating climate change. The Solar Energy Research Centre in Odeillo, France, is one example of a solar park, with guided tours, interactive exhibits, and educational programs for school groups (Planan & philltrope, 2019).

Renewable energy installations have enormous potential to serve as one-of-a-kind tourist attractions that provide visitors with educational and interactive experiences. These installations can help the public understand the importance of sustainable energy and the transition to a greener future by showcasing clean energy technology and promoting sustainability.

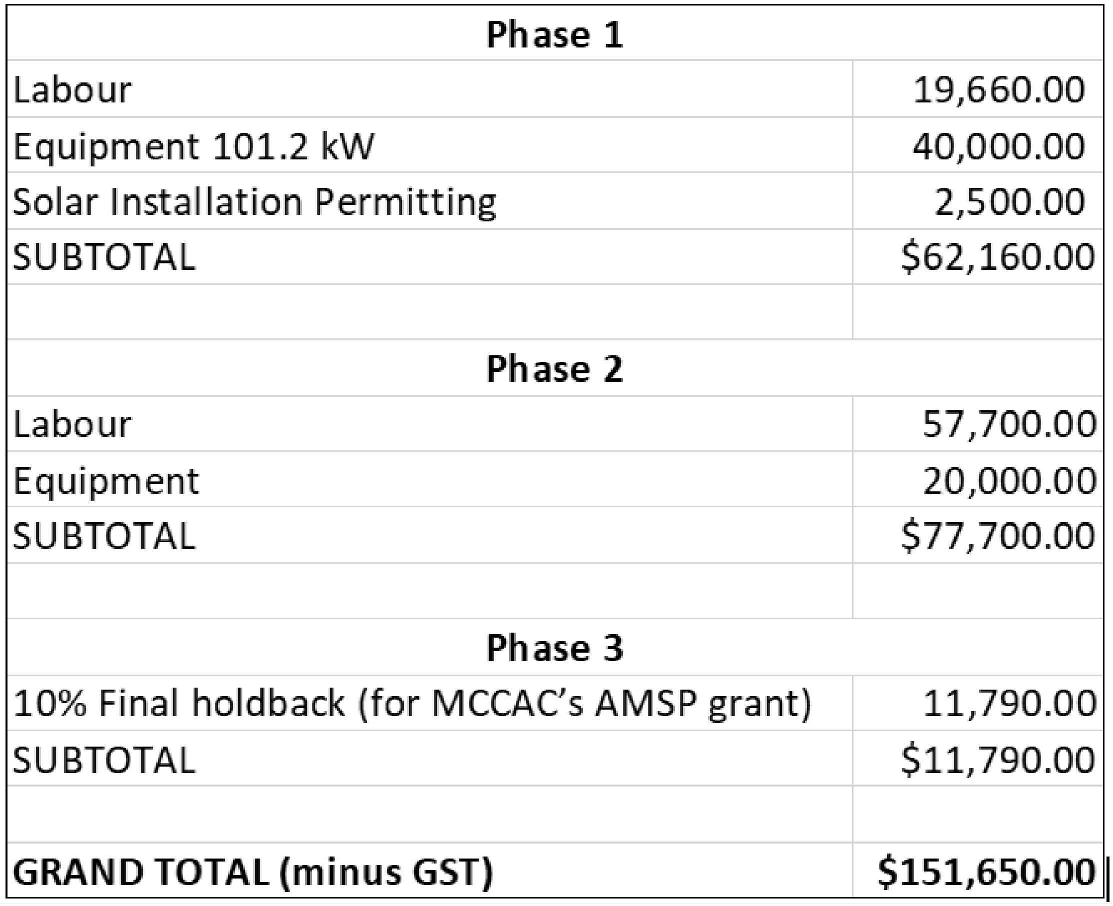
Furthermore, by attracting tourism and creating job opportunities in the tourism sector, these installations can help local economies grow.

5.2 Cost of utility-scale project

5.2.1 Solar System

The costs were calculated based on previous solar project at Devon. (See Figure 6) Assumed utility size solar farm installation and material costs would be 30% cheaper than rooftop mounted solar panels.

Table 7 Costs Breakdown of the 2015 Solar Project (T. Santucci, personal communication, February 27, 2023)



Phase 1	
Labour	19,660.00
Equipment 101.2 kW	40,000.00
Solar Installation Permitting	2,500.00
SUBTOTAL	$62,160.00
Phase 2	
Labour	57,700.00
Equipment	20,000.00
SUBTOTAL	$77,700.00
Phase 3	
10% Final holdback (for MCCAC’s AMSP grant)	11,790.00
SUBTOTAL	$11,790.00
GRAND TOTAL (minus GST)	**$151,650.00**

For the total projected cost in 2023, use the inflation rate (1:1.25 $) to reflect the equivalent cost ($1 in 2015 divided by 2023, Inflation Calculator, n.d.). This is about $9 Million.

Compared to rooftop solar systems, solar farms cost about 30% less to build and operate (Meehan, 2019). This brings the total cost down to about $6.3 Million. The Alberta Municipal Solar Program (AMSP) Guidebook from MCCAC that allows to determine the maximum rebates the project is eligible for (See Figure 7) (ALBERTA MUNICIPAL SOLAR PROGRAM GUIDEBOOK, 2021). Thus, the total rebates will be approximately $1.89 million.

Table 8 Rebates based on Total Installed System Capacity (Alberta Municipal Solar Program Guidebook, 2021)

Total Installed System Capacity (DC)	Rebate
<10 kilowatts	$0.90/watt
10 kilowatts to <150 kilowatts	$0.75/watt
150 kilowatts to <2 Megawatts	$0.60/watt
2 Megawatts to 5 Megawatts	$0.55/watt
In all cases, total rebate funding provided by the MCCAC will not exceed 30% of the total eligible expenses per project, as defined in section 3.4	

In total, the cost to be financed minus rebates would be about $4.41 Million. Yearly costs for staff and maintenance would be approximately $125,000.00. This cost would be shared between the federal and local governments through rebates. The repayment period for the loan is five years. It is expected that the new system will be operational within the next two years

5.2.2 Wind System

Capital costs for utility-scale wind and solar projects in Canada in 2017 were C$1600/kW and C$1800/kW (in 2016 dollars). These are based on estimates from other studies and include costs for materials, equipment, labor, and development. Individual projects may have higher or lower capital costs depending on their location in the country or the size of the project (Regulator, n.d.).

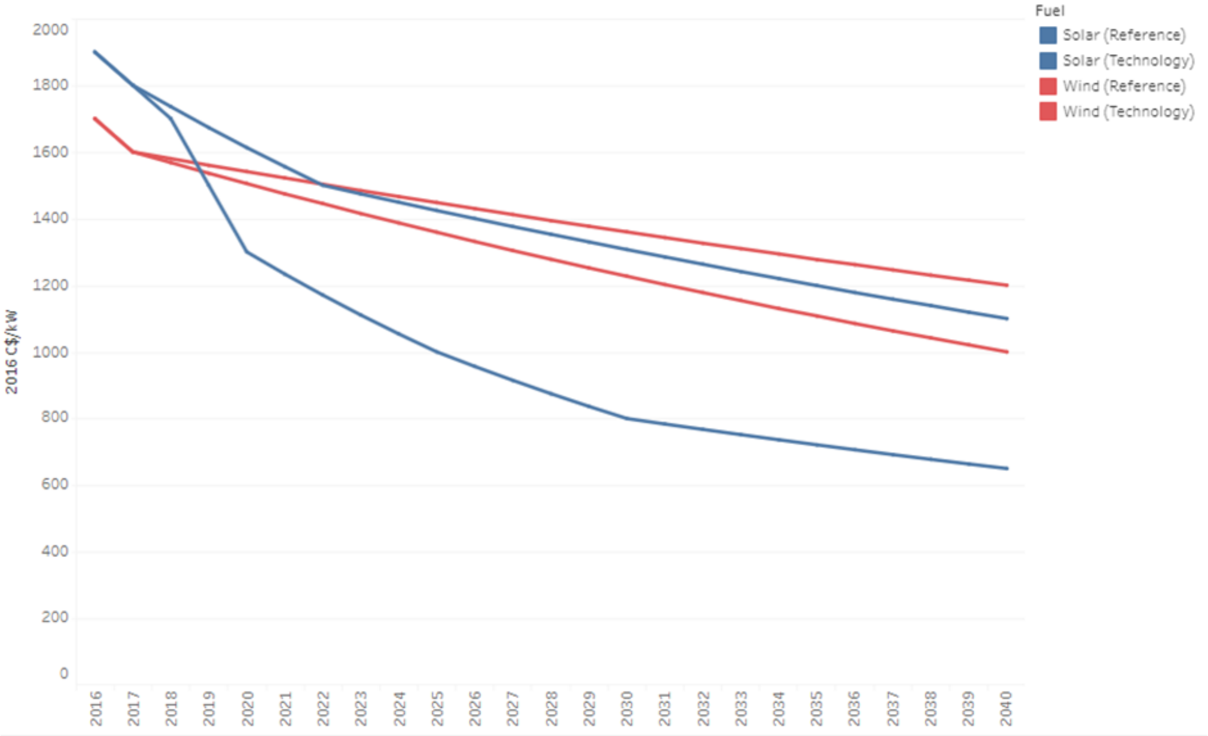


Figure 21 :Capital cost of Wind and Solar power in Canada 2017 to 2040 (Regulator, n.d.)

The above graph depicts the capital cost of wind turbines which includes the cost of materials, labour, equipment, and miscellaneous costs. It is clearly shown that capital costs are declining as we move forward, this is because of the advancements in technology and the implementation of policies which support renewable energy growth. Wind Capital Cost is projected to decline to C$1200/kW by the year 2040 compared to C$1800/kW in 2016.

A wide range of cost estimates are available in the market for wind which may differ from region to region. By taking the reference of the source above which is related to Canada the capital cost for Wind Turbine in 2022 is estimated C$1400/kW. A simple calculation of the least amount of money required for the project will be quoted here and the operation and maintenance cost of the project will be neglected.

According to our wind energy calculations two 2000 kW (2 MW) are proposed in Devon, Alberta, the efficiency of the wind turbine has been estimated to be 30%. Each 2MW turbine would cost (2000)(1400) = C$2.8 million, we are installing two turbines of same capacity for C$5.6 million. The turbine is expected to generate after considering the array efficiency is 7,008,000 kWh/year.

In the written explanation we will show the analysis by taking average market rate which is 6%. In the next section we will provide Net Present Value analysis for 6% and provide a sensitivity analysis for different interest rates corresponding with different rates of electricity. Let us assume 6% as the interest spread over 25 years which is the projected life of wind turbines in general would be C$560,000. So, the cost of electricity to pay only for the equipment, labour, material, and development will be (C$560,000)/ (7,008,000 kWh/year) = C$0.0799/kWh or 7.99¢/kWh.

The above value depicts that the owner should make at least 7.99¢/kWh to reach the breakeven at the end of 25 years period. Now, let us compare the results with the electricity rate in Alberta to get a better idea if this is feasible or not.

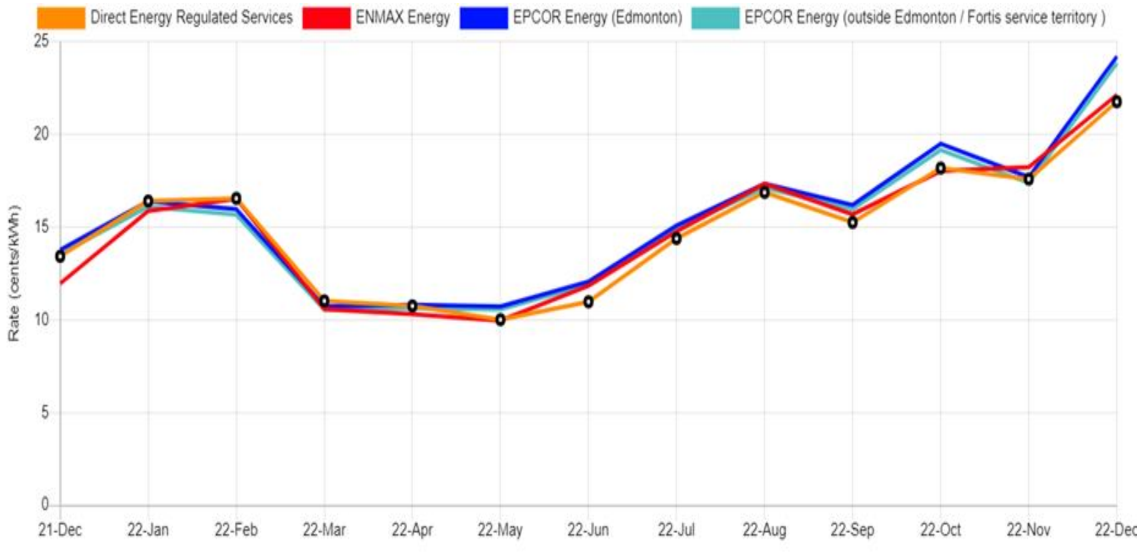


Figure 22 Variable Regulated rate option (RPO) (Commision, n.d.)

The rates shown above are the per-kilowatt-hour energy rates charged to utility customers who have preselected a variable RRO rate with a competitive retailer (kWh). If a customer does not select a retail contract for utility service, the service is usually provided by the "default supply provider" at a variable RRO rate (Commision, n.d.). We assumed that customers are taking default service providers outside Edmonton which is where Devon is situated, EPCOR Energy will be the one to provide them, and the electricity rates have been variable in the range of 14¢/kWh – 25¢/kWh. According to our analysis, the wind turbine project is going to cost 7.99¢/kWh (without operation and maintenance costs) which is low than the rate EPCOR Energy charges to the consumers.

Power plants have operating costs, which are the cost for running the projects. Because renewables have no fuel costs for running projects, which means capital costs are by far the most expensive costs for the project initiation. As from the graph above the capital cost of wind is continuing to fall, they are becoming competitive the fossil fuels in generating power and are going to become greater sources of power generation in near future (Regulator, n.d.).

6 Environmental Assessment

Increasingly, environmental concerns like global warming are causing more concern. To solve this problem, industries and governments are seeking ways to reduce carbon emissions. Since distributed generation is the trend and motivation towards it is increasing, coal-powered units or central steam are getting old. When consumers are closer to renewable energy sources, distributed generation can facilitate the penetration of different renewable energy sources.

6.1 Life-Cycle Analysis

Life cycle assessment assesses the impact of different technologies on the environment (Evangelisti, Tagliaferri, Brett, & Lettieri, 2017). Lee, Benavides, & Wang (2020) evaluate the environmental impact of each component of a product's supply chain as part of a whole life cycle assessment. In a life cycle assessment, raw materials are extracted or produced, and the production phase is followed by all supply chain steps until waste disposal. A typical product lifecycle can be seen in the figure below.

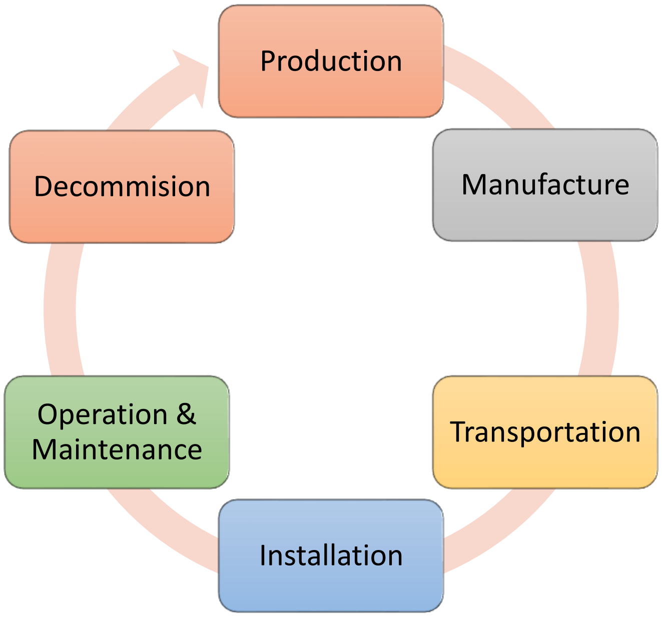


Figure 21: General product lifecycle (Based on Evangelisti, Tagliaferri, Brett, & Lettieri, 2017)

Considering the limited resources, limited access to information, and the fact that not all components will take place in Devon, Alberta, this project does not intend to conduct a full life cycle assessment. Appendix 9.4 includes additional assumptions that were made for the LCA assessment. The report focuses on the final phases, operation and maintenance, and decommissioning. Our assessment of the two DERs used in the system, the wind and solar energy sources, maintenance and decommissioning of the system will take place during the operational phase.

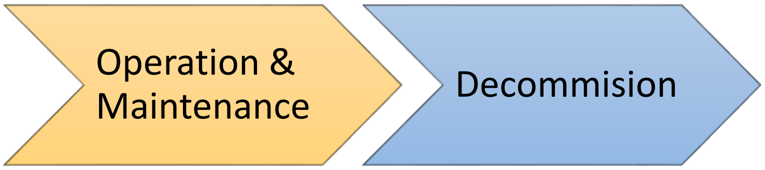


Figure 22: SPEEDER Project LCA analysis components

LCAs are mainly determined by the environmental impacts to be assessed. This project investigates how much GHG emissions would be reduced. Using the Pembina Institute's Life-Cycle Value Assessment Process, we compared the overall impact of the two electricity generation systems within the SPEEDIER project as well as the Alberta Inter-connected System (AIS) grid (since this affects Alberta's overall impact because of the integration of this system) (McCulloch, M., Raynolds, M., & Laurie, M., 2000). A GHG offset calculation was the main calculation conducted during the life cycle assessment. Using 1000 kWh as a functional unit, the offset of GHG emission and the carbon saving is calculated. This is done to determine how much electricity can be provided by two wind turbines or solar panels.

6.1.1 Result

6.1.1.1 GHG Emission

In addition to carbon dioxide (CO_2), methane (CH_2) and nitrous oxide (N_2O) are the predominant greenhouse gases. Both compounds have a weighted greenhouse gas impact. Total offsets are reported as carbon dioxide equivalents (CO_2 eq.). For calculating total potential offsets, wind and solar offsets are combined to provide a value of 14 456 tonnes of CO_2 equivalent within the first year. Following are the GHG emissions for each system:

Table 9 Yearly GHG Emissions Offset of CO2 for the different systems.

System	KWH Produced	GHG Equivalent for AIS (kg CO_2 per 1,000 kWH)	GHG Offset Equivalent (kg CO_2)	GHG Equivalent for the system	GHG Offset Equivalent (tonne CO_2)
Wind	7,008.000	1,092	7,652,736	26	7,653
Solar	6,230,000	1,092	6,803,160	41	6,803*

This was calculated by using the equation below:

$$GHG\ offset\ equivalent = Total\ Produced\ X\ GHG\ for\ AIS) - GHG\ Equivalent\ for\ the\ System *$$

In addition to the depreciation of 0.05% of the power produced annually, solar also incurs a depreciation. Based on table 6, you can see that Wind and Solar emit very few greenhouse gases compared to those offset by them. Based on these, we also calculated the GHG reduction credits using a credit value of $50 per tonne of CO_2 equivalent. Based on this, a carbon savings of

$17.5M is generated over a 25-year period. A complete dataset can be found in Appendix 9.1-9.3.

Table 10 :Yearly GHG savings monetary equivalent in $

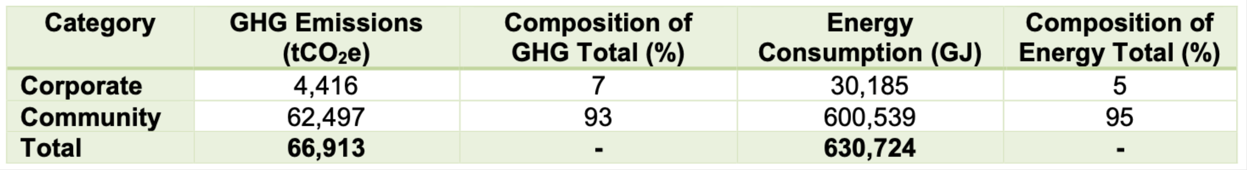
System	Total GHG Offset (tonne CO_2)	GHG Pricing/ tonne	Total Carbon Savings
Wind	7,653	$50	$382,156
Solar	6,803*	$50	$340,156

This was calculated by using the equation below:

$$GHG\ offset\ equivalent\ x\ GHG\ price\ =\ Carbon\ savings$$

To sheds light on the quantity of GHG emissions produced by the project and the impact of its carbon savings, a 2018 report detailing the Greenhouse Gas (GHG) and energy inventory of the Town of Devon will be used as a model to show the expected change (Thcir A., 2018). Approximately 66,913 tonnes of greenhouse gas emissions were discharged into the atmosphere by the Town of Devon in 2015, according to the report. Corporate GHG emissions accounted for around 7% of the total emission, while community GHG emissions accounted for about 93% (Thcir A., 2018).

Table 11 Town of Devon GHG Emission Summary (Thcir A., 2018)



Category	GHG Emissions (tCO_2e)	Composition of GHG Total (%)	Energy Consumption (GJ)	Composition of Energy Total (%)
Corporate	4,416	7	30,185	5
Community	62,497	93	600,539	95
Total	**66,913**	**-**	**630,724**	**-**

Therefore, the SPEEDIER project will directly contribute to the town's green and economic development strategies, as well as its plan. A visual representation of GHG emission reductions in Figure 23 is provided for the business-as-usual scenario (blue), the implementation of SPEEDIER (red), and the expansion of the system (green). In addition to reducing GHG emissions, it will also reduce greenhouse gas emissions (Figure 23's red line). Due to the exponential reduction in greenhouse gas emissions resulting from its implementation, the town will be able to achieve net zero goals more quickly if Alberta's regulations permit it to expand. However, it is also important to consider the potential drawbacks of the SPEEDIER project. If residents do not use the system regularly, the system may not be effective in reducing GHG emissions.

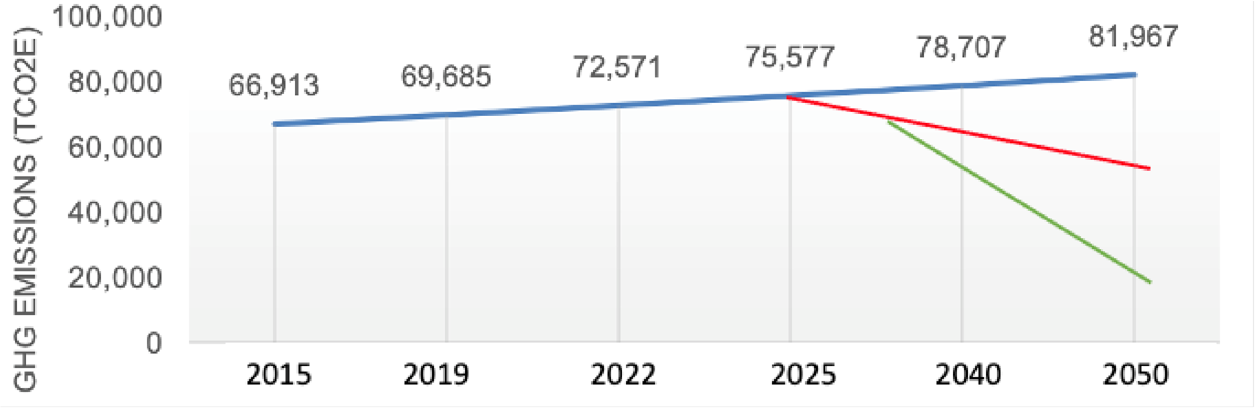


Figure 23 SPEEDIER impact on GHG Emission (Reconstructed based on Thcir A. (2018) GHG Emission graph)

In light of the lack of data on anticipated GHG emissions for upcoming years as well as the absence of recent reports, it is not possible to accurately represent changes in GHG emissions at this time. The graph above, however, illustrates the potential impact Speedier could have in the future. We are limited by the MCCA regulations to a maximum of 4-5MW, which makes it difficult to estimate the impact of more distributed energy resources (DERs) (ALBERTA MUNICIPAL SOLAR PROGRAM GUIDEBOOK, 2021). If additional wind turbines are integrated into the project or if the microgrid expands its solar system and battery storage capacity, as well as adopts natural solutions and electric vehicles (EVs), it can accelerate the achievement of net zero. A town like this can achieve net zero sooner with such initiatives.

6.1.1.2 Operation and Maintenance

In the year that the Speedier is expected to be operational, we expect emissions to decrease after the spike caused by the construction phase. Using the model of demand-side management (DSM) strategies will allow us to assess demand response, energy efficiency, and load shifting, which can contribute to optimizing energy consumption and reducing fossil fuel-based power generation, thereby reducing greenhouse gas emissions. This will result in savings on energy costs, as well as improved reliability and resiliency of the energy system. DSM strategies are an effective way to reduce greenhouse gas emissions and improve energy efficiency (Bhamidi, L & Sivasubramani, S., 2019). There are negligible air pollutants produced by renewable energy sources, including solar power and wind power, which results in cleaner air and fewer health risks. Microgrids can significantly alleviate this environmental burden in urban areas where air pollution is particularly severe. However, no information is available regarding their impact on operation and maintenance. Lakeland Solutions should conduct a GHG emissions assessment after the Speedier project implementation in Ontario. This will determine whether it has had any negative impact and what can be expected once implemented.

6.1.1.3 Decommissioning and Recycling management

6.1.1.3.1 Wind System

Wind energy is one of the most rapidly expanding renewable energy sources, and wind turbines are a critical component of wind energy production. Wind turbines, however, must be decommissioned and recycled at the end of their operational life to ensure safe and environmentally responsible disposal. This report provides a detailed overview of the Enercon E-82 wind turbine decommissioning and recycling process, including statistics and information on the materials used and recycled.

The Enercon E-82 wind turbine is a model that has been in service since the early 2000s. The turbine has a rotor diameter of 82 metres and a rated capacity of 2.3 MW. Because of its high efficiency and low noise emissions, the E-82 has become a popular model for onshore wind farms (Enercon.de, 2023).

The Enercon E-82 wind turbine decommissioning process typically consists of several stages. The first step is to evaluate the site and the wind turbine components. This evaluation entails identifying potential safety hazards and determining the best methods for dismantling and removing the components. The wind turbine components, including the tower, nacelle, rotor blades, and foundation, are dismantled in the second stage. Heavy machinery, such as cranes and excavators, are typically used to dismantle the tower and foundation. Specialized tools and equipment are used to remove the nacelle and rotor blades. After dismantling, the components are transported to a recycling facility for processing. The components are typically processed by sorting and separating the various materials for recycling or disposal (Sustainability Report 2020, 2020).

Steel, copper, and aluminum are among the recyclable materials used in the Enercon E-82 wind turbine. The rotor blades are made of fiberglass, which is recyclable. To create new products, the materials are typically shred and melted during the recycling process. Steel is the most recycled material from wind turbines, and it is used to make a variety of products such as building materials, appliances, and vehicles. Copper and aluminum are also frequently recycled and reused in the manufacture of new electrical components and wiring.

Fiberglass recycling is a more difficult process due to the material's multiple layers of resin and fibers. However, recent technological advances have enabled the recycling of fiberglass into a variety of products, including building materials and insulation.

According to an International Renewable Energy Agency report, the global wind energy sector generated 17.4 million tonnes of waste in 2019. Decommissioned wind turbines, rotor blades, and other components were among the items in this waste (Enercon.de, 2023).

Wind turbine components are required to be recycled or reused in the European Union, and the EU has set a target of recycling at least 50% of wind turbine components by 2025. Wind turbine recycling is still in its early stages in the United States, but several initiatives have been launched to promote the recycling of wind turbine components (Enercon.de, 2023).

GE Renewable Energy announced a collaboration with Veolia North America to recycle blades from its onshore wind turbines in 2020. Over 90% of the blade material is expected to be recycled by the partnership and used to create new products such as cement and insulation (Frangoul, 2021).

6.1.1.3.2 Solar System

Presently, Canadian regulations do not mandate the recycling of solar panels, nor do they offer instructions on the reuse or disposal of panels that have surpassed their lifespan. Nonetheless, the Canadian Renewable Energy Association (CANREA) has released a detailed information sheet that scrutinizes the current recycling alternatives for solar panels. These photovoltaic devices are recyclable by up to 90% of their mass, and their components can be repurposed, reconditioned, or upcycled at the end of their lifespan, with the eventual goal of recycling them. Solar energy systems contain reusable materials, such as copper (used for cabling), aluminum (for racking), steel (for posts), glass, and electronic components. Precious metals, such as silver, have significantly reduced in proportion over recent years, resulting in a significant decrease in solar energy costs. After directing the glass and metal through well-established recycling methods, only a minute portion of mass remains that requires special treatment. Various recycling methods exist for the solar panels themselves, including disassembly and shredding (Sustainable Energy: Recycling Renewables, n.d.).

It is highly probable that legislation will be introduced to establish guidelines for the ecologically responsible recycling of photovoltaic (PV) panels, especially as a significant proportion of solar projects were installed during the 2000s and will soon necessitate decommissioning or dismantling. Consequently, the decommissioning of solar panels must be factored into the planning of this proposed project once such legislation is enacted. It is imperative to develop a comprehensive strategy for the environmentally sustainable disposal of these panels to minimize their ecological impact. This would entail implementing effective collection and transportation procedures, as well as identifying appropriate recycling methodologies that maximize the recovery of valuable materials while minimizing waste. Furthermore, it is critical to consider the potential economic benefits of recycling PV panels, as the retrieval and reuse of valuable resources can contribute to the development of a circular economy.

6.2 Addition consideration

6.2.1 Natural Resource use

There are both positive and negative impacts of microgrids incorporating wind and solar energy. It can be beneficial for land and water resources to incorporate microgrids that incorporate renewable energy sources like wind and solar to reduce greenhouse gas emissions and mitigate climate change. As an example, reducing greenhouse gas emissions can lower global warming rates, which in turn can decrease the impact of droughts and floods on land and water resources. By choosing sites less prone to environmental impacts and using low-impact installation techniques, microgrids can be designed to minimize their impact on land and water resources. By using installation techniques that minimize soil disturbance and erosion, microgrid developers can select disturbed or degraded sites, such as brownfields or abandoned industrial sites (Hatziargyriou, N. D., et. Al, 2009; Lopes, J. A., et. Al, 2019).

Wind and solar microgrids, however, can have negative impacts on land and water resources if they are not designed and operated correctly. To install and operate solar panels, battery storage, and wind turbines, a significant amount of land is required, which may negatively impact natural habitats, crop production, and water availability. The proposed land does not appear to be destined for alternative development and is not active farmland, so it is assumed that it will not impact crop production or water streams. Community and stakeholders would need to be consulted and assessed in person to determine how best to proceed (Lopes, J. A., et. Al, 2019).

A microgrid can impact natural habitats and water resources due to its transmission and distribution infrastructure. Additional environmental assessments along with the one in this report need to be conducted to minimize these impacts, and measures to mitigate impacts on land and water resources must be incorporated.

6.2.2 Wildlife and habitat

Much of the wildlife and habitat impact is from the DERs that are in the SPEEDIER system. Wind and solar developments have both direct and indirect impacts on wildlife and wildlife habitat. In direct impact, wind facilities can directly cause mortalities to birds and bats, primarily by collisions or barotrauma (barotrauma refers to injuries caused by changes in air pressure) (Lopes, J. A., et. Al, 2019; Liu, P., & Barlow, C. Y., 2016). Recent research also indicates that avoidance of wind energy facilities by wildlife increases threats to at-risk wildlife populations.

According to AUC Rule 007, all wind applications in Alberta require the approval of the Wildlife Biologist. As part of the application to the AUC, the Wildlife Biologist should provide a referral letter detailing how the project proposal complies with the Directive. This letter should be included in the application. A detailed explanation of the situation must be included in the application if the applicant cannot get a referral letter or cannot agree to a mitigation plan with the Wildlife Biologist. Additionally, as necessary, avoidance and standard mitigation options are applied to reduce the risk of development impacting wildlife and wildlife habitat (Raven, K., et. Al, 2022; Government of Alberta., n.d.)

Since solar energy has an indirect impact compared to wind energy. In fact, solar energy can have both positive and negative impacts on wildlife, depending on various factors such as the location, design, and operation of the solar installations. Here are some ways solar energy can impact wildlife. Some positive notes to consider are, solar panels (in our colocation) can help preserve natural habitats by reducing the need for land development for traditional energy generation methods. It would help to consult the wildlife land use guidelines proposed by the Government of Alberta. The guidelines have been developed for selected wildlife species, species groups and ecological regions of the province to assist land managers, landowners, and land users in avoiding or minimizing potential adverse impacts to wildlife from various land use activities. (Government of Alberta, n.d.). This guideline can also help with reducing habitat fragmentation as it will allow us to determine if the proposed land contains any endangered or threatened species. In addition, it is important to understand how the local ecosystem will be impacted. Due to limited data, this information was not readily available.

6.2.3 Noise pollution

Microgrids that incorporate wind and solar energy typically produce much less noise pollution than traditional energy sources such as fossil fuel-powered generators. This is because wind turbines and solar panels do not produce any noise during operation, whereas fossil fuel generators produce noise due to the combustion of fuel and the mechanical operation of the generator (Lasseter, R., et Al, 2002).

However, it's important to note that some noise may still be generated by ancillary equipment associated with the wind and solar components of a microgrid. For example, inverters, transformers, and cooling systems may produce some level of noise. However, the noise produced by these components is typically much lower than the noise produced by fossil fuel generators (Lasseter, R., et Al, 2002). Generally, the impact of noise pollution from a wind and solar-powered microgrid is likely to be minimal, especially when compared to the noise produced by traditional energy sources. However, as with any power generation system, it's important to consider the potential impact of noise on nearby communities and take steps to mitigate any negative effects. This can include siting microgrid components away from sensitive receptors, using noise barriers, and implementing operating protocols that minimize noise emissions.

The Alberta government has noise pollution guidelines for renewable energy projects as well. The guidelines are intended to help minimize the potential negative impacts of noise on nearby communities and wildlife. The Alberta Noise Control Guidelines provide recommendations for maximum acceptable noise levels for different land uses and times of day. For example, the guideline suggests that the maximum acceptable noise level in residential areas during the day is 50 decibels, while the maximum acceptable noise level during the night is 45 decibels (*Hydro and Electric Energy Act - Open Government*, n.d.). In addition to the guidelines, the Alberta government has also enacted legislation related to noise pollution. The Environmental Protection and Enhancement Act (EPEA) and Hydro and Electricity Act (HEEA) includes provisions related to noise pollution (see policy assessment for rule 012) and gives the province the authority to regulate and enforce noise control measures.

For wind energy projects, the guidelines recommend that developers conduct a pre-construction sound survey to establish baseline noise levels and determine the potential impact of the wind turbines on nearby communities. The guidelines also provide recommended maximum noise levels for wind energy projects at different times of day, depending on the proximity of the turbines to residential areas. For solar energy projects, the guidelines recommend that developers take steps to minimize the noise generated by ancillary equipment such as inverters and transformers. The guidelines suggest using sound barriers and other noise mitigation measures as necessary to reduce the impact of noise on nearby communities. In addition to the guidelines, the Alberta government requires renewable energy developers to comply with applicable regulations related to noise pollution, including the Environmental Protection and Enhancement Act (EPEA) and the Alberta Utilities Commission (AUC) Noise Control Rules (*Hydro and Electric Energy Act - Open Government*, n.d.).

Overall, the Alberta government's noise pollution guidelines for renewable energy projects are intended to help ensure that these projects are developed in a way that minimizes the negative impact of noise on nearby communities and wildlife.

6.2.4 Climate change Mitigation

Considering the Speedier project's leading role in mitigating climate change, it can also be included in the Municipal Climate Change Action Centre's (MCCAC) Climate Resilience

Capacity Building Program. As a partnership between the Government of Alberta and the Alberta Urban Municipalities Association, the MCCAC assists Alberta's municipalities in reducing greenhouse gas emissions and adapting to climate change impacts.

The MCCAC provides support for microgrid projects through its Climate Resilience Capacity Building program (CRCBP), which provides funding and technical assistance to municipalities for climate change mitigation and adaptation projects (*Climate Resilience Capacity Building Program | MCCAC*, n.d.). The program provides funding for feasibility studies, energy assessments, and project implementation for a variety of climate change projects, including microgrid projects.

It recognizes the potential of microgrids to mitigate and adapt to climate change. By integrating renewable energy sources such as solar and wind into the local energy mix, microgrids can help municipalities reduce greenhouse gas emissions. By providing a local, reliable source of energy less susceptible to power outages caused by extreme weather events, they can also help municipalities become more resilient to climate change.

7 Social Assessment

For this project, the social assessment is conducted based on theoretical information available as no survey or data was available for the town of Devon, Alberta to identify social needs. These social considerations range from being widespread and pertaining to the public of Alberta, to more specific impacts to neighboring communities.

7.1 Net-zero transition considerations

In addition to addressing the province's technical, environmental, and economic needs, achieving net zero emissions will require addressing its social needs. New jobs must be created to replace lost jobs in the fossil fuel industry as Alberta transitions to a low-carbon economy. Workers in renewable energy, energy efficiency, and other low-carbon industries can gain skills through training and education. There needs to be a focus on ensuring that the transition to net zero is equitable and beneficial to all communities and individuals. To achieve this, policies and programs must prioritize including marginalized and vulnerable communities in the transition process. The Town of Devon has proposed a 2050 Economic Development strategy that emphasizes the involvement and inclusion of the vulnerable or marginalized community. Working with the stakeholder team and stakeholders will achieve a smoother transition (Town of Devon, 2020) Engagement and participation of the community in the transition to net zero is critical to its success. Involving stakeholders and communities in decision-making processes is crucial to addressing their needs and concerns. Furthermore, it would allow the team implementing SPEEDIER to identify concerns and channel behaviours so that the project could be reviewed for social acceptance (Town of Devon, 2020).

There is a unique perspective and knowledge among indigenous peoples in Alberta, including Devon, that should be incorporated into the net zero transition. Indigenous peoples' rights and interests should be prioritized in policies and programs, and reconciliation efforts should be supported. In Smokey Lake, Alberta, the Métis Crossing Solar Project won the Municipal Community Generation Program award, which demonstrates the benefits of collaborating with indigenous communities. Smoky Lake County and Smoky Lake Township collaborated on the project as well as the Métis Nation of Alberta. A cultural landmark of the Métis people in Canada, Métis Crossing is the site of the Métis Crossing Solar Project. After engaging with over 300 Métis citizens across 18 communities, the Métis Crossing Solar Project was conceptualized as a key initiative of the Métis Nation of Alberta Climate Change Action Plan (Municipal Climate Change Action Centre, 2019).

As part of its efforts to address this issue, the Town of Devon has worked closely with its community over the past three years. Moreover, they indicated a strategy refinement that the implementation team can utilize in their 2050 Economic Development Strategy. To ensure expectations are met and impacts are maximized (2050 Economic Development Strategy, 2020), the improvements identified in the review checkpoint are incorporated into the implementation of the strategy.

Alberta nor other provinces have health impacts directly associated with microgrids. Microgrids use energy sources such as wind and solar power, which reduce air pollution and greenhouse gas emissions and benefit public health. As a result, air pollution will be less likely to cause respiratory and cardiovascular diseases, such as asthma and heart disease. Alberta microgrids can improve energy reliability and resilience, particularly in rural or remote areas. In addition to improving healthcare access, this can also improve public health. However, it is also imperative to note that microgrids can produce noise and vibration while being built and operated.

Microgrids can cause annoyance, sleep disruptions, and other adverse health and well-being impacts if they are located close to residential areas or sensitive receptors, such as hospitals or schools. To minimize these impacts, the team in charge must reduce noise and vibration levels and design microgrids accordingly. It is unlikely that the proposed site will impact the town much since it is farther away from the core. Still, we should carefully consider using noise barriers and low-noise equipment at appropriate times of the day while actively communicating with the community.

For Alberta to achieve net zero emissions, addressing these social needs is vital. This will require collaboration and partnerships across sectors and communities to ensure that everyone can contribute to and benefit from the transition.

7.2 Socio – Cultural Views Towards Distributed Energy Resources

There may be various reasons for Albertans' misconceptions about wind, solar, and storage (WSS), including their lack of awareness and exposure to these technologies, their lack of understanding of their benefits, and their perceptions of their cost-effectiveness. In Alberta, solar PV systems account for 77% of all residential installations, 11% of commercial installations, 11% of farm installations, and 1% of all other installations (Municipal Climate Change Action Centre, 2019). In addition, by 2021, Alberta's electricity grid was equipped with 358 MW of wind energy capacity (French J., 2022.). Despite this, renewable energy is perceived differently in Alberta. The following observations have been made:

Table 12: Types of Social views in Albertan perspective of wind, solar and storage (Patel, S., et Al., 2020)

Types of view	Description
Positive	Some Albertans may view WSS technologies positively, seeing them as a way to reduce greenhouse gas emissions, improve air quality, and increase energy independence. They may appreciate the environmental benefits of WSS and their potential to create jobs and economic development in the province.
Neutral	Other Albertans may have a neutral view towards WSS technologies, not having strong feelings one way or the other. They may be open to learning more about WSS and their benefits but are not actively advocating for or against them.
Skeptical	Some Albertans may view WSS technologies skeptically, seeing them as unproven or unreliable technologies that may not be able to provide a consistent and reliable supply of energy. They may also be concerned about the cost-effectiveness of WSS compared to traditional centralized energy systems.
Negative	Finally, some Albertans may view WSS technologies negatively, seeing them as a threat to traditional energy systems and the jobs and economic benefits they provide. They may also be skeptical of the environmental benefits of WSS and view them as an unnecessary expense.

In the case of Devon, in 2016, the Canadian Association of Municipal Administrators (CAMA) recognized the environmental excellence demonstrated by Devon with its solar program by awarding the Town with the 2016 National Municipal Environmental Award. Devon’s solar program began in 2015 with solar lights installed in the dog park, boat launch and parking area of Voyageur Park. Soon after, the town installed solar lights for pedestrian crosswalks. A big part of the program was the installation of 393 solar panels on the roof of the Devon Community Centre. The efforts reduce the Town's environmental footprint and the amount of public funds spent on electricity for municipal facilities (Programs Plans and Initiatives-Town of Devon, n.d).This already provides a positive views of how the community could take on the system as there is clearly a strong understanding of renewable energy, more specifically solar energy.

Though new implementations of wind energy are not evidently present as much in Alberta. Towns within Alberta have implemented wind in the past and have shown positive intake. For example, Pincher Creek, a town in Alberta, has been a hub for wind energy development since the early 2000s. The development of wind energy in Pincher Creek has had several social impacts on the community, both positive and negative. The development has brought new jobs and economic opportunities to the community. This includes jobs in the construction and operation of wind turbines, as well as in the local supply chain that supports the wind energy industry. This has helped to diversify the local economy and has provided new opportunities for residents. It also brought new revenue to the community in the form of taxes and royalties. This revenue can be used to support local services and infrastructure, such as schools, roads, and healthcare facilities (Sprague, C., & Parkins, J. R., 2012). Due to the positive intake, Pincher Creek became the leader in renewable Alberta at the time, providing more awareness of renewable energy and sustainability issues in the community (Sprague, C., & Parkins, J. R., 2012).

On the other hand, there have also been negative social impacts associated with wind energy development in Pincher Creek. One of the major concerns raised by residents is the potential impact of wind turbines on scenic landscapes and wildlife. Some residents have expressed concern that wind turbines could detract from the natural beauty of the area and could impact the migration patterns of birds and other wildlife. Another concern raised by residents is the potential impact of wind turbines on property values. Some residents are concerned that the presence of wind turbines could reduce the value of their homes or property (Sprague, C., & Parkins, J. R., 2012).

Thus, for the SPEEDIER project to be successful in this town, in Devon, Alberta specifically, cultural views may be shaped by a range of factors, including the town's history and economic dependence on the oil and gas industry, as well as its proximity to renewable energy projects such as wind farms. To better understand the cultural views of Devon residents towards WSS technologies, it may be useful to consult local community leaders, residents, and stakeholders, and to engage in community outreach and education efforts to increase awareness and understanding of the benefits and potential impacts of these technologies.

7.3 Proposed approach for SPEEDIER project

To ensure Devon’s acceptance of the SPEEDIER project with wind, we need to consider 7 steps to implement SPEEDIER smoothly (Chandak, S., & Rout, P. K., 2021).

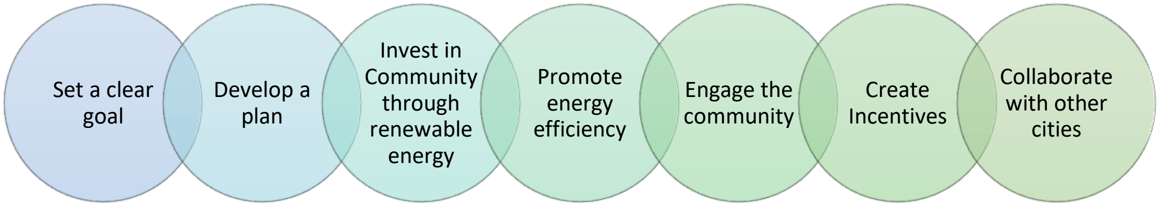


Figure 24 Seven step approach for the implementation of the SPEEDIER project (Chandak, S., & Rout, P. K., 2021).

Devon Council has high ambitions to become the first Net-Zero municipality in Canada (Programs Plans and Initiatives-Town of Devon, n.d). By leveraging its already ambitious goals, the town could adopt the project. After setting a goal, developing a plan to accomplish it is imperative. A plan should include specific actions and timelines for reducing emissions and strategies for engaging stakeholders and the community. As an example of how the project would be deployed, we have proposed a timeline in appendix 9.6 that will provide a guide to deploy the project in 4 years. This timeline can be used as a starting point for key steps that would need to be taken to address the project and community’s needs.

The Town of Devon generated approximately 66,913 tonnes of greenhouse gases in 2015, as we know from our previous assessment (Thcir A., 2018). As the town seeks to become Canada's first net zero community, this project would incentivize them to do so. Through education on the various types of energy sources in addition to Solar, the town will be able to explore other options on how to independently set up an energy grid that will help them achieve this goal. It would allow more opportunities to create new jobs and reduce carbon emissions if we communicated that accepting the project is an investment in our community (Maguire, B., & Cartwright, S., 2008; Santos, A. Q., et. Al, 2018).

The most important aspect of this is that transitioning to net zero requires the support and participation of the entire community. This can be achieved through public education campaigns, community outreach and engagement, and partnerships with local organizations. In addition, incentives such as tax breaks, grants, and rebates can encourage individuals and businesses to adopt sustainable practices and technologies. This can help to accelerate the transition to net zero emissions (Santos, A. Q., et. Al, 2018).

Many of Devon's property owners are currently participating in the Clean Energy Improvement Program, or CEIP, which provides an innovative method of financing home energy efficiency upgrades and renewable energy installations up to 100%. Make repayment convenient through your property's regular tax bill (Alberta Municipalities Strength in Members-Clean Energy Improvement Program, n.d.). As a result, the following table summarizes all incentives available to the community individually:

Table 13 :Incentives offered to residents (Alberta Municipalities Strength in Members-Clean Energy Improvement Program, n.d.).

Incentive Names	Description
Devon EnerGuide Home Evaluation Incentive	Incentives of $600 are available for completing EnerGuide Version 15 Home Evaluations before and after the project begins.
Devon Upgrade Incentive	Completed CEIP projects are eligible for an Upgrade Incentive of $500. The incentive will be awarded on a first-come, first-served basis.
Canada Greener Homes Initiative	There are many incentives available through the Town of Devon CEIP that may be stacked with the incentives offered by the federal government's Canada Greener Homes Initiative.

In our consultation with the representatives of the Town of Devon (see appendix 9.5), we found that solar energy has become an increasingly popular source of power for many homes within the area. Consequently, if the town has sufficient information and incentives to take in SPEEDIER, it will be able to take in SPEEDIER more effectively.

Finally, Public awareness and education are important in building support for the transition to net zero by leveraging the town's economic development strategy, existing incentives, and general awareness of renewable energy. It is possible to inform the public about the benefits of a low-carbon economy and to encourage them to participate in it through educational programs and public awareness campaigns. The team can leverage some of the pre-existing programs offered by Alberta, such as the MCCAC, which provides training and resources to help municipalities develop and implement microgrid projects in a safe, reliable, and resilient way to climate change impacts. In addition to selecting appropriate technologies, this document also discusses how to design, operate, and integrate microgrids into larger energy systems.

8 Conclusion & Recommendations

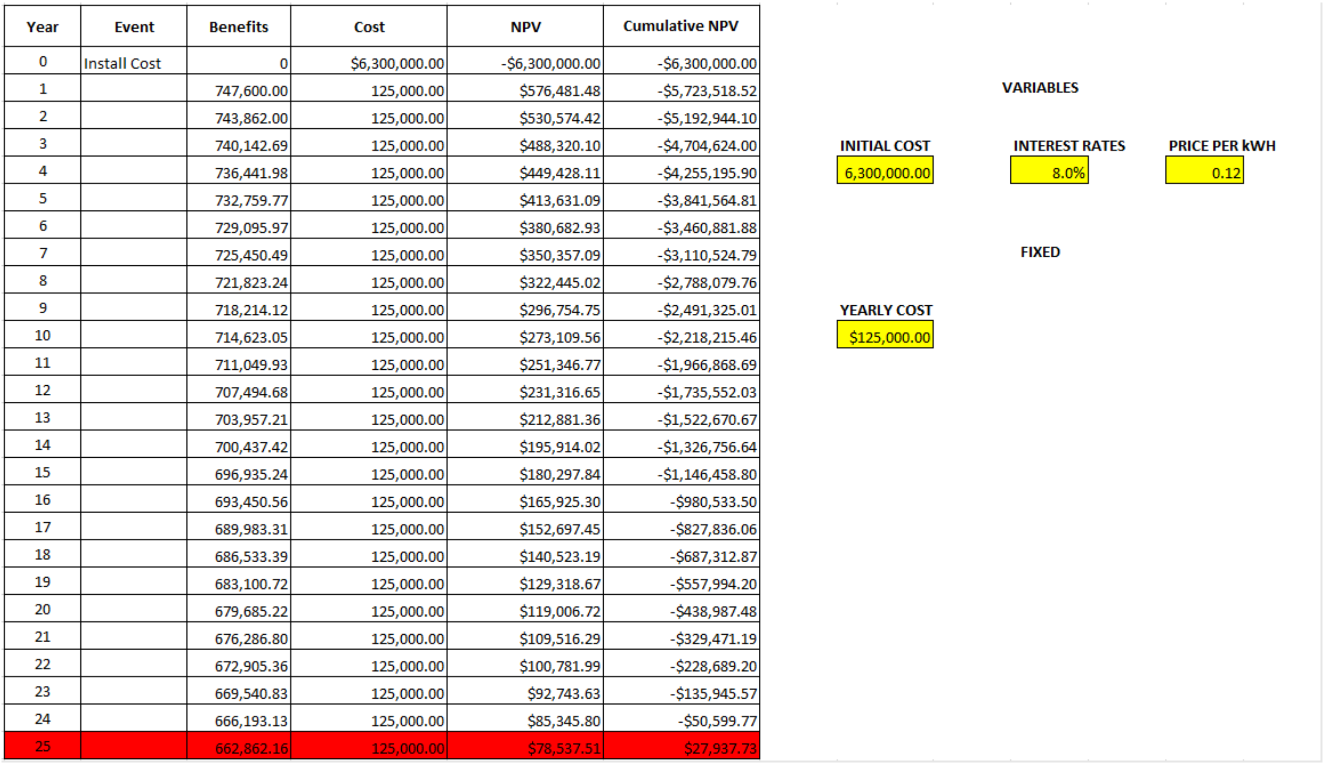
Decarbonization represents not only an environmental imperative and generational challenge but also economic opportunity. As a catalyst for clean energy investment into rural communities that have faced the spectre if not the full force of deindustrialization for decades, decarbonization is a critical opportunity for revival that cannot be neglected. With the Town of Devon being a hub for energy technology research, skilled workforce, and proximity to Edmonton, it is an attractive destination for clean energy investment. Recent regulatory and financial developments have resulted in governments steering capital director into renewable power through a mix of direct grants, co-investments, cheap financing, and tax credits. These support mechanisms alongside a more favourable regulatory climate makes decarbonization and the expansion of clean electricity generation by Devon a prime opportunity. To execute the proposal suggested by this report timeline proposed in appendix 9.6, we suggest the following recommendations be enacted by both the developer and the Town of Devon:

1. Engage with civic actors such as community organizations and local politicians to showcase why clean energy investment is critical for the growth of Devon.
2. Offer community incentives such as local employment partnerships to secure community support for the project.
3. Leverage pre-existing plans and strategies proposed by the Town of Devon and with Alberta.
4. Assess how the project will impact the Parry Sound, Ontario community in the operational phase, which will provide an indication of how Alberta will be affected.
5. Ensure key regulatory measures to de-risk the project. These include motions from council to directly support the project or early interconnection permission to ensure that the viability of completing the project is not an issue.
6. Secure a long-term power purchase agreement with the Town of Devon or other public entity guaranteeing a market and fixed prices for the electricity generated.
7. Partner with publicly owned financial institutions such as the Canada Infrastructure Bank or ATB Financial to secure low-cost financing solutions.

9 Appendix

9.1 Solar Energy Net Present Value and Sensitivity Analysis Results

Table 14 NPV for no rebates, 8% interest rate and power purchase of 0.12 cents. (Worst Case Scenario)



Year	Event	Benefits	Cost	NPV	Cumulative NPV
0	Install Cost	0	$6,300,000.00	-$6,300,000.00	-$6,300,000.00
1		747,600.00	125,000.00	$576,481.48	-$5,723,518.52
2		743,862.00	125,000.00	$530,574.42	-$5,192,944.10
3		740,142.69	125,000.00	$488,320.10	-$4,704,624.00
4		736,441.98	125,000.00	$449,428.11	-$4,255,195.90
5		732,759.77	125,000.00	$413,631.09	-$3,841,564.81
6		729,095.97	125,000.00	$380,682.93	-$3,460,881.88
7		725,450.49	125,000.00	$350,357.09	-$3,110,524.79
8		721,823.24	125,000.00	$322,445.02	-$2,788,079.76
9		718,214.12	125,000.00	$296,754.75	-$2,491,325.01
10		714,623.05	125,000.00	$273,109.56	-$2,218,215.46
11		711,049.93	125,000.00	$251,346.77	-$1,966,868.69
12		707,494.68	125,000.00	$231,316.65	-$1,735,552.03
13		703,957.21	125,000.00	$212,881.36	-$1,522,670.67
14		700,437.42	125,000.00	$195,914.02	-$1,326,756.64
15		696,935.24	125,000.00	$180,297.84	-$1,146,458.80
16		693,450.56	125,000.00	$165,925.30	-$980,533.50
17		689,983.31	125,000.00	$152,697.45	-$827,836.06
18		686,533.39	125,000.00	$140,523.19	-$687,312.87
19		683,100.72	125,000.00	$129,318.67	-$557,994.20
20		679,685.22	125,000.00	$119,006.72	-$438,987.48
21		676,286.80	125,000.00	$109,516.29	-$329,471.19
22		672,905.36	125,000.00	$100,781.99	-$228,689.20
23		669,540.83	125,000.00	$92,743.63	-$135,945.57
24		666,193.13	125,000.00	$85,345.80	-$50,599.77
25		662,862.16	125,000.00	$78,537.51	$27,937.73

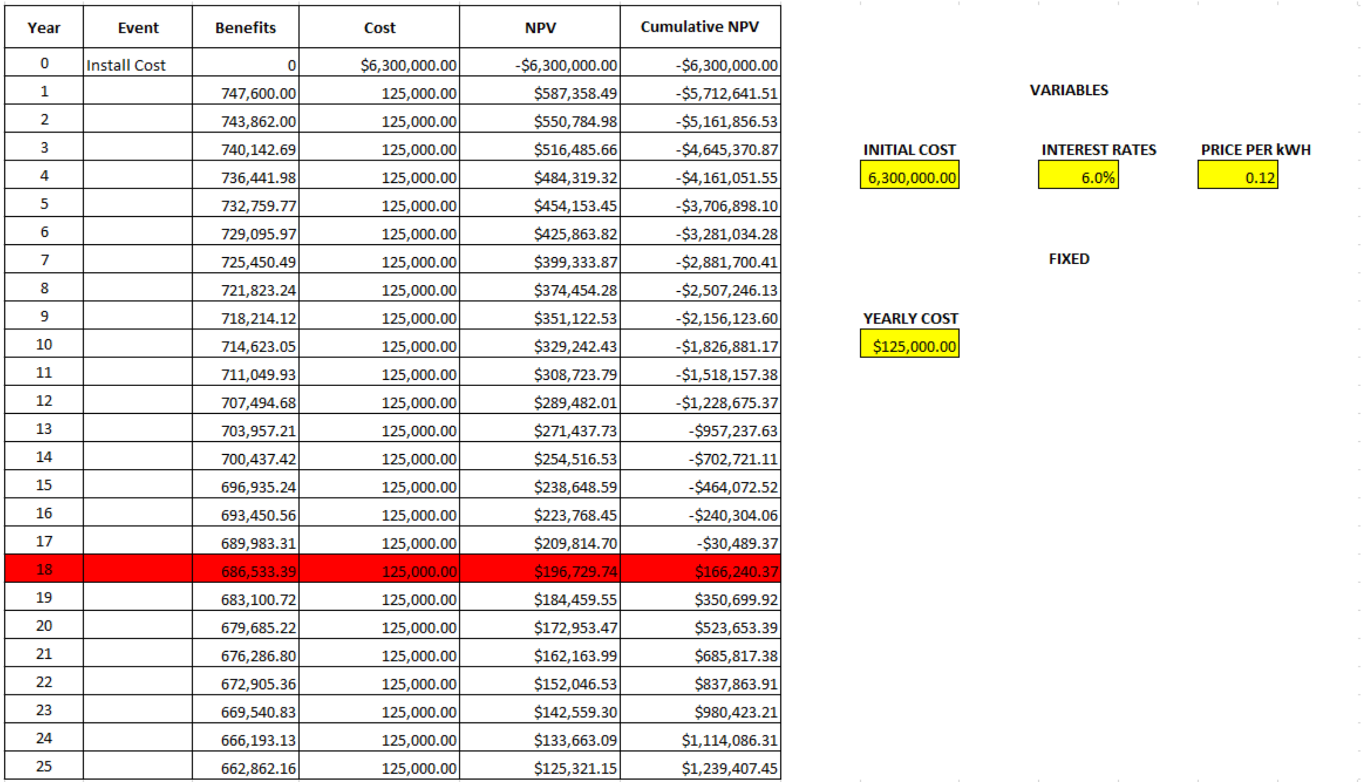
VARIABLES

INITIAL COST	INTEREST RATES	PRICE PER kWH
6,300,000.00	8.0%	0.12

FIXED

YEARLY COST
$125,000.00

Table 15 NPV for no rebates, 6% interest rate and power purchase of 0.12 cents.



Year	Event	Benefits	Cost	NPV	Cumulative NPV
0	Install Cost	0	$6,300,000.00	-$6,300,000.00	-$6,300,000.00
1		747,600.00	125,000.00	$587,358.49	-$5,712,641.51
2		743,862.00	125,000.00	$550,784.98	-$5,161,856.53
3		740,142.69	125,000.00	$516,485.66	-$4,645,370.87
4		736,441.98	125,000.00	$484,319.32	-$4,161,051.55
5		732,759.77	125,000.00	$454,153.45	-$3,706,898.10
6		729,095.97	125,000.00	$425,863.82	-$3,281,034.28
7		725,450.49	125,000.00	$399,333.87	-$2,881,700.41
8		721,823.24	125,000.00	$374,454.28	-$2,507,246.13
9		718,214.12	125,000.00	$351,122.53	-$2,156,123.60
10		714,623.05	125,000.00	$329,242.43	-$1,826,881.17
11		711,049.93	125,000.00	$308,723.79	-$1,518,157.38
12		707,494.68	125,000.00	$289,482.01	-$1,228,675.37
13		703,957.21	125,000.00	$271,437.73	-$957,237.63
14		700,437.42	125,000.00	$254,516.53	-$702,721.11
15		696,935.24	125,000.00	$238,648.59	-$464,072.52
16		693,450.56	125,000.00	$223,768.45	-$240,304.06
17		689,983.31	125,000.00	$209,814.70	-$30,489.37
18		686,533.39	125,000.00	$196,729.74	$166,240.37
19		683,100.72	125,000.00	$184,459.55	$350,699.92
20		679,685.22	125,000.00	$172,953.47	$523,653.39
21		676,286.80	125,000.00	$162,163.99	$685,817.38
22		672,905.36	125,000.00	$152,046.53	$837,863.91
23		669,540.83	125,000.00	$142,559.30	$980,423.21
24		666,193.13	125,000.00	$133,663.09	$1,114,086.31
25		662,862.16	125,000.00	$125,321.15	$1,239,407.45

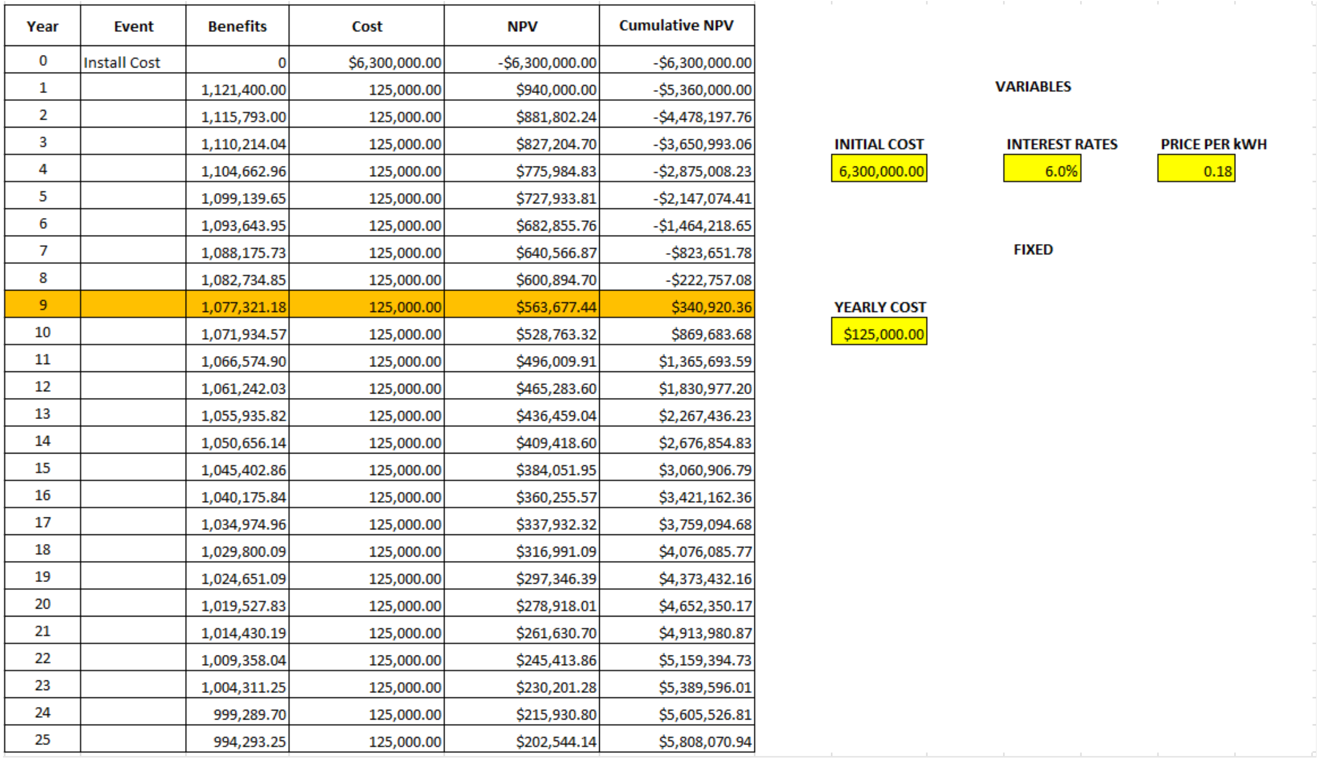
VARIABLES

INITIAL COST	INTEREST RATES	PRICE PER kWH
6,300,000.00	6.0%	0.12

FIXED

YEARLY COST
$125,000.00

Table 16: NPV for no rebates, 6% interest rate and power purchase of 0.18 cents.



Year	Event	Benefits	Cost	NPV	Cumulative NPV
0	Install Cost	0	$6,300,000.00	-$6,300,000.00	-$6,300,000.00
1		1,121,400.00	125,000.00	$940,000.00	-$5,360,000.00
2		1,115,793.00	125,000.00	$881,802.24	-$4,478,197.76
3		1,110,214.04	125,000.00	$827,204.70	-$3,650,993.06
4		1,104,662.96	125,000.00	$775,984.83	-$2,875,008.23
5		1,099,139.65	125,000.00	$727,933.81	-$2,147,074.41
6		1,093,643.95	125,000.00	$682,855.76	-$1,464,218.65
7		1,088,175.73	125,000.00	$640,566.87	-$823,651.78
8		1,082,734.85	125,000.00	$600,894.70	-$222,757.08
9		1,077,321.18	125,000.00	$563,677.44	$340,920.36
10		1,071,934.57	125,000.00	$528,763.32	$869,683.68
11		1,066,574.90	125,000.00	$496,009.91	$1,365,693.59
12		1,061,242.03	125,000.00	$465,283.60	$1,830,977.20
13		1,055,935.82	125,000.00	$436,459.04	$2,267,436.23
14		1,050,656.14	125,000.00	$409,418.60	$2,676,854.83
15		1,045,402.86	125,000.00	$384,051.95	$3,060,906.79
16		1,040,175.84	125,000.00	$360,255.57	$3,421,162.36
17		1,034,974.96	125,000.00	$337,932.32	$3,759,094.68
18		1,029,800.09	125,000.00	$316,991.09	$4,076,085.77
19		1,024,651.09	125,000.00	$297,346.39	$4,373,432.16
20		1,019,527.83	125,000.00	$278,918.01	$4,652,350.17
21		1,014,430.19	125,000.00	$261,630.70	$4,913,980.87
22		1,009,358.04	125,000.00	$245,413.86	$5,159,394.73
23		1,004,311.25	125,000.00	$230,201.28	$5,389,596.01
24		999,289.70	125,000.00	$215,930.80	$5,605,526.81
25		994,293.25	125,000.00	$202,544.14	$5,808,070.94

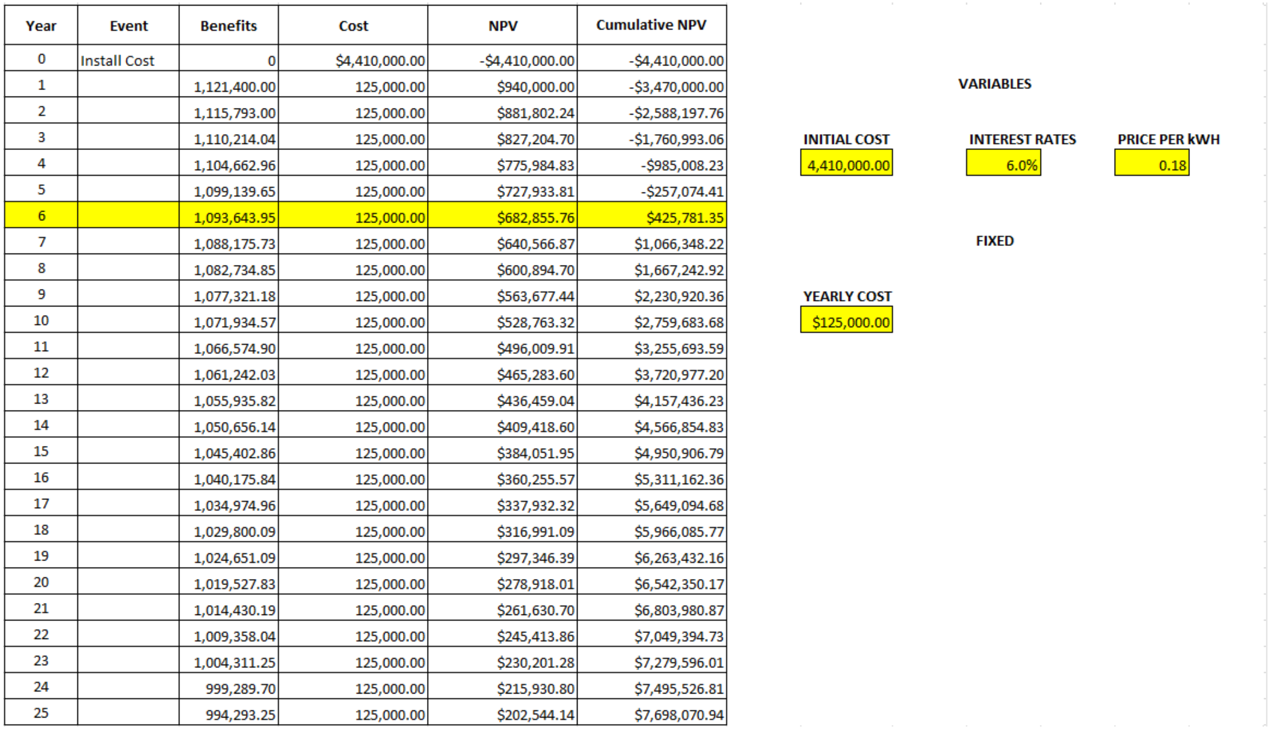
VARIABLES

INITIAL COST	INTEREST RATES	PRICE PER kWH
6,300,000.00	6.0%	0.18

FIXED

YEARLY COST
$125,000.00

Table 17 NPV with rebates, 6% interest rate and power purchase of 0.18 cents. (Best Case Scenario)



Year	Event	Benefits	Cost	NPV	Cumulative NPV
0	Install Cost	0	$4,410,000.00	-$4,410,000.00	-$4,410,000.00
1		1,121,400.00	125,000.00	$940,000.00	-$3,470,000.00
2		1,115,793.00	125,000.00	$881,802.24	-$2,588,197.76
3		1,110,214.04	125,000.00	$827,204.70	-$1,760,993.06
4		1,104,662.96	125,000.00	$775,984.83	-$985,008.23
5		1,099,139.65	125,000.00	$727,933.81	-$257,074.41
6		1,093,643.95	125,000.00	$682,855.76	$425,781.35
7		1,088,175.73	125,000.00	$640,566.87	$1,066,348.22
8		1,082,734.85	125,000.00	$600,894.70	$1,667,242.92
9		1,077,321.18	125,000.00	$563,677.44	$2,230,920.36
10		1,071,934.57	125,000.00	$528,763.32	$2,759,683.68
11		1,066,574.90	125,000.00	$496,009.91	$3,255,693.59
12		1,061,242.03	125,000.00	$465,283.60	$3,720,977.20
13		1,055,935.82	125,000.00	$436,459.04	$4,157,436.23
14		1,050,656.14	125,000.00	$409,418.60	$4,566,854.83
15		1,045,402.86	125,000.00	$384,051.95	$4,950,906.79
16		1,040,175.84	125,000.00	$360,255.57	$5,311,162.36
17		1,034,974.96	125,000.00	$337,932.32	$5,649,094.68
18		1,029,800.09	125,000.00	$316,991.09	$5,966,085.77
19		1,024,651.09	125,000.00	$297,346.39	$6,263,432.16
20		1,019,527.83	125,000.00	$278,918.01	$6,542,350.17
21		1,014,430.19	125,000.00	$261,630.70	$6,803,980.87
22		1,009,358.04	125,000.00	$245,413.86	$7,049,394.73
23		1,004,311.25	125,000.00	$230,201.28	$7,279,596.01
24		999,289.70	125,000.00	$215,930.80	$7,495,526.81
25		994,293.25	125,000.00	$202,544.14	$7,698,070.94

VARIABLES

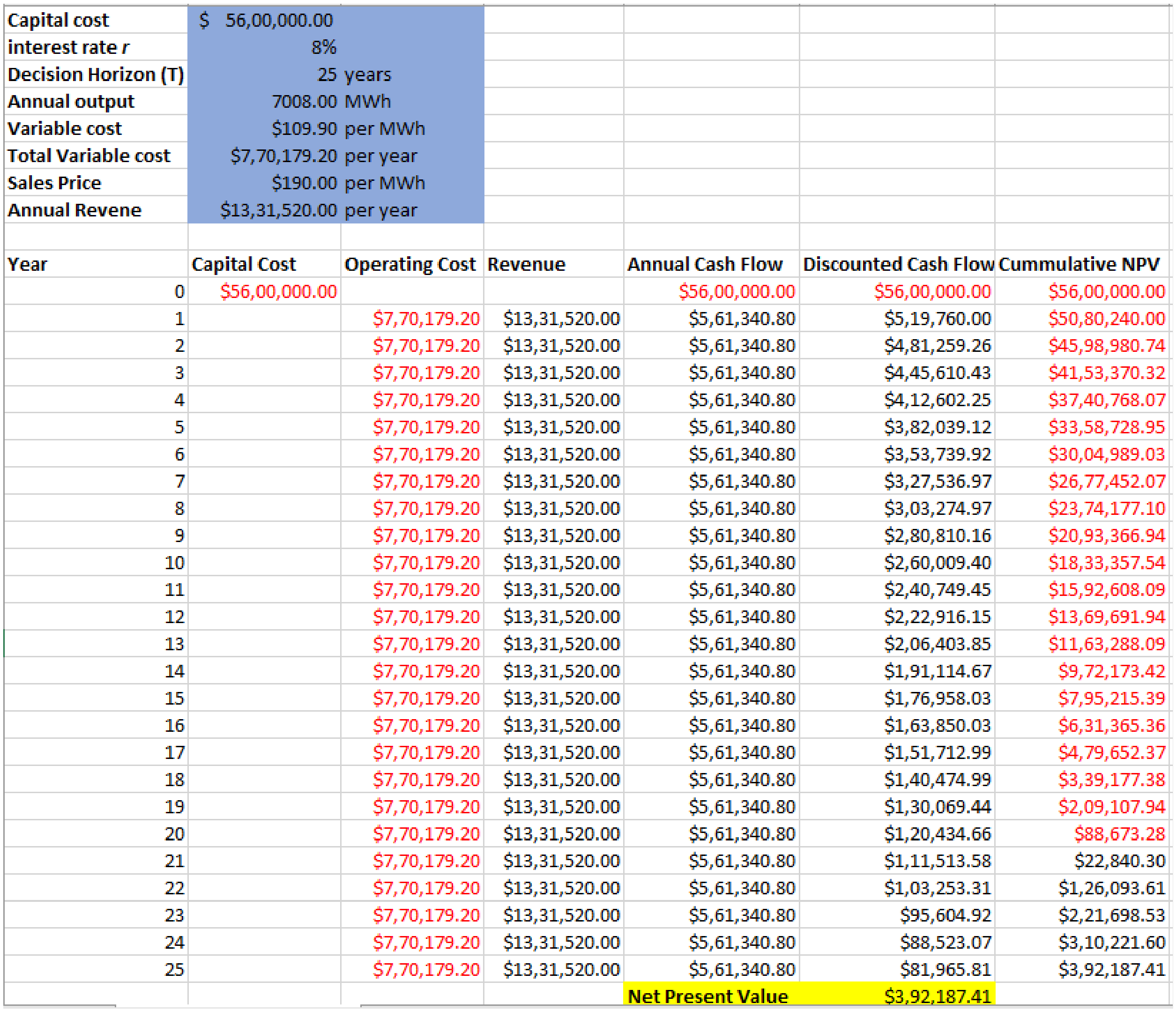
INITIAL COST	INTEREST RATES	PRICE PER kWH
4,410,000.00	6.0%	0.18

FIXED

YEARLY COST
$125,000.00

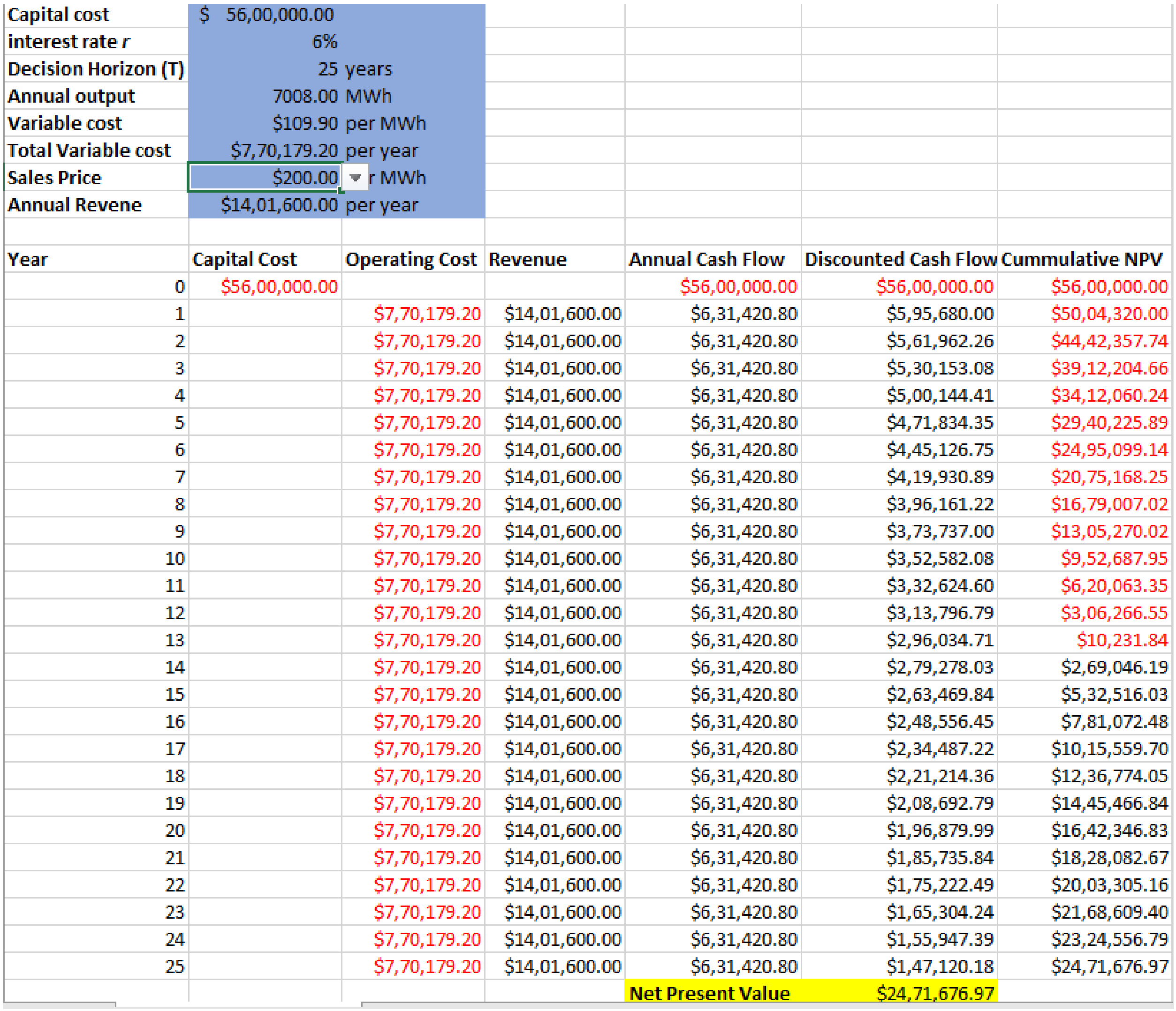
9.2 Wind Energy Net Present Value and Sensitivity Analysis Results

Table 18. NPV for interest rate 8% and sales price $190 per MWh (Worst-Case Scenerio)



Capital cost	$ 56,00,000.00					
interest rate *r*	8%					
Decision Horizon (T)	25	years				
Annual output	7008.00	MWh				
Variable cost	$109.90	per MWh				
Total Variable cost	$7,70,179.20	per year				
Sales Price	$190.00	per MWh				
Annual Revene	$13,31,520.00	per year				
Year	**Capital Cost**	**Operating Cost**	**Revenue**	**Annual Cash Flow**	**Discounted Cash Flow**	**Cummulative NPV**
0	$56,00,000.00			$56,00,000.00	$56,00,000.00	$56,00,000.00
1		$7,70,179.20	$13,31,520.00	$5,61,340.80	$5,19,760.00	$50,80,240.00
2		$7,70,179.20	$13,31,520.00	$5,61,340.80	$4,81,259.26	$45,98,980.74
3		$7,70,179.20	$13,31,520.00	$5,61,340.80	$4,45,610.43	$41,53,370.32
4		$7,70,179.20	$13,31,520.00	$5,61,340.80	$4,12,602.25	$37,40,768.07
5		$7,70,179.20	$13,31,520.00	$5,61,340.80	$3,82,039.12	$33,58,728.95
6		$7,70,179.20	$13,31,520.00	$5,61,340.80	$3,53,739.92	$30,04,989.03
7		$7,70,179.20	$13,31,520.00	$5,61,340.80	$3,27,536.97	$26,77,452.07
8		$7,70,179.20	$13,31,520.00	$5,61,340.80	$3,03,274.97	$23,74,177.10
9		$7,70,179.20	$13,31,520.00	$5,61,340.80	$2,80,810.16	$20,93,366.94
10		$7,70,179.20	$13,31,520.00	$5,61,340.80	$2,60,009.40	$18,33,357.54
11		$7,70,179.20	$13,31,520.00	$5,61,340.80	$2,40,749.45	$15,92,608.09
12		$7,70,179.20	$13,31,520.00	$5,61,340.80	$2,22,916.15	$13,69,691.94
13		$7,70,179.20	$13,31,520.00	$5,61,340.80	$2,06,403.85	$11,63,288.09
14		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,91,114.67	$9,72,173.42
15		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,76,958.03	$7,95,215.39
16		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,63,850.03	$6,31,365.36
17		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,51,712.99	$4,79,652.37
18		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,40,474.99	$3,39,177.38
19		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,30,069.44	$2,09,107.94
20		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,20,434.66	$88,673.28
21		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,11,513.58	$22,840.30
22		$7,70,179.20	$13,31,520.00	$5,61,340.80	$1,03,253.31	$1,26,093.61
23		$7,70,179.20	$13,31,520.00	$5,61,340.80	$95,604.92	$2,21,698.53
24		$7,70,179.20	$13,31,520.00	$5,61,340.80	$88,523.07	$3,10,221.60
25		$7,70,179.20	$13,31,520.00	$5,61,340.80	$81,965.81	$3,92,187.41
				Net Present Value	$3,92,187.41	

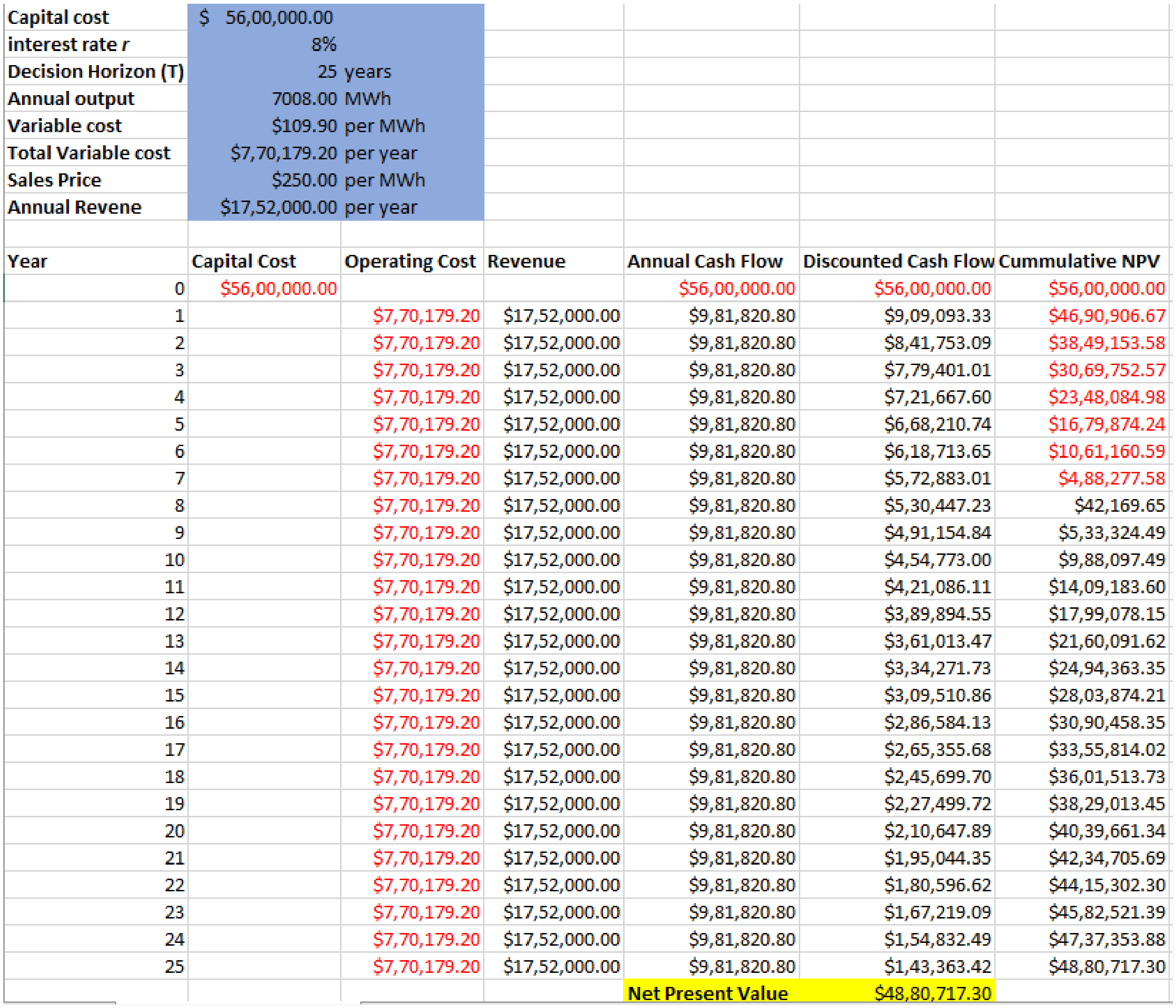
Table 19. NPV for interest rate 6% and sales price $200 per MWh (Market Price)



Capital cost	$ 56,00,000.00	
interest rate *r*	6%	
Decision Horizon (T)	25	years
Annual output	7008.00	MWh
Variable cost	$109.90	per MWh
Total Variable cost	$7,70,179.20	per year
Sales Price	$200.00	r MWh
Annual Revene	$14,01,600.00	per year

Year	**Capital Cost**	**Operating Cost**	**Revenue**	**Annual Cash Flow**	**Discounted Cash Flow**	**Cummulative NPV**
0	$56,00,000.00			$56,00,000.00	$56,00,000.00	$56,00,000.00
1		$7,70,179.20	$14,01,600.00	$6,31,420.80	$5,95,680.00	$50,04,320.00
2		$7,70,179.20	$14,01,600.00	$6,31,420.80	$5,61,962.26	$44,42,357.74
3		$7,70,179.20	$14,01,600.00	$6,31,420.80	$5,30,153.08	$39,12,204.66
4		$7,70,179.20	$14,01,600.00	$6,31,420.80	$5,00,144.41	$34,12,060.24
5		$7,70,179.20	$14,01,600.00	$6,31,420.80	$4,71,834.35	$29,40,225.89
6		$7,70,179.20	$14,01,600.00	$6,31,420.80	$4,45,126.75	$24,95,099.14
7		$7,70,179.20	$14,01,600.00	$6,31,420.80	$4,19,930.89	$20,75,168.25
8		$7,70,179.20	$14,01,600.00	$6,31,420.80	$3,96,161.22	$16,79,007.02
9		$7,70,179.20	$14,01,600.00	$6,31,420.80	$3,73,737.00	$13,05,270.02
10		$7,70,179.20	$14,01,600.00	$6,31,420.80	$3,52,582.08	$9,52,687.95
11		$7,70,179.20	$14,01,600.00	$6,31,420.80	$3,32,624.60	$6,20,063.35
12		$7,70,179.20	$14,01,600.00	$6,31,420.80	$3,13,796.79	$3,06,266.55
13		$7,70,179.20	$14,01,600.00	$6,31,420.80	$2,96,034.71	$10,231.84
14		$7,70,179.20	$14,01,600.00	$6,31,420.80	$2,79,278.03	$2,69,046.19
15		$7,70,179.20	$14,01,600.00	$6,31,420.80	$2,63,469.84	$5,32,516.03
16		$7,70,179.20	$14,01,600.00	$6,31,420.80	$2,48,556.45	$7,81,072.48
17		$7,70,179.20	$14,01,600.00	$6,31,420.80	$2,34,487.22	$10,15,559.70
18		$7,70,179.20	$14,01,600.00	$6,31,420.80	$2,21,214.36	$12,36,774.05
19		$7,70,179.20	$14,01,600.00	$6,31,420.80	$2,08,692.79	$14,45,466.84
20		$7,70,179.20	$14,01,600.00	$6,31,420.80	$1,96,879.99	$16,42,346.83
21		$7,70,179.20	$14,01,600.00	$6,31,420.80	$1,85,735.84	$18,28,082.67
22		$7,70,179.20	$14,01,600.00	$6,31,420.80	$1,75,222.49	$20,03,305.16
23		$7,70,179.20	$14,01,600.00	$6,31,420.80	$1,65,304.24	$21,68,609.40
24		$7,70,179.20	$14,01,600.00	$6,31,420.80	$1,55,947.39	$23,24,556.79
25		$7,70,179.20	$14,01,600.00	$6,31,420.80	$1,47,120.18	$24,71,676.97
				Net Present Value	$24,71,676.97	

Table 20: NPV for interest rate 8% and sales price $250 per MWh (Best-Case Scenario)

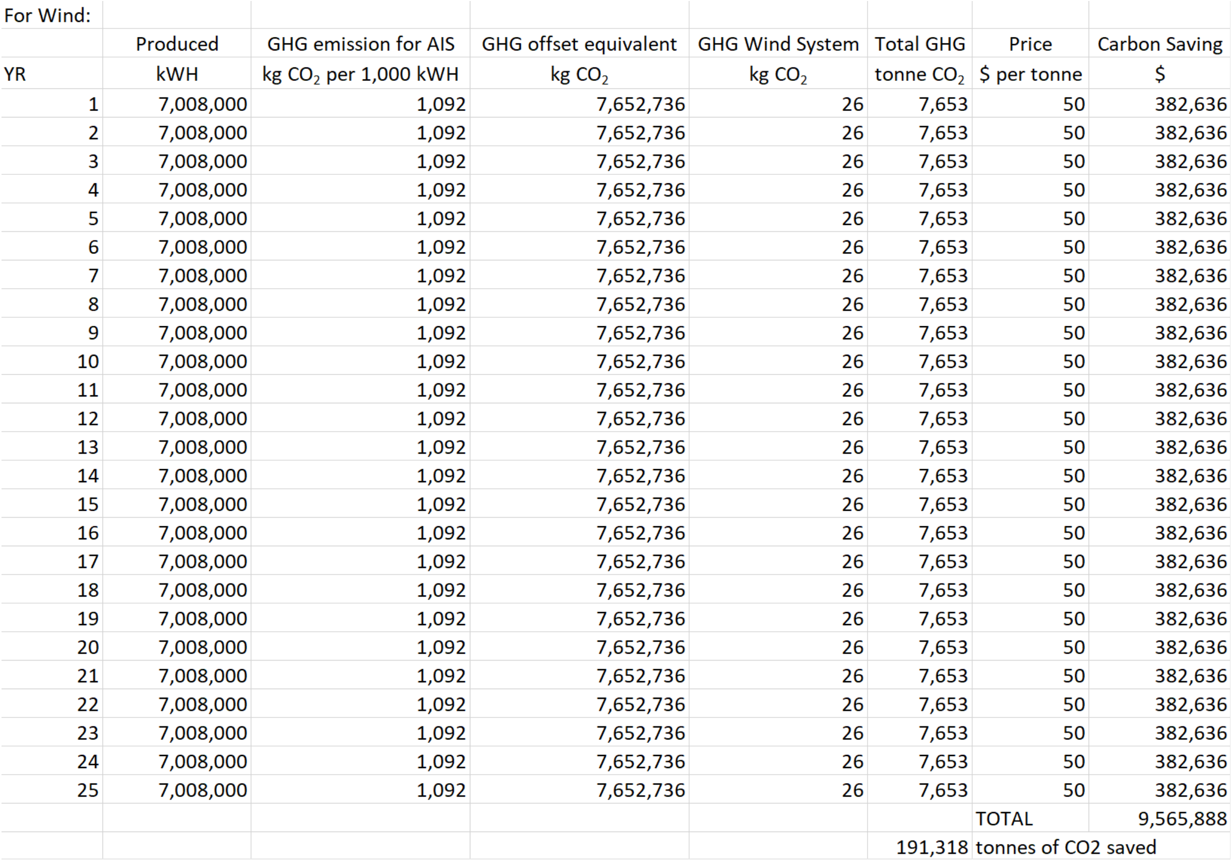


Capital cost	$ 56,00,000.00	
interest rate *r*	8%	
Decision Horizon (T)	25	years
Annual output	7008.00	MWh
Variable cost	$109.90	per MWh
Total Variable cost	$7,70,179.20	per year
Sales Price	$250.00	per MWh
Annual Revene	$17,52,000.00	per year

Year	**Capital Cost**	**Operating Cost**	**Revenue**	**Annual Cash Flow**	**Discounted Cash Flow**	**Cummulative NPV**
0	$56,00,000.00			$56,00,000.00	$56,00,000.00	$56,00,000.00
1		$7,70,179.20	$17,52,000.00	$9,81,820.80	$9,09,093.33	$46,90,906.67
2		$7,70,179.20	$17,52,000.00	$9,81,820.80	$8,41,753.09	$38,49,153.58
3		$7,70,179.20	$17,52,000.00	$9,81,820.80	$7,79,401.01	$30,69,752.57
4		$7,70,179.20	$17,52,000.00	$9,81,820.80	$7,21,667.60	$23,48,084.98
5		$7,70,179.20	$17,52,000.00	$9,81,820.80	$6,68,210.74	$16,79,874.24
6		$7,70,179.20	$17,52,000.00	$9,81,820.80	$6,18,713.65	$10,61,160.59
7		$7,70,179.20	$17,52,000.00	$9,81,820.80	$5,72,883.01	$4,88,277.58
8		$7,70,179.20	$17,52,000.00	$9,81,820.80	$5,30,447.23	$42,169.65
9		$7,70,179.20	$17,52,000.00	$9,81,820.80	$4,91,154.84	$5,33,324.49
10		$7,70,179.20	$17,52,000.00	$9,81,820.80	$4,54,773.00	$9,88,097.49
11		$7,70,179.20	$17,52,000.00	$9,81,820.80	$4,21,086.11	$14,09,183.60
12		$7,70,179.20	$17,52,000.00	$9,81,820.80	$3,89,894.55	$17,99,078.15
13		$7,70,179.20	$17,52,000.00	$9,81,820.80	$3,61,013.47	$21,60,091.62
14		$7,70,179.20	$17,52,000.00	$9,81,820.80	$3,34,271.73	$24,94,363.35
15		$7,70,179.20	$17,52,000.00	$9,81,820.80	$3,09,510.86	$28,03,874.21
16		$7,70,179.20	$17,52,000.00	$9,81,820.80	$2,86,584.13	$30,90,458.35
17		$7,70,179.20	$17,52,000.00	$9,81,820.80	$2,65,355.68	$33,55,814.02
18		$7,70,179.20	$17,52,000.00	$9,81,820.80	$2,45,699.70	$36,01,513.73
19		$7,70,179.20	$17,52,000.00	$9,81,820.80	$2,27,499.72	$38,29,013.45
20		$7,70,179.20	$17,52,000.00	$9,81,820.80	$2,10,647.89	$40,39,661.34
21		$7,70,179.20	$17,52,000.00	$9,81,820.80	$1,95,044.35	$42,34,705.69
22		$7,70,179.20	$17,52,000.00	$9,81,820.80	$1,80,596.62	$44,15,302.30
23		$7,70,179.20	$17,52,000.00	$9,81,820.80	$1,67,219.09	$45,82,521.39
24		$7,70,179.20	$17,52,000.00	$9,81,820.80	$1,54,832.49	$47,37,353.88
25		$7,70,179.20	$17,52,000.00	$9,81,820.80	$1,43,363.42	$48,80,717.30
				Net Present Value	$48,80,717.30	

9.3 Greenhouse Gas Emission data

Table 21 GHG Emission Offset for Wind System for the projected 25 Years Lifetime



For Wind:							
	Produced	GHG emission for AIS	GHG offset equivalent	GHG Wind System	Total GHG	Price	Carbon Saving
YR	kWH	kg CO_2 per 1,000 kWH	kg CO_2	kg CO_2	tonne CO_2	$ per tonne	$
1	7,008,000	1,092	7,652,736	26	7,653	50	382,636
2	7,008,000	1,092	7,652,736	26	7,653	50	382,636
3	7,008,000	1,092	7,652,736	26	7,653	50	382,636
4	7,008,000	1,092	7,652,736	26	7,653	50	382,636
5	7,008,000	1,092	7,652,736	26	7,653	50	382,636
6	7,008,000	1,092	7,652,736	26	7,653	50	382,636
7	7,008,000	1,092	7,652,736	26	7,653	50	382,636
8	7,008,000	1,092	7,652,736	26	7,653	50	382,636
9	7,008,000	1,092	7,652,736	26	7,653	50	382,636
10	7,008,000	1,092	7,652,736	26	7,653	50	382,636
11	7,008,000	1,092	7,652,736	26	7,653	50	382,636
12	7,008,000	1,092	7,652,736	26	7,653	50	382,636
13	7,008,000	1,092	7,652,736	26	7,653	50	382,636
14	7,008,000	1,092	7,652,736	26	7,653	50	382,636
15	7,008,000	1,092	7,652,736	26	7,653	50	382,636
16	7,008,000	1,092	7,652,736	26	7,653	50	382,636
17	7,008,000	1,092	7,652,736	26	7,653	50	382,636
18	7,008,000	1,092	7,652,736	26	7,653	50	382,636
19	7,008,000	1,092	7,652,736	26	7,653	50	382,636
20	7,008,000	1,092	7,652,736	26	7,653	50	382,636
21	7,008,000	1,092	7,652,736	26	7,653	50	382,636
22	7,008,000	1,092	7,652,736	26	7,653	50	382,636
23	7,008,000	1,092	7,652,736	26	7,653	50	382,636
24	7,008,000	1,092	7,652,736	26	7,653	50	382,636
25	7,008,000	1,092	7,652,736	26	7,653	50	382,636
						TOTAL	9,565,888
					191,318	tonnes of CO2 saved	

Table 22 GHG Emission Offset for Solar System for the projected 25 Years Lifetime

For Solar:							
	Produced	GHG emission for AIS	GHG offset equivalent	GHG Wind System	Total GHG	Price	Carbon Saving
YR	kWH	kg CO_2	kg CO_2	kg CO_2	tonne CO_2	$ per tonne	$
1	6,230,000	1,092	6,803,160	41	6,803	50	340,156
2	6,198,850	1,092	6,769,144	41	6,769	50	338,455
3	6,167,856	1,092	6,735,298	41	6,735	50	336,763
4	6,137,016	1,092	6,701,622	41	6,702	50	335,079
5	6,106,331	1,092	6,668,114	41	6,668	50	333,404
6	6,075,800	1,092	6,634,773	41	6,635	50	331,737
7	6,045,421	1,092	6,601,599	41	6,602	50	330,078
8	6,015,194	1,092	6,568,591	41	6,569	50	328,428
9	5,985,118	1,092	6,535,748	41	6,536	50	326,785
10	5,955,192	1,092	6,503,070	41	6,503	50	325,151
11	5,925,416	1,092	6,470,554	41	6,471	50	323,526
12	5,895,789	1,092	6,438,202	41	6,438	50	321,908
13	5,866,310	1,092	6,406,011	41	6,406	50	320,298
14	5,836,979	1,092	6,373,981	41	6,374	50	318,697
15	5,807,794	1,092	6,342,111	41	6,342	50	317,103
16	5,778,755	1,092	6,310,400	41	6,310	50	315,518
17	5,749,861	1,092	6,278,848	41	6,279	50	313,940
18	5,721,112	1,092	6,247,454	41	6,247	50	312,371
19	5,692,506	1,092	6,216,217	41	6,216	50	310,809
20	5,664,044	1,092	6,185,136	41	6,185	50	309,255
21	5,635,723	1,092	6,154,210	41	6,154	50	307,708
22	5,607,545	1,092	6,123,439	41	6,123	50	306,170
23	5,579,507	1,092	6,092,822	41	6,093	50	304,639
24	5,551,609	1,092	6,062,357	41	6,062	50	303,116
25	5,523,851	1,092	6,032,046	41	6,032	50	301,600
						TOTAL	8,012,694
					160,254	tonnes of CO2 saved	

9.4 LCA Assumption

- Raw Material Extraction stage: Excluding the impact of the infrastructures for all energy supply options.
- Manufacturing stage will consider the impact of the energy input.
- Transportation stage: the transportation from raw material extraction stage to manufacturing stage is excluded for.
- Operation stage: the processes of an assembly, installation and maintenance are excluded for all electricity supply options. all three electricity supply options.

- LCA assessment for the battery is excluded due to not being manufactured in the town, but we can assume the life expectancy will decrease. Due to time constraint and missing information, we did not assess the battery's LCA.

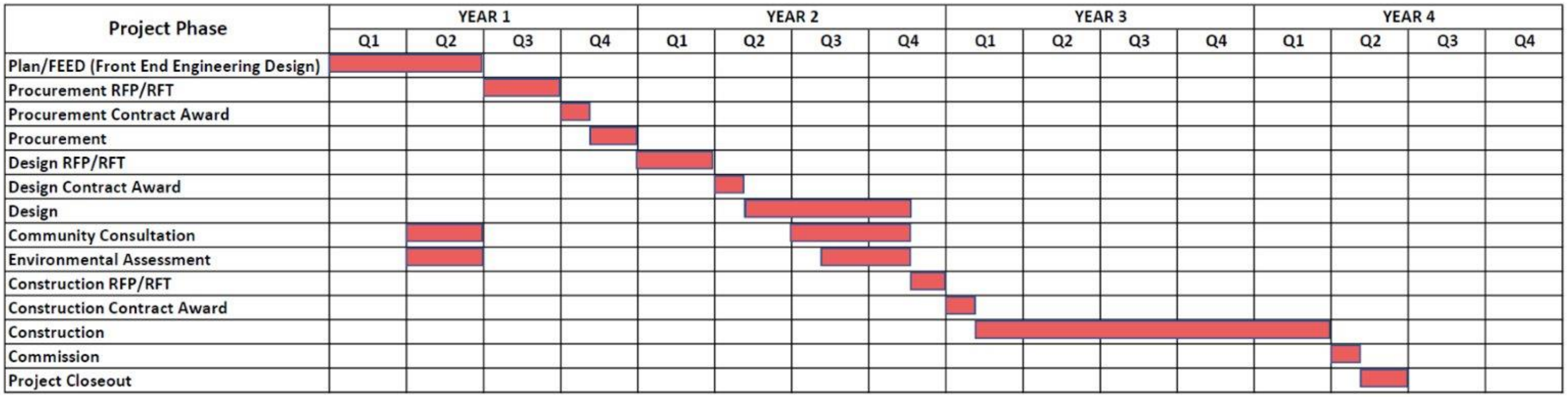
9.5 List of Stakeholder Consulted

Our work would not have been possible without the help of our contacts and stakeholders we met along the way.

Organization	**Person of contact**
Fortis Alberta	Keaton Wheeler Graeme Cowie
Town of Devon	Torrie Santucci Sean Goin
Pembina	Jason Wang Binnu Jeyakumar
Lakeland Solutions/SPEEDIER team	Peter Ewald Marjorie MacDonald
CanREA	Nicholas Gall
Georgian College	Scott McCrindle

9.6 Project Deployment Timeline

This time should serve as a guide to key phases that need to be conducted for the implementation of SPEEDIER.



Project Phase	YEAR 1				YEAR 2				YEAR 3				YEAR 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Plan/FEED (Front End Engineering Design)	🟥	🟥														
Procurement RFP/RFT			🟥													
Procurement Contract Award				🟥												
Procurement				🟥												
Design RFP/RFT					🟥											
Design Contract Award						🟥										
Design						🟥	🟥	🟥								
Community Consultation		🟥					🟥	🟥								
Environmental Assessment		🟥					🟥	🟥								
Construction RFP/RFT								🟥								
Construction Contract Award									🟥							
Construction									🟥	🟥	🟥	🟥	🟥			
Commission														🟥		
Project Closeout														🟥		

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