PRELIMINARY ASSESSMENT OF ALTERNATIVE ENERGY POTENTIAL IN COASTAL LABRADOR

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newfoundland labrador hydro
a nalcor energy company

EXECUTIVE SUMMARY

The Coastal Labrador Alternative Energy study is a joint venture between Newfoundland and Labrador Hydro (Hydro) and the Government of Newfoundland and Labrador. In 2009, Government invested approximately $250,000 for Hydro to investigate the potential for the integration of alternative energy sources, including solar, wind and small scale hydroelectric facilities into isolated communities that rely on diesel generation as a primary means of electricity.

To ensure the success of the study, coastal Labrador communities were pre-screened for the project based on specific criteria developed by Hydro. The criteria included: annual minimum load of 200 kilowatts, forecasted growth in electricity consumption over the next five years and annual energy consumption in excess of 3000 megawatt hours. Based on these criteria seven communities were selected for the study: Cartwright, Charlottetown, Hopedale, Makkovik, Mary's Harbour, Nain and Port Hope Simpson.

Weather stations were deployed in each of these communities to collect information on the wind speed, rainfall, and solar radiation experienced in each community. The weather stations had staggered commissioning dates ranging from April 2009 to August 2009. As a result, there are currently four to eight months of weather data available for each location in the study. Data was compared with information available from Environment Canada, the Canadian Wind Atlas, and NASA's Surface Meteorology and Solar Radiation database.

Hatch Ltd. was retained by Newfoundland and Labrador Hydro to conduct an assessment of the hydraulic potential of the selected communities. Three scales of hydro projects were considered; micro, mini and small.

An assessment of the resources and the economics was completed considering numerous schemes for each location. The economic feasibility evaluation included examination of the annual community power requirements; the energy potential for each resource (i.e. solar, wind, hydro); the possibility of hybrid systems; and the economics for the implementation of each proposed solution.

Study Findings

Wind

Wind is more prevalent in winter months. It provides a nice fit with winter peaking systems. Installation of meteorological towers capable of measuring wind speeds at hub height at sites optimally located for a wind energy installation is recommended for Cartwright, Hopedale, Makkovik and Nain.

Hydrology

36 potential sites were identified, out of which 13 sites were recommended for further consideration. Interconnection possibilities were considered for Port Hope Simpson, Charlottetown, and Mary's Harbour. Three potential sites were identified with two of those capable of meeting the entire energy requirements of all three communities. Some of the hydro generation sites identified are capable of completely displacing diesel generation in certain locations; however, the scope of this study was limited to run-of-river installations. To replace diesel generation in these locations, solutions with storage capability would likely be required. Prefeasibility hydro investigations should be carried out at Sites 4, MK S-1, 5, 1, MH S-2A, 2, MK S-2, MH S-4, PHS S-1, CH S-3, 12, PHS S-3, and PHS S-5.

More detailed mapping should be produced to further delineate the hydro and wind sites. This could be accomplished through a LIDAR Survey covering the sites identified in the study, and could be extended to the whole coast. Such data could potentially yield a greater number of sites, and provide the data necessary to move to the next step.

Solar

Though Labrador has a moderate solar resource, the development and deployment of solar installations remains very expensive and existing technologies have poor energy conversion efficiency. Should the cost of solar energy decrease significantly, it would be worth revisiting the economic feasibility assessment to account for this decrease and determine if solar energy has become a more attractive choice.

In summary, based on the existing weather data, it is reasonable to confirm that Labrador possesses alternative energy resources that, under the right economic conditions, could be developed to reduce the usage of diesel generation in many communities.

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INTRODUCTION

1.1 Objective

The Coastal Labrador Alternative Energy study is a joint venture between Newfoundland and Labrador Hydro and the Government of Newfoundland and Labrador. In 2009, Government invested approximately $250,000 for Hydro to investigate the potential for the integration of alternative energy sources into isolated, off-grid communities that rely on diesel generation as a primary means of electricity. This initiative consisted of an evaluation of the renewable resources available in selected communities and a preliminary feasibility assessment of the financial and technical requirements associated with integrating alternatives in the existing energy systems. Energies explored included solar, wind and small-scale hydroelectric facilities. As the study is a preliminary assessment of resources available in the identified communities, its main objective is to distinguish sites where development is technically and economically feasible from those where it is not. Further assessment of the resource potential is required before advancing with any potentially feasible projects. A full list of recommendation can be found in Section 6.2 Recommendations.

This initiative is primarily guided by the two main objectives outlined in the Newfoundland and Labrador Energy Plan: protection of the environment through the reduction of emissions, and the development of energy projects in the best long-term interests of residents of the province. Through integration of renewable energy systems, fuel consumption and the operating costs of the diesel generation facilities can be reduced.

1.2 Scope of Work

The scope of work was as follows:

- Determine a set of criterion to screen potential communities, ensuring identification of the communities with the greatest likelihood of success.
- Select and deploy weather monitoring stations in each of the selected communities.
- Retain consulting services to assess hydraulic potential in identified communities.
- Collect information from weather stations concerning wind and solar energy potential in the selected communities.
- Perform economic analysis for each location using detailed cost information for each energy alternative.
- Model data to determine the most promising alternatives for each location.

It is important to note that this study will provide preliminary estimates of the alternative energy potential available at each of the sites in question. The methods employed to determine the availability and quality of the resources is only suited to preliminary inquiries. The conclusions of this study will provide recommendations for further suggested investigation and action based on these results.

1.3 Background

Newfoundland and Labrador Hydro operates 22 isolated diesel systems province wide, 16 of which are located in Labrador. The forecasted energy demands for 2009 were used as the baseline for the energy requirements for each system, and the forecasted energy demands for 2011 through 2015 were used for modeling and subsequent analysis. Town locations are illustrated below.

Figure 1 - Communities under study

1.3.1 Nain

Nain is both the northernmost and largest community considered in the alternative energy study, with a population of approximately 1000 (1). In keeping with home heating requirements due to its northern position, Nain experiences its highest peak loads and net energy consumption during the winter months. This is illustrated in Figure 2 - Nain 2008 Monthly Net Peak Load and Figure 3 - Nain 2008 Monthly Net Energy. Nain is classified as a winter peaking system.

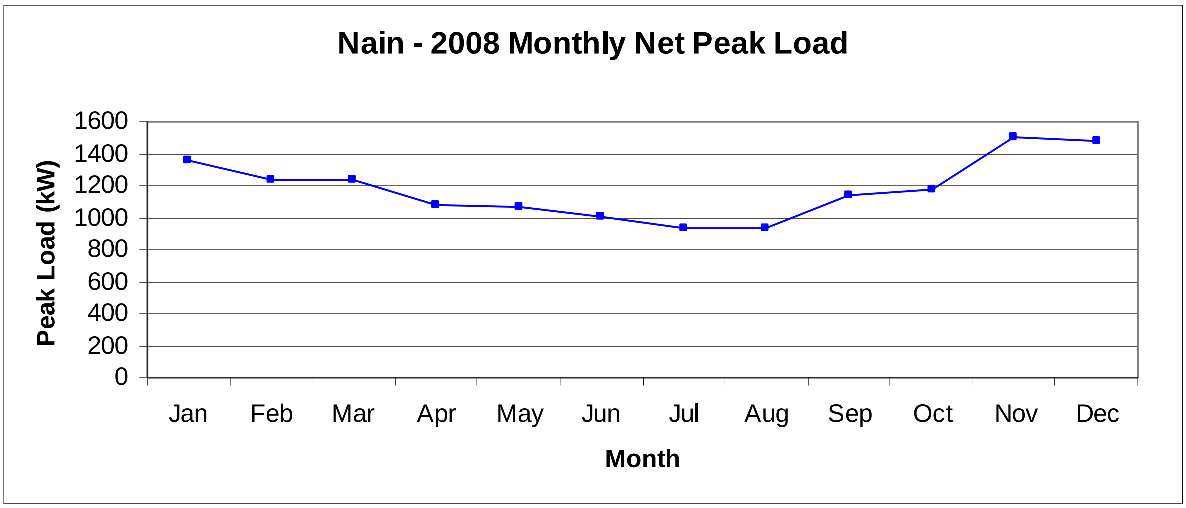


Figure 2 - Nain 2008 Monthly Net Peak Load

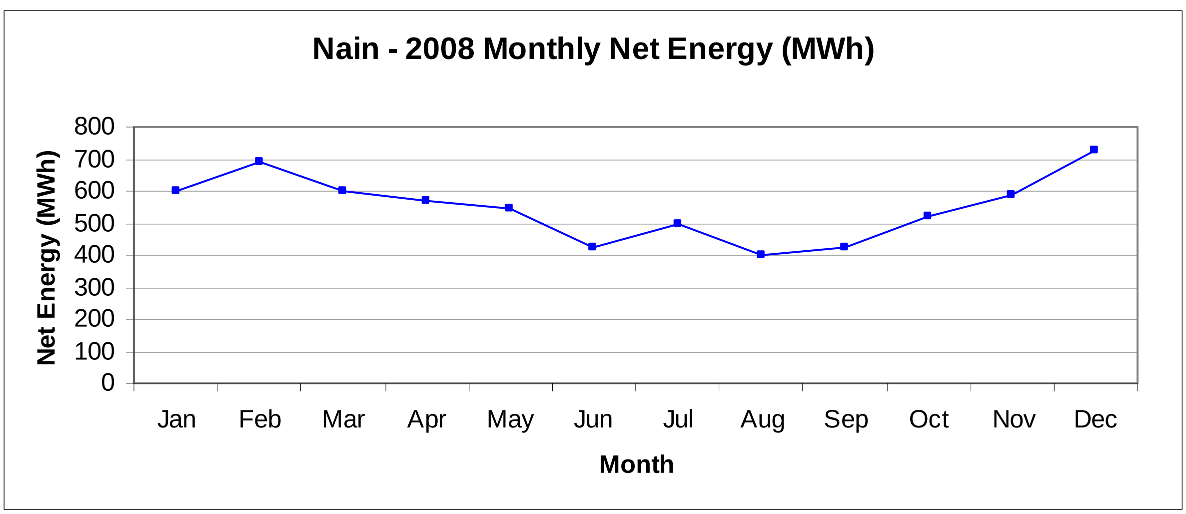


Figure 3 - Nain 2008 Monthly Net Energy

1.3.2 Hopedale

Hopedale is one of the more northern communities studied, situated on the northern Labrador coast. It has a population of approximately 530 people (1). Due to its northern location, the Hopedale system typically experiences its peak demand and highest energy requirement during winter months, as heating requirements and subsequently furnace usage and energy required for water heating are typically higher during these months. This is illustrated in Figure 4 - Hopedale 2008 Monthly Net Peak Load, and Figure 5 - Hopedale 2008 Monthly Net Energy. Hopedale is thus classified as a winter peaking system.

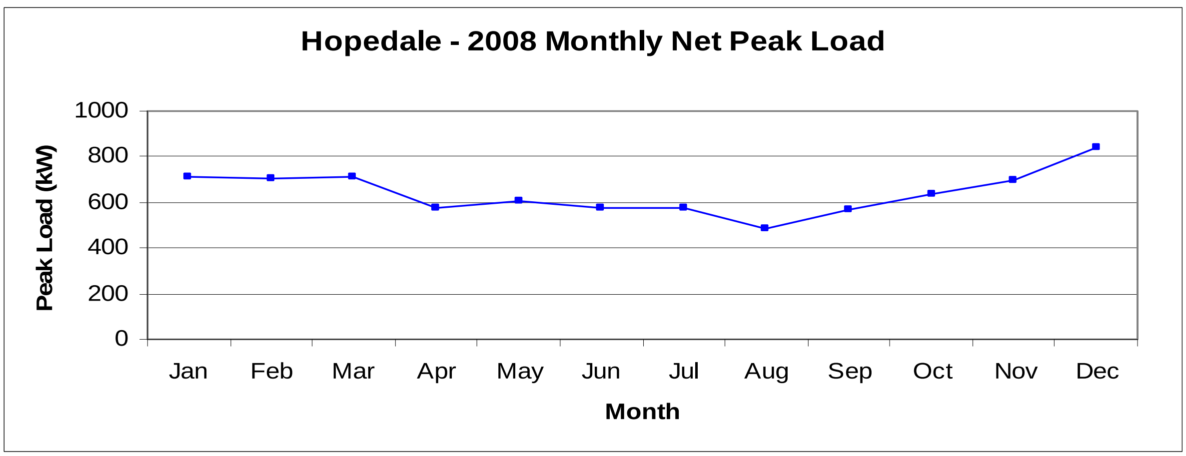


Figure 4 - Hopedale 2008 Monthly Net Peak Load

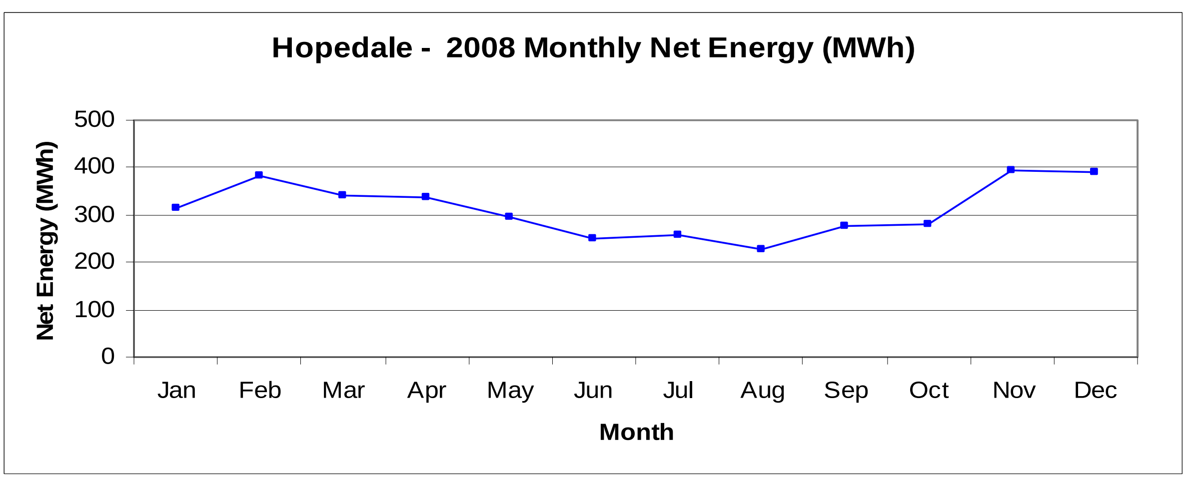


Figure 5 - Hopedale 2008 Monthly Net Energy

1.3.3 Makkovik

Makkovik is a northern community with approximately 360 inhabitants (1). As evident in Figure 6 - Makkovik 2008 Monthly Net Peak Load, Makkovik experiences two periods of high net peak loads; one in July and August, the other in December. The summer system peak is due to the seasonal operation of a local crab plant. The winter system peak is due to increased home heating requirements. These observations are strengthened by examining Figure 7 - Makkovik 2008 Monthly Net Energy, as highest energy consumption coincides with these system peaks.

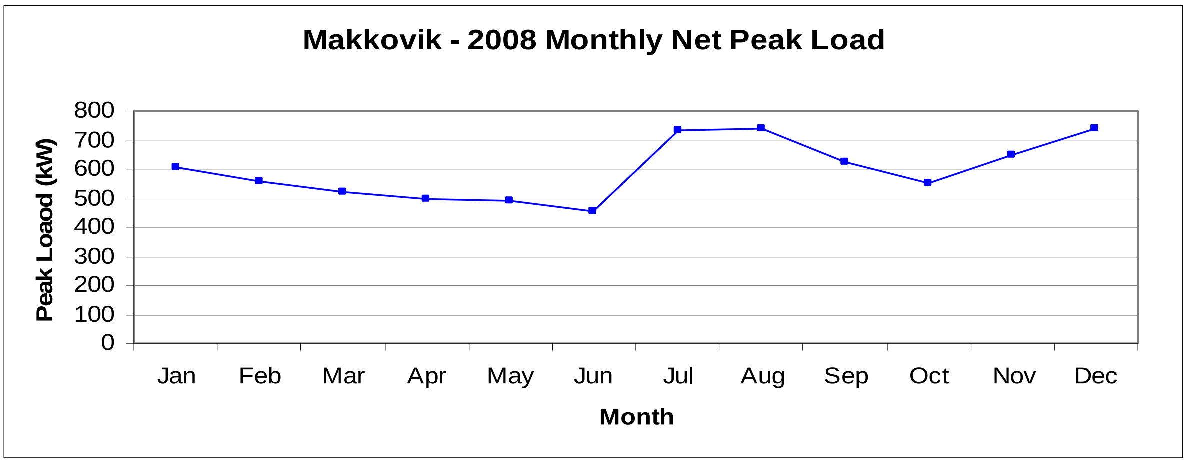


Figure 6 - Makkovik 2008 Monthly Net Peak Load

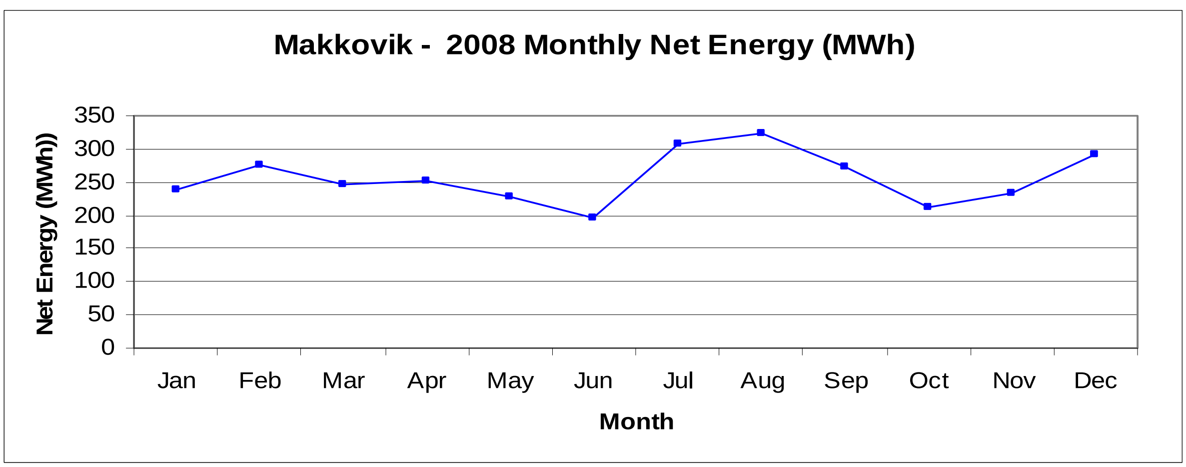


Figure 7 - Makkovik 2008 Monthly Net Energy

1.3.4 Cartwright

Cartwright is a community with a population of approximately 550 people (1), located at the entrance of Sandwich Bay. As evident in Figure 8 - Cartwright 2008 Monthly Net Peak Load, highest system loads typically occur in June and July. In addition, as shown in Figure 9 - Cartwright 2008 Monthly Net Energy, the highest energy consumption also occurs in this time period. These findings are as expected, due to the seasonal operation of a local crab plant. As a result, Cartwright is classified as a summer peaking system.

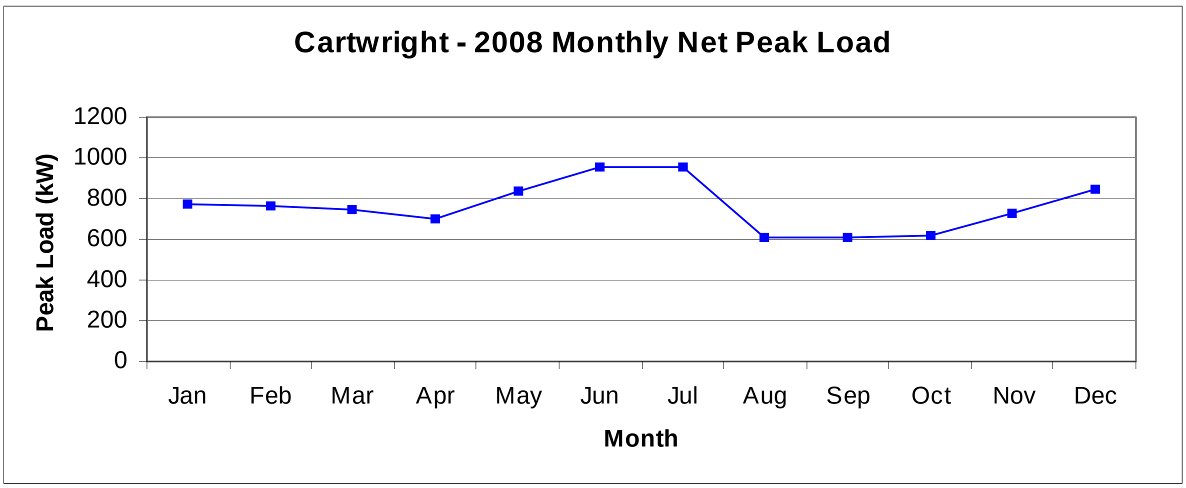


Figure 8 - Cartwright 2008 Monthly Net Peak Load

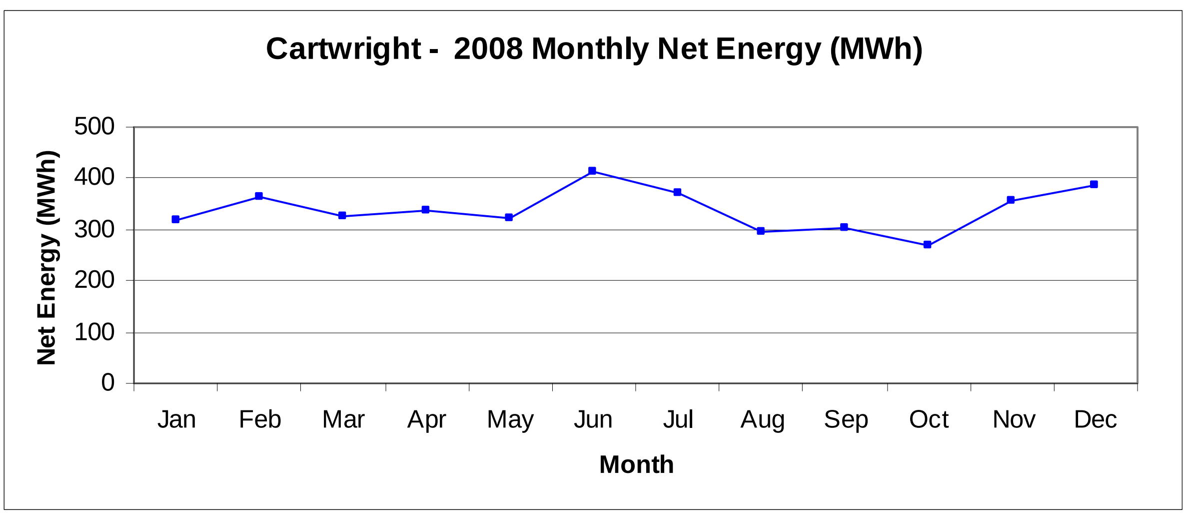


Figure 9 - Cartwright 2008 Monthly Net Energy

1.3.5 Charlottetown

It is one of the smaller communities included in the Coastal Labrador Alternative Energy study with a population of approximately 360 people (1). As evident in Figure 10 - Charlottetown 2008 Monthly Net Peak Load, Charlottetown experiences its highest system loads between June and August. In addition, July and August exhibit the highest net energy consumption, as illustrated in Figure 11 - Charlottetown 2008 Monthly Net Energy. These findings are as expected, due to the annual operating period of the local shrimp plant. As a result, Charlottetown is classified as a summer peaking system.

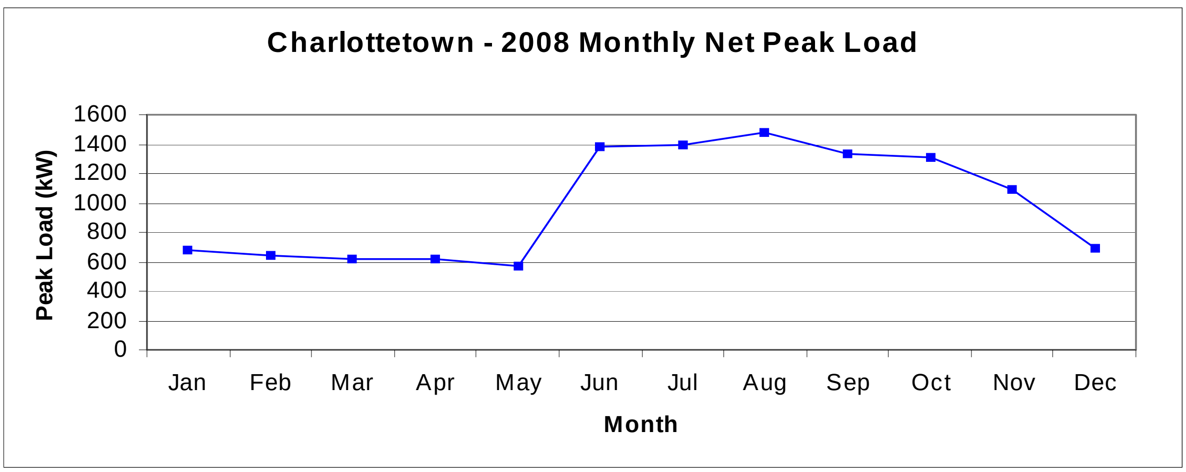


Figure 10 - Charlottetown 2008 Monthly Net Peak Load

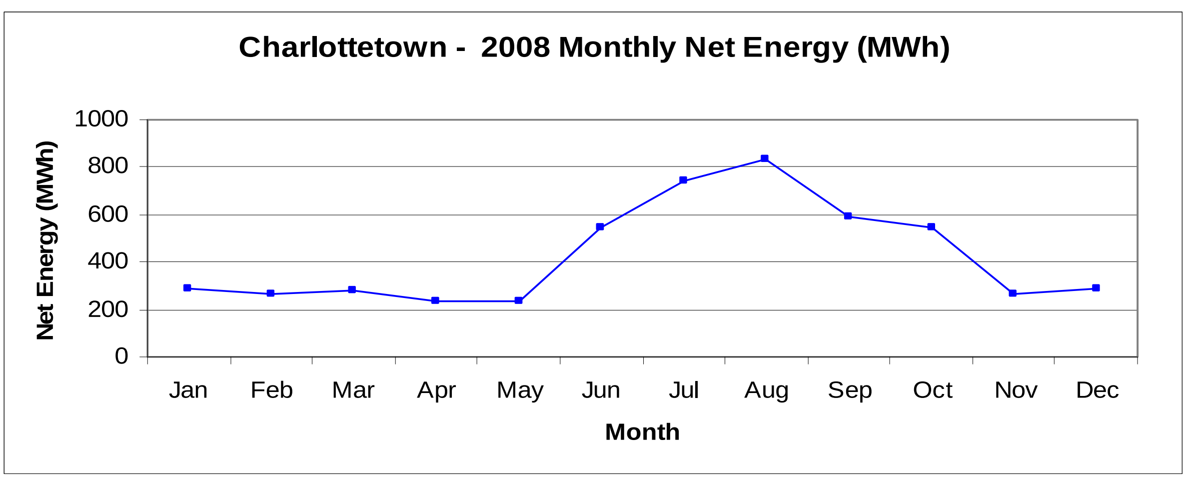


Figure 11 - Charlottetown 2008 Monthly Net Energy

1.3.6 Port Hope Simpson

Port Hope Simpson is located in southern Labrador at the mouth of the Alexis River. It has a population of approximately 529 people (1). As illustrated in Figure 12 - Port Hope Simpson 2008 Monthly Net Peak Load and Figure 13 - Port Hope Simpson 2008 Monthly Net Energy, Port Hope Simpson experiences highest system loads and net energy consumption during winter months. As a result, Port Hope Simpson is classified as a winter peaking system.

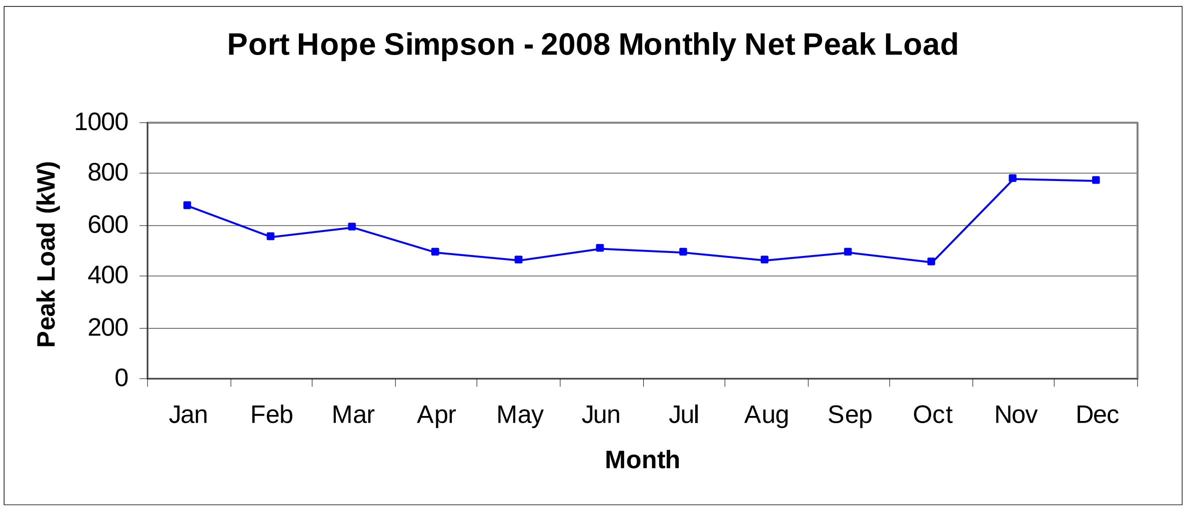


Figure 12 - Port Hope Simpson 2008 Monthly Net Peak Load

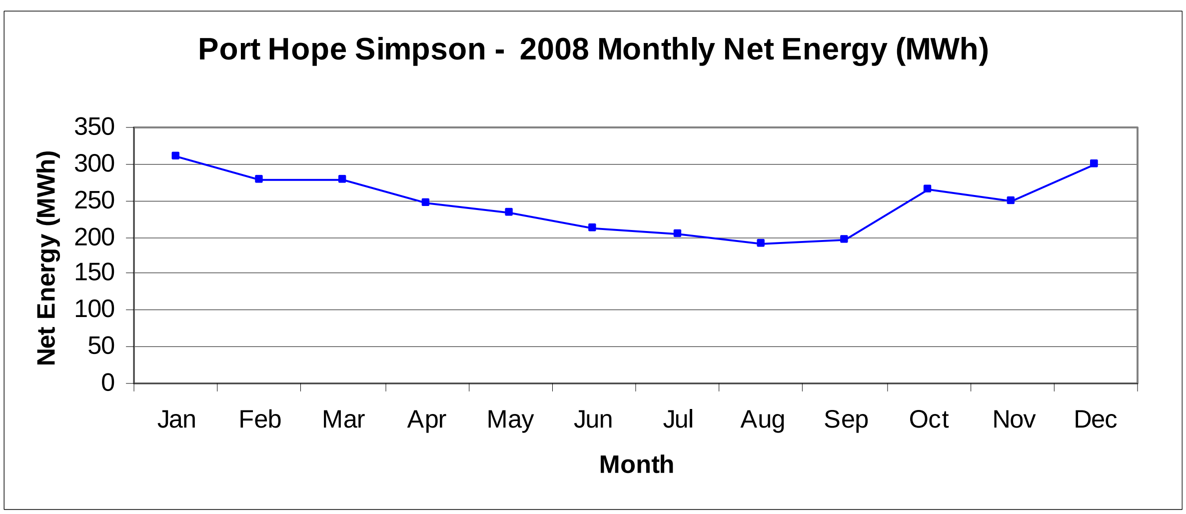


Figure 13 - Port Hope Simpson 2008 Monthly Net Energy

1.3.7 Mary's Harbour

Located on the southern coast of Labrador, Mary's Harbour is located at the mouth of the St. Mary's River. The community has a population of approximately 417 people (1). As illustrated in Figure 14 - Mary's Harbour 2008 Monthly Net Peak Load, Mary's Harbour experiences peak loads during the summer months, due to seasonal operation of the local crab processing facility. This is supported by Figure 15 - Mary's Harbour 2008 Monthly Net Energy, illustrating highest energy consumption in June. It is important to note that the illustrated May peak load in Figure 14 is a possible anomalous value. The value of the same reading for 2007 was 644 kW and for 2009 was 702 kW. It is expected the May 2008 value should have read somewhere in this range. Mary's Harbour is classified as a summer peaking system.

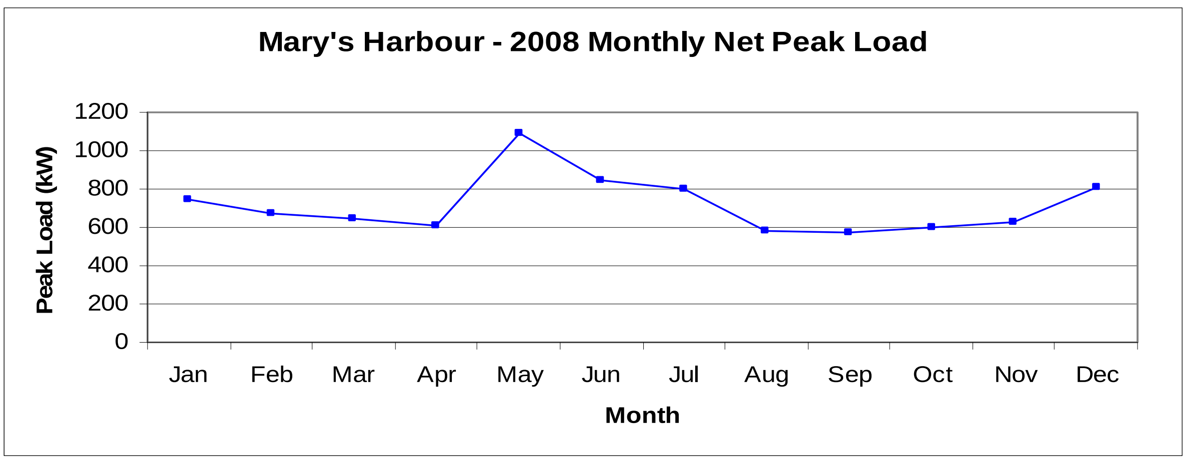


Figure 14 - Mary's Harbour 2008 Monthly Net Peak Load

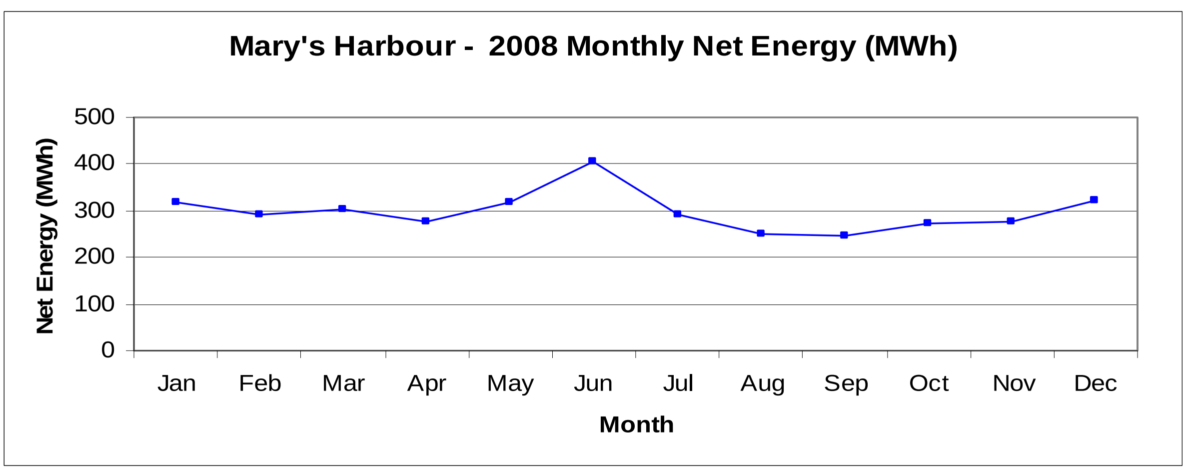


Figure 15 - Mary's Harbour 2008 Monthly Net Energy

2 METHODOLOGY

To determine the existing energy potential in each location, it was necessary to decide what energies to focus on, obtain as much weather data for each site as possible, and model collected data to assess economic viability.

2.1 Community Selection

Due to the large number of isolated systems in coastal Labrador, it was decided to narrow the scope of the study to only include those communities which had the greatest likelihood of technical success. The integration of alternative energy sources into an isolated system is a technically challenging feat. Since the alternative energy sources such as solar, wind, and run-of-river hydro are continuously random and variable, they cannot be installed to provide capacity for the system. Rather they provide energy to the system in continuously varying amounts and serve to displace energy produced by burning diesel fuel. To ensure the system has adequate capacity (energy required by the load at any instant), the alternative energy must be electrically paralleled with the existing diesel generators. In addition, the available potential and volatility of the alternative energy source can have unpredictable effects on the system; if the source is too small, much of the available energy will not be converted into electricity, if the source is too large, system stability and quality issues rise to the forefront.

A set of selection criteria was developed by Newfoundland and Labrador Hydro to pre-screen communities for inclusion in the study. The criteria were as follows:

1) Annual minimum load equal to or in excess of 200 kW in 2007.
2) Annual energy consumption equal to or in excess of 3000 MWh in 2007.
3) Growth in consumption forecasted for the system over the five-year forecast horizon.

Based on these criteria, seven communities were selected: Nain, Hopedale, Makkovik, Cartwright, Charlottetown, Port Hope Simpson, and Mary's Harbour.

2.2 Alternative Energies Considered

The solar, wind, and hydraulic potential of each location was studied. These three were chosen since reasonable potential was expected in these locations and the economics associated with these ventures does not make them prohibitive in small, isolated communities. In addition, these alternative energies are more widely used and are better known.

Hydro projects were considered on three scales: small, mini, and micro. A request for proposal (RFP) for consultant services was issued in April with awarding of the contract to Hatch Ltd. in May for completion in October. Solar and wind energy analysis was completed by Newfoundland and Labrador Hydro's System Planning department.

2.3 Data Sources

2.3.1 Weather Stations

Eight weather stations were purchased to assist in the determination of possible energy resources. Seven were deployed in Labrador, with one in each of the communities studied. The eighth station was kept in office for configuration and testing purposes.

The choice of weather station was an important decision made in the early part of the project. A Request for Quotation (RFQ) was issued for public tender in November 2008. From the proposals submitted, the Davis Vantage Pro2 was selected for deployment. For the purposes of this study, the Vantage Pro2 was required to monitor and record wind speed, solar radiation, and rainfall amounts.

The weather stations had staggered deployments from April through August 2009. All seven systems were operational in August 2009. As a result, there is currently four to eight months of complete data sets available for each location. For more information on data collected for a specific location, please refer to the appendix for that community.

2.3.2 Other Sources of Data

Due to the date of deployment of the weather stations, it was not possible to gather one complete year of data before beginning analysis and evaluation. As a result, it was necessary to obtain alternate sources of data capable of providing this information.

Environment Canada operates and maintains a National Climate Data and Information Archive. The archive provides an online collection of official climate and weather observations from across Canada. Through this resource wind speed information was obtained for five of the seven locations. Cartwright, Hopedale, and Makkovik each have an Environment Canada weather monitoring station in the community. Both Mary's Harbour and Nain each have two Environment Canada weather stations. One is located in the community, and the other at the local airport. Though this resource could not provide detailed historical information for Charlottetown and Port Hope Simpson, their geographic proximity to Mary's Harbour and the similarities in the measured data for the locations made the use of available Mary's Harbour data suitable for initial model development.

The Environment Canada Canadian Wind Atlas also provided valuable information on the wind resources to be expected in each of the locations. The Canadian Wind Atlas models long term atmospheric data and statistical properties to obtain a small scale picture of the wind speeds in a particular area. Unlike the National Climate Data and Information Archive, the information provided by the Canadian Wind Atlas is purely theoretical and is not based on actual recorded measurements. This data was available for all seven locations.

The NASA Atmospheric Science Data Centre has developed a Surface Meteorology and Solar Energy website for use by the general public. This website uses information from over 200 satellites to derive meteorology and solar energy parameters. Collected information is then monthly averaged over 22 years of data. This provided accurate monthly solar radiation data for each of the seven locations in the study.

2.4 HOMER

Developed at the United States National Renewable Energy Laboratory, HOMER is a powerful software tool for economic analysis of renewable power systems, distributed power systems, and hybrid power systems. It allows users to model off-grid and grid-connected systems that consider numerous alternative energies. Based on the user supplied information, HOMER runs a series of calculations and returns a list of options that meet the system load demand, ranked in terms of cost-effectiveness. This software is available online free of charge.

HOMER uses a sensitivity function to illustrate how the economics of a particular project can vary with alterations in input. In the HOMER models developed for this study, the sensitivities used included scaled annual average flow, to account for hydro installations on different rivers within one community model, fuel price, to monitor economics as fuel price increases, and scaled annual average load, to monitor economics as system load increases. The sensitivity values used for scaled annual average flow were derived from the Hatch Review of Hydraulic Potential of Coastal Labrador study. The sensitivity values used for fuel prices were obtained using the Nalcor Energy/ Newfoundland and Labrador Hydro Fuel Price Forecast. The sensitivity values used for scaled annual average load were obtained using the Newfoundland and Labrador Hydro Operating Load Forecast Hydro Rural Systems Fall 2010 for the years 2010 through 2015.

2.5 Constraints

Newfoundland and Labrador Hydro remains committed to maintaining a firm generation capacity that can sustain the system load under abnormal operating conditions. The diesel plants currently in operation in the communities involved in this study are capable of continuing to meet the energy demand even in situations where the largest generation unit is out of service. All Hydro's isolated systems must maintain firm capacity.

As the alternative energies considered in this study are non-dispatchable meaning they cannot be called upon to supply energy when demanded, they can only supply energy when it is available. Therefore, none of the energies are capable of completely displacing the diesel plants unless some form of energy storage is incorporated into the system. To date, the alternative energies have only been considered as a means of diesel fuel displacement and the capacity will continue to be supplied by the existing diesel plants. Only run-of-river hydro installations were considered for this study as they are generally significantly lower cost to construct than a facility with a reservoir, and thus the least cost means to develop hydro power.

This means that hydro energy would be dependant on natural run-off; during wet periods, the plant would generate a lot of energy, however, during dry spells it will generate relatively little. Further efforts into the investigation of storage potential at the hydro sites could identify that year-round hydroelectricity could be supplied to the communities.

3 PRELIMINARY COST ESTIMATES

For evaluation in HOMER, cost information was required for each of the energy alternatives. These cost estimates were developed with information from vendors and Engineering Services at Newfoundland and Labrador Hydro. All cost estimates detailed in this section are approximate in 2009 dollars.

3.1 Diesel Generators

The following table details the replacement costs and annual operations and maintenance costs for each of the diesel generators located in the communities being studied.

The replacement cost reflects the purchasing and installation of a new, same-size generator. The operation and maintenance cost is comprised of a base cost, oil replacement cost, and overhaul cost.

Existing Diesel Plant Replacement and Operating Cost Summary (Updated 2009 11 04)						
Location	Region	Unit #	Model	Capacity (kW)	Replacement Cost ($)	Unit Operating Cost ($/yr)
Nain	TRO Labrador Isolated	574	Detroit Series 2000	865	600000	21801
		2085	Caterpillar 3512	1275	1120000	26888
		576	Detroit Series 2000	865	600000	21801
Hopedale	TRO Labrador Isolated	2053	Caterpillar 3412	545	400000	14749
		2054	Caterpillar 3508	448	400000	14749
		2074	Caterpillar 3412	569	600000	14749
Makkovik	TRO Labrador Isolated	2029	Caterpillar D3412	620	600000	16210
		2059	Caterpillar D3412	635	600000	16210
		3033	Caterpillar 3412	450	400000	14749
Cartwright	TRO Labrador Isolated	567	Perkins CV12	470	400000	14749
		2036	Caterpillar D3412	450	400000	14749
		2045	Caterpillar D3412	450	400000	14749
		2052	Caterpillar D3512	720	600000	16210
Charlottetown	TRO Northern Isolated	204	Caterpillar D343	250	380000	9877
		2019	Caterpillar 3406	250	380000	9877
		2034	Caterpillar 3412	300	380000	9877
		2060	Caterpillar 3412	725	600000	16210
		2061	Caterpillar 3412	725	600000	16210
Mary' s Harbour	TRO Northern Isolated	2037	Caterpillar D3412	545	600000	16210
		2038	Caterpillar D3412	545	600000	16210
		2048	Caterpillar 3508	810	600000	21801
Port Hope Simpson	TRO Northern Isolated	2042	Caterpillar 3412	455	400000	14749
		2043	Caterpillar 3412	455	400000	14749
		2073	Caterpillar 3456	455	400000	14749

Table 1 - Diesel Engine Replacement and Operating Cost Estimates

3.2 Wind Turbines

Cost information for the wind turbines is based on the unit cost of NorthWind 100 turbines, as employed in the Newfoundland and Labrador Hydro Wind Turbine installation in Ramea.

Turbine Size		Cost ($)
100 kW	Capital	500,000
	Replacement	400,000
	Annual Operation and Maintenance	10,000

Table 2 - Wind Turbine Cost Estimates

3.3 Solar Panels

Cost information for the solar panel installation was obtained from Carmanah, a leading off-grid solar installation vendor.

Solar Installation Size		Cost ($)
50 kW	Capital	500,000
	Replacement	400,000
	Annual Operation and Maintenance	10,000
100 kW	Capital	940,000
	Replacement	750,000
	Annual Operation and Maintenance	15,000

Table 3 - Solar Installation Cost Estimates

4 ENERGY ESTIMATES

Comprehensive analysis of the various data sources including the weather station meteorological data, the Environment Canada National Climate Data and Information Archive data, the Canadian Wind Atlas theoretical values, the NASA Solar Radiation data, and the HOMER economic viability data was concluded in December 2009.

The analysis was conducted in two parts: the first evaluated the potential of each resource, the second found the maximum amount of energy from each resource that could be utilized in each of the locations with the project remaining economically viable. The first part of the analysis relied heavily on examination of the weather station data, its correlation with the other data sources identified above, and review of the commissioned evaluation of hydraulic potential. The second part of the analysis largely relied on the use of HOMER, though the inputs into HOMER were results from the first stage of data analysis and cost information as detailed in Section 3 Preliminary Cost Estimates.

Though these estimates have been developed following detailed analysis of available data and information, they do not reflect the level of detail required to move to the project development or deployment stages. As this study is a preliminary investigation into the alternative energy potential available in each location, these estimates have been developed to determine if the integration of alternative energies in the considered systems is economically viable and if so, the best alternative energy fit for each location. Further information on the suggested subsequent stages for each location is available in Section 6.2 Recommendations.

In general, wind energy has been found to be more prevalent in winter months, and solar more prevalent in summer months. Some hydro sites have been identified that are capable of meeting or exceeding the forecasted demand. In further studies, investigation into storage potential at these sites would be required before they could be installed with the intention to completely replace the existing diesel plants. Hydro sites with interconnection potential have also been identified. These plants have been identified as capable of serving the system load of all communities in the interconnection with required extra costs, as detailed in the Section 4.3 Hydraulic Potential.

4.1 Wind Energy

Wind energy is thought to have the most promise for the future of alternative energy in coastal Labrador. Most sites studied were found to be able to economically integrate some quantity of wind energy into their generation plan. The amount of energy that could be integrated varied between sites. For detailed, site specific information, please refer to Section 5 Site Evaluation. Monthly wind speed plots, wind duration curves, and average wind speed trends are provided by community in the appropriate appendix.

4.2 Solar Energy

Though Labrador has a moderate solar resource, the development and deployment of solar installations remains very expensive and existing technologies have poor energy conversion efficiency. Should the cost of solar energy decrease significantly, it would be worth revisiting the economic feasibility assessment to account for this decrease and determine if solar energy has become a more attractive choice. Monthly solar radiation plots and clearness index plots are provided by community in the appropriate appendix.

4.3 Hydraulic Potential

Hatch Ltd. performed a screening-level study of the hydraulic potential available in the seven communities. For detailed information on this exercise please refer to the report, Review of Hydraulic Potential of Coastal Labrador, released in November 2009.

Section 6 of the report ranks the potential sites by the ratio of cost to average annual energy in $/kWh. The following tables expand on this estimate and have ranked the hydro options in terms of nominal levelized unit energy costs (LUEC). The LUEC is the estimated cost of producing energy at a specific site. It reflects the minimum price at which the energy can be sold to break even on the project. Table 4 - LUEC based on actual system load ranks the projects by unit energy cost as if the plants to be installed meet but do not exceed the system demand. System load growth is accounted for using the Operating Load Forecast Fall 2009 provided by Market Analysis in the System Planning department and extended through 2068. Table 5 - LUEC based on proposed plant capacity ranks the projects by unit energy cost if the plants were built to full potential, regardless of system load. Though cost values are significantly lower in Table 5 than Table 4, it is important to note that the energy in exceedance of the system load is essentially wasted.

Site Number	Nearest Town	Plant Capacity (MW)	Direct Project Cost ($ Millions)	Total Project Cost* ($ Millions)	2009 System Energy from Hydro Plant (GWh)	Maximum Possible Plant Output (GWh)	Nominal LUEC (¢/kWh in 2009$)
4	Mary's Harbour	0.450	2.60	**3.17**	**2.92**	**2.92**	8
MK S-1	**Makkovik**	**0.240**	**1.90**	**2.32**	**1.48**	**1.48**	**10**
5.b	**Charlottetown Port Hope Simpson and**	**1.46**	**22.40**	**28.45**	**9.55**	**9.55**	**12**
5.a	Charlottetown and Port Hope Simpson	1.46	13.00	**16.63**	**8.38**	**9.55**	13
1	Makkovik	0.660	6.90	**8.42**	**3.22**	**4.13**	14
5	Charlottetown	1.460	8.90	**11.38**	**5.31**	**9.55**	15
MH S-2A	Mary's Harbour	0.580	8.00	**9.76**	**3.80**	**3.80**	16
2	**Mary's Harbour**	**0.54**	**7.50**	**9.15**	**3.51**	**3.51**	**17**
MK S-2	Makkovik	0.220	3.30	**4.03**	**1.37**	**1.37**	18
MH S-4	**Mary's Harbour**	**0.24**	**4.00**	**4.88**	**1.60**	**1.60**	**19**
PHS S-1	Port Hope Simpson	0.090	1.70	**2.07**	**0.60**	**0.60**	21
CH S-3	Charlottetown	0.140	2.90	**3.54**	**0.94**	**0.94**	23
12	**Hopedale**	**0.53**	**10.10**	**12.32**	**3.21**	**3.21**	**24**
PHS S-3	**Port Hope Simpson**	**0.17**	**3.50**	**4.27**	**1.09**	**1.09**	**24**
PHS S-5	**Port Hope Simpson**	**0.150**	**3.20**	**3.90**	**0.95**	**0.95**	**25**
9.c	**Port Hope Simpson, Mary's Harbour, & Charlottetown**	**5.38**	**42.10**	**59.42**	**12.08**	**35.14**	**26**
3	**Port Hope Simpson**	**1.11**	**13.20**	**16.88**	**3.07**	**7.28**	**26**
6	Charlottetown	0.670	16.40	**20.01**	**4.35**	**4.35**	28
10	**Cartwright**	**2.00**	**17.70**	**21.63**	**4.15**	**13.00**	**29**
9.b	Port Hope Simpson & Charlottetown	5.380	34.80	**49.12**	**8.38**	**35.14**	31
CH S-1	Charlottetown	0.210	6.10	**7.13**	**1.37**	**1.37**	32
MK S-3	Makkovik	0.200	5.60	**6.83**	**1.28**	**1.28**	33
MH S-5	**Mary's Harbour**	**0.16**	**4.70**	**5.73**	**1.06**	**1.06**	**33**
PHS S-4	**Port Hope Simpson**	**0.09**	**3.40**	**4.15**	**0.62**	**0.62**	**36**
9.a	**Port Hope Simpson & Mary's Harbour**	**5.38**	**35.10**	**49.54**	**6.77**	**35.14**	**37**
CA S-1	Cartwright	0.070	2.20	**2.68**	**0.43**	**0.43**	38
8.c	Port Hope Simpson, Mary's Harbour, & Charlottetown	7.790	64.40	**90.90**	**12.08**	**50.87**	40
13	Nain	4.830	55.50	**67.84**	**7.04**	**26.37**	46
7	**Charlottetown**	**1.99**	**34.80**	**42.53**	**5.31**	**13.01**	**46**
CH S-5	Charlottetown	0.100	4.30	**5.25**	**0.68**	**0.68**	47
CH S-4	Charlottetown	0.070	3.20	**3.90**	**0.47**	**0.47**	50
8.b	**Port Hope Simpson & Charlottetown**	**7.79**	**57.30**	**80.88**	**8.38**	**50.87**	**50**
14	Nain	0.110	4.60	**5.61**	**0.59**	**0.59**	57
FH S-2	Mary's Harbour	0.100	5.00	**6.10**	**0.62**	**0.62**	59
PHS S-2	Port Hope Simpson	0.050	2.60	**3.17**	**0.32**	**0.32**	59
9	**Port Hope Simpson**	**5.38**	**27.70**	**39.10**	**3.07**	**35.14**	**60**
8.a	**Port Hope Simpson & Mary's Harbour**	**7.79**	**57.30**	**80.88**	**6.77**	**50.87**	**60**
11	**Hopedale**	**10.550**	**35.90**	**50.67**	**3.79**	**64.16**	**72**
FH S-1	Mary's Harbour	0.080	6.90	**8.42**	**0.54**	**0.54**	93
8	Port Hope Simpson	7.790	50.20	**70.86**	**3.07**	**50.87**	106
PHS S-6	Port Hope Simpson	0.060	1.70	**7.42**	**0.36**	**0.36**	122
CH S-2	Charlottetown	0.020	2.50	**3.05**	**0.13**	**0.13**	139
MH S-3	Mary's Harbour	0.010	1.70	**2.07**	**0.06**	**0.06**	204
MH S-6	Mary's Harbour	0.010	3.70	**4.51**	**0.06**	**0.06**	443

* Please note: The total capital costs have been calculated using the Nalcor Energy Project Proposal Form
** Please note: Forecasted system energy was calculated based on the Nalcor Energy 2009 Corporate Planning Assumptions.
This is the maximum amount of energy the diesel system could consume from the hydro plant. If value is less than 'Maximum possible plant output' this indicates that the hydro plant is not being fully utilized.

Table 4 - LUEC based on actual system load

Site Number	Nearest Town	Plant Capacity (MW)	Direct Project Cost ($ Millions)	Total Project Cost* ($ Millions)	Average Annual Energy (GWh)	Nominal LUEC (¢/kWh 2009$)
11	**Hopedale**	**10.55**	**35.90**	**50.67**	**64.16**	**5**
9	**Port Hope Simpson**	**5.38**	**27.70**	**39.10**	**35.14**	**7**
9.a	**Port Hope Simpson & Mary's Harbour**	**5.38**	**35.10**	**49.54**	**35.14**	**9**
9.b	**Port Hope Simpson & Charlottetown**	**5.38**	**34.80**	**49.12**	**35.14**	**9**
9.c	**Port Hope Simpson, Mary's Harbour, & Charlottetown**	**5.38**	**42.10**	**59.42**	**35.14**	**11**
4	**Mary's Harbour**	**0.450**	**2.60**	**3.17**	**2.920**	**8**
5	**Charlottetown**	**1.46**	**8.90**	**11.38**	**9.55**	**9**
5.a	**Charlottetown and Port Hope Simpson**	**1.46**	**13.00**	**16.63**	**9.55**	**17**
5.b	**Charlottetown, Port Hope Simpson, & Mary's Harbour**	**1.46**	**22.40**	**28.45**	**9.55**	**27**
8	**Port Hope Simpson**	**7.79**	**50.20**	**70.86**	**50.87**	**9**
8.a	**Port Hope Simpson & Mary's Harbour**	**7.79**	**57.30**	**80.88**	**50.87**	**14**
8.b	**Port Hope Simpson & Charlottetown**	**7.79**	**57.30**	**80.88**	**50.87**	**10**
8.c	**Port Hope Simpson, Mary's Harbour, & Charlottetown**	**7.79**	**64.40**	**90.90**	**50.87**	**16**
MK S-1	**Makkovik**	**0.240**	**1.90**	**2.32**	**1.480**	**10**
10	**Cartwright**	**2.00**	**17.70**	**21.63**	**13.00**	**16**
1	**Makkovik**	**0.660**	**6.90**	**8.42**	**4.13**	**13**
3	**Port Hope Simpson**	**1.11**	**13.20**	**16.88**	**7.28**	**16**
13	**Nain**	**4.83**	**55.50**	**67.84**	**26.37**	**17**
MH S-2A	Mary's Harbour	0.580	8.00	9.76	3.800	16
2	Mary's Harbour	0.540	7.50	9.15	3.510	17
MK S-2	Makkovik	0.220	3.30	4.03	1.370	18
MH S-4	Mary's Harbour	0.240	4.00	4.88	1.600	19
7	Charlottetown	1.99	34.80	42.53	13.01	21
PHS S-1	Port Hope Simpson	0.090	1.70	2.07	0.600	21
CH S-3	Charlottetown	0.140	2.90	3.54	0.940	23
12	Hopedale	0.530	10.10	12.32	3.210	24
PHS S-3	Port Hope Simpson	0.170	3.50	4.27	1.090	24
PHS S-5	Port Hope Simpson	0.150	3.20	3.90	0.950	25
6	Charlottetown	0.670	16.40	20.01	4.350	28
MK S-3	Makkovik	0.200	5.60	6.83	1.280	33
CH S-1	Charlottetown	0.210	6.10	7.13	1.370	32
MH S-5	Mary's Harbour	0.160	4.70	5.73	1.060	33
PHS S-6	Port Hope Simpson	0.060	1.70	7.42	0.360	122
CA S-1	Cartwright	0.070	2.20	2.68	0.430	38
PHS S-4	Port Hope Simpson	0.090	3.40	4.15	0.620	40
CH S-5	Charlottetown	0.100	4.30	5.25	0.680	47
CH S-4	Charlottetown	0.070	3.20	3.90	0.470	50
14	Nain	0.110	4.60	5.61	0.590	57
FH S-2	Mary's Harbour	0.100	5.00	6.10	0.620	59
PHS S-2	Port Hope Simpson	0.050	2.60	3.17	0.320	59
FH S-1	Mary's Harbour	0.080	6.90	8.42	0.540	93
CH S-2	Charlottetown	0.020	2.50	3.05	0.130	139
MH S-3	Mary's Harbour	0.010	1.70	2.07	0.060	204
MH S-6	Mary's Harbour	0.010	3.70	4.51	0.060	443
* Please note: The total project cost been escalated to include contingencies and interest during construction using the Nalcor Energy Project Proposal Form						

Table 5 - LUEC based on proposed plant capacity

Interconnection potential for hydro projects was also investigated. Due to the requirement for the interconnected towns to have fairly close proximity to one another for the option to remain economically viable, for the purposes of this study, this arrangement was only considered feasible for the communities of Charlottetown, Mary's Harbour, and Port Hope Simpson.

There were three possible sites large enough to consider for interconnection. Site 8, a 7.79 MW site approximately 11 km south of Port Hope Simpson, and Site 9, a 5.38 MW site approximately 13 km south of Port Hope Simpson, and Site 5, a 1.46 MW site approximately 12 km south of Charlottetown. The generation capacity of site 8 and site 9 are capable of supporting an interconnection between Port Hope Simpson and Mary's Harbour, Port Hope Simpson and Charlottetown, or all three communities. Site 5 is not considered capable of supporting the system load of all three communities, however a larger plant could be considered for this site. Table 6 provides site specific information on the additional cost associated with each of the interconnection opportunities. For further detailed information, please refer to Section 7 of Hatch's Review of Hydraulic Potential of Coastal Labrador.

Interconnection	Additional Overland Transmission (km)	Additional Submarine Transmission (km)	Additional Cost ($M)	System Load (GWh)	Project Cost		Maximum Possible Plant Output (GWh)	Nominal LUEC (¢/kWh)
					Without inter-connection ($M)	With inter-connection ($M)		
Site 8								
Mary's Harbour	35	0	7.1	6.77	50.2	57.3	50.9	60
Charlottetown	27	2	7.1	8.38	50.2	57.3	50.9	50
Mary's Harbour / Charlottetown	62	2	14.1	12.08	50.2	64.3	50.9	40
Site 9								
Mary's Harbour	37	0	7.4	6.77	27.7	35.2	35.1	37
Charlottetown	27	2	7.1	8.38	27.7	34.8	35.1	31
Mary's Harbour / Charlottetown	64	2	14.4	12.08	27.7	42.2	35.1	26
Site 5								
Port Hope Simpson	17.2	0.8	4.1	8.38	8.9	13.0	9.6	13
Port Hope Simpson/ Mary's Harbour	56.2	2.8	13.5	12.08	8.9	22.4	9.6	12

Table 6 – Summary of Site Interconnectivity Cost

5 SITE EVALUATION

The following site evaluations are based on the information collected from the site-specific weather stations and the developed HOMER models. More detailed results from these sources are available by location in the appropriate appendix. Though cost estimates are the basis for the comparison of systems, these costs are preliminary, and much more detailed work would be required to obtain more accurate cost information.

5.1 Nain

5.1.1 Energy Potential Analysis

Nain possesses a good wind resource. The discrepancies between the data available from the diesel plant station and the two local Environment Canada stations is the result of poor siting of the diesel plant weather station anemometer. Looking at the average wind speed trends in Nain, it is readily apparent that though wind speeds are somewhat lower in the summer months, they increase steadily throughout the fall and into the winter. This is an excellent fit with Nain's winter peaking energy requirements. Based on the wind duration curves available for the fall months, wind speeds measured at the diesel plant are in exceedance of 5m/s approximately 30% of the time. As it has been determined that the diesel plant weather station is not optimally sited, it is reasonable to assume that the percentage of time with wind speeds greater than the 5 m/s threshold is in fact higher. Based on daily check of the weather station communications feed, the anemometer has frozen several times during December. This suggests that any wind installations in Nain would have to be arctic grade as icing will surely be a factor, as with all sites on the Labrador Coast. For data plots for Nain, please refer to Appendix A.

Site 13 is one identified economically feasible hydro site capable of serving Nain. Its cost of energy is lower than both that of diesel generation and the predicted cost of a wind diesel hybrid system. It is advised that further analysis of site 13 be performed to ascertain its true hydro potential.

Nain possesses a moderate solar resource in late spring and throughout summer, but extremely short days mean its solar resource is poor in winter months. This does not suggest a good fit for solar energy with the system's winter peaking nature.

5.1.2 Economic Analysis

Based on simulation results, using current estimates of wind, hydro and solar potential, Nain could easily use wind turbine to supply 30% of its required system load. As forecasted system growth occurs and diesel fuel prices rise, the percentage of load that could be supplied by wind energy increases slightly to 31% with the addition of an extra turbine. There is an immediate financial benefit to using wind energy in comparison with diesel fuel prices, and this benefit increases as fuel prices rise.

5.2 Hopedale

5.2.1 Energy Potential Analysis

There is a reasonable amount of potential in wind energy in Hopedale. Wind speed measurements obtained from the diesel plant weather station provide lower monthly averages than those of the local Environment Canada weather station. Looking at the monthly wind speed plots, it is evident that on average the diesel plant is seeing lower winds on a daily basis; however the general behaviour of the wind is the same in both locations. The similarity in the shape of the wind speed curves but discrepancy in measured speeds suggests that the weather station at the diesel plant is not optimally sited and better wind potential exists than that indicated by the diesel plant weather station. For data plots for Hopedale, please refer to Appendix B.

One economically viable hydro plant was identified for Hopedale. Site 12 could potentially supply the community with 3.21 GWh annually at a cost of energy 2-3 ¢/kWh less expensive than diesel generation.

Hopedale has one of the smaller solar resources examined in the study based on available data. Though moderate solar potential is available in the few summer months, the majority of months do not exhibit this potential.

5.2.2 Economic Analysis

The simulation of wind turbines in the Hopedale system provides the largest savings through use of wind energy over diesel fuel in the study. Based on the 2011 forecasted system load, turbines could be used to supply 43% of the community's energy requirements. As the system load and fuel prices increase, an additional turbine could be integrated to increase the system load met by wind energy to 47%. In addition, as these increases in costs are encountered, the margin in savings over diesel fuel increases as well, making wind energy even more economically beneficial.

5.3 Makkovik

5.3.1 Energy Potential Analysis

In terms of wind energy, Makkovik has more wind potential than the diesel plant weather station would suggest. Environment Canada has a much better situated weather station in Makkovik that consistently records higher wind speeds than those recorded at the diesel plant with discrepancies between the two sources reaching as high as 10 m/s. This suggests that the weather station at the diesel plant is not optimally sited for wind speed measurement. The full potential of Makkovik is still not understood as the Environment Canada station only records data for eight hours per day. Based on the available data Makkovik has an excellent wind resource, with average speeds estimated in exceedance of 10m/s throughout autumn. For data plots for Makkovik, please refer to Appendix C.

In addition, Makkovik has excellent hydro resources that can provide extremely cheap electricity in comparison to diesel fuel generated electricity. Sites MK S-1, 1 and MK S-2 all offer unit energy costs below the current price of diesel fuel. If storage solutions were considered, Site 1 could be capable of completely displacing the Makkovik diesel plant. Sites MK S-1 and MK S-2, while too small to displace the diesel plant do offer inexpensive energy compared to diesel generation.

In comparison with the promise offered by the other alternative energies, solar is thought to have the least potential for a viable solution for Makkovik.

5.3.2 Economic Analysis

Makkovik has a choice of viable alternative energy solutions: both wind and hydro offer financially attractive options. With respect to wind energy, Makkovik could potentially integrate multiple wind turbines. Based on the 2011 load forecast, the turbines could supply the system with 35% of its required energy. As fuel prices and system load increase, the model suggests that no additional wind turbines be added to the system. Consequently, the proportion of wind energy supplied to the system remains constant.

Hydro generation appears to be an economically attractive option for Makkovik. The unit energy costs of Sites MK S-1, 1, and MK S-2 are lower than the current costs of diesel energy, and the cost of energy from the hybrid system noted above. As the price of diesel rises, these hydro options become increasingly attractive. Site 1 could possibly replace the Makkovik diesel plant, but will require the inclusion of the cost of reservoir storage as part of the project.

5.4 Cartwright

5.4.1 Energy Potential Analysis

In Cartwright, wind energy holds the highest promise in terms of alternative energies. Examining the data collected by the diesel plant weather station, it is evident that the during summer periods, the wind speeds in Cartwright are smaller than those experienced during winter months. As illustrated in the wind duration curves, the amount of time with winds in excess of 5 m/s is at its lowest in July and increases steadily throughout the remaining months of the year. For data plots for Cartwright, please refer to Appendix D.

The close correlation of daily wind speeds between the measured data with that of the Cartwright Environment Canada weather station increases the confidence in the measurements obtained at the Cartwright diesel plant. Looking at the plots in Appendix D, it is easy to verify that the same peak speeds and periods of low winds are encountered at both sites, with slightly higher measurements recorded at the Environment Canada location. This suggests the placement of the weather station at the Cartwright diesel plant is not indicative of the highest wind speeds in the area. To ensure the wind energy potential in Cartwright is accurately understood, it is advised that additional measurements be obtained by deploying a met tower in a location optimally sited for a wind farm.

Though hydro sites have been identified for Cartwright, the high cost of energy associated with these plants does not make hydro an economically feasible option.

In terms of solar energy, Cartwright possesses a moderate solar resource. However, in comparison to the same system served with wind energy, solar remains a more expensive option. This summer peaking alternative energy coincides nicely with Cartwright's load profile.

5.4.2 Economic Analysis

During modeling, the addition of wind turbines resulted in an extremely small decline in the cost of energy. This makes the integration a financially neutral choice when compared to the continued operating cost of the Cartwright diesel plant. In HOMER simulation, the wind turbines were capable of supplying 12% of the community load. In addition, the excess electricity produced by the system was approximately 0%, meaning no wind energy was wasted in simulation.

As system load and diesel fuel prices are increased in the model, an additional turbine is suggested and the margin between the cost of energy of the hybrid grid versus the diesel plant widens slightly. This increase remains well below 1¢/kWh, however. Therefore, even as the system grows and fuel becomes more expensive, there is no forecasted significant financial benefit in moving to a hybrid system. Such a project is considered viable for environmental reasons.

5.5 Charlottetown

5.5.1 Energy Potential Analysis

Measured wind speeds in Charlottetown are among the lowest of those obtained in the study. Analysis of the Charlottetown data suggests that though there are some periods of prolonged high wind speeds, lower wind speeds tend to dominate during the months for which data is available. For data plots for Charlottetown, please refer to Appendix E.

In this case, there is no Environment Canada station in Charlottetown to compare the collected data with. As such, there is only six months of collected data available for Charlottetown at this point, meaning that its wind energy potential is not fully understood at this point. It is advised to continue monitoring the wind speeds in Charlottetown and revisit the analysis once one complete year of data is available.

Hydro options exist for Charlottetown both in terms of shared interconnections with Mary's Harbour and/or Port Hope Simpson and plants that would serve Charlottetown alone. The interconnection options are discussed in Section 5.8 Interconnection Possibilities. Sites 5 and CH S-3 both offer costs of energy lower than those of diesel generation.

In terms of solar energy, Charlottetown presents a moderate solar resource, peaking in July. This summer peak fits well with the Charlottetown load profile.

5.5.2 Economic Analysis

Based on simulation results, with the current estimates of wind, solar, and hydraulic potential, there are no economic benefits in integrating renewable energies into the Charlottetown system. The integration of a wind turbine is the most economic renewable option, however this option remains slightly more expensive than the continued operation of the diesel plant. As the system grows and the price of fuel increases, the diesel plant remains the most economical option.

Charlottetown could possibly benefit from interconnection to a larger hydro plant, shared with Port Hope Simpson and/or Mary's Harbour. The results of this hydraulic analysis are found in Section 5.8 Interconnection Possibilities.

5.6 Port Hope Simpson

5.6.1 Energy Potential Analysis

Port Hope Simpson has one of the lower wind resources identified in the study. With low monthly averages from June through November it is thought that wind energy is not the best match for Port Hope Simpson in terms of alternative energies. For data plots for Port Hope Simpson, please refer to Appendix F.

Hydro offers promising options for Port Hope Simpson on its own or as an interconnection with Charlottetown and/or Mary's Harbour. The interconnection possibilities are examined in Section 5.8 Interconnection Possibilities. Though the proximity of site 9 and site 8 to Port Hope Simpson makes it possible for them to serve Port Hope Simpson alone, the plants are far too large for the needs of the community and the associated cost of energy would be too high. Sites 3 and PHS S-1 offer attractive alternatives for hydro plants that would serve only Port Hope Simpson. Both have costs of energy less expensive than that of diesel fuel generation.

Though solar resources are moderate in the area, when compared to the hydro potential, they are more expensive, less efficient and technically challenging.

5.6.2 Economic Analysis

Diesel energy remains less expensive than hybrid installations with solar or wind energy. In analysis of the modeling results, Port Hope Simpson could potentially integrate one wind turbine at a slightly higher cost compared to diesel fuel. As the system load increases, the number of suggested turbines remains constant at one. In addition, the percentage of system load supplied by the wind turbine is 5% in both cases. This suggests that the wind resource in Port Hope Simpson is not the most economic alternative energy solution and has little potential for growth as the towns energy requirements increase. It is worth nothing, however, that Port Hope Simpson is located in a valley surrounded by hills. Wind resources may be good at the hill tops, but these resources have not been assessed.

As reflected in both Table 4 - LUEC based on actual system load and Table 5 - LUEC based on proposed plant capacity, site 8 exists as a Hydro option that could supplement the community energy supply with clean, renewable energy at a considerable savings over diesel fuel.

5.7 Mary's Harbour

5.7.1 Energy Potential Analysis

Based on measured data, average wind speeds in Mary's Harbour would classify the resource as having small wind potential. Mary's Harbour has three sources of wind speed data; the diesel plant station, and two local Environment Canada stations. All data sets in a given monthly wind plot have the same shape and roughly the same peak values. Discrepancies in measurement results from the time interval between measurements; the diesel plant provides data values at ten minute intervals, whereas one Environment Canada station samples every hour and the other once per hour for eight hours per day. In this case, for the months where data from the diesel plant is available, it is thought that this data provides the most accurate picture of the wind behaviour in Mary's Harbour. Based on the wind duration curves for June through August, the available wind potential in Mary's Harbour is not high enough for turbines to support a large percent of the load. However, an increase in wind speed is evident throughout

October and November and it is expected that this increase would continue through the rest of winter. Therefore, it is advised to continue monitoring the wind speeds in Mary's Harbour using the current diesel plant weather station. For data plots for Mary's Harbour, please refer to Appendix G.

Potential hydro sites have been identified for Mary's Harbour, both in terms of interconnection possibilities and sites that would serve Mary's Harbour alone. Interconnection opportunities are discussed in Section 5.8 Interconnection Possibilities. With respect to sites identified to serve Mary's Harbour alone, Site 4 was identified as a good potential site as well as Sites MH S-2A and MH S-4. These sites indicate energy prices lower than that of diesel fuel, but have a higher energy cost than Site 4. All three sites merit further consideration for possible development.

Mary's Harbour does have moderate solar potential which would fit nicely with its summer peaking load shape. Should solar technology become more efficient and less expensive, it should be reconsidered as an option for Mary's Harbour.

5.7.2 Economic Analysis

Diesel energy remains less expensive than hybrid installations with solar or wind energy. In analysis of the modeling results, Mary's Harbour could potentially integrate one wind turbine at a slightly higher cost compared to diesel fuel. However as system load increases and fuel prices rise, the number of suggested turbines remains constant at one turbine. In addition, the percentage of the system load served by wind remains constant at five percent. This suggests that wind energy is not the most suitable fit for Mary's Harbour.

As reflected in both Table 4 - LUEC based on actual system load and Table 5 - LUEC based on proposed plant capacity, Hydro options exist that could supplement the community energy supply with clean, renewable energy at a considerable savings over diesel fuel.

5.8 Interconnection Possibilities

Interconnection possibilities exist at Sites 5, 8, and 9. As discussed in Section 4.3 Hydraulic Potential, both site 8 and site 9 have average annual energies that could support the load of Charlottetown, Port Hope Simpson and Mary's Harbour. If further analysis was conducted and storage solutions were explored, either of these plants could potentially replace all three community diesel plants. In the unit energy cost analysis performed, the extra costs associated with interconnection did not increase the unit energy cost by a significant amount. All interconnection possibilities (i.e. Site 8 to Port Hope Simpson and Mary's Harbour and/or Charlottetown, Site 9 to Port Hope Simpson and Mary's Harbour and/or Charlottetown) remain economically favourable when compared to the price of diesel fuel (estimated at an average cost of 25¢/kWh across the three communities). The estimated cost of energy for the interconnection sites are reflected in Table 4 - LUEC based on actual system load and Table 5 - LUEC based on proposed plant capacity.

Site 5 differs from the other sites identified for interconnection as, based on proposed capacity; it can only sustain the load of two out of three communities; Charlottetown and Port Hope Simpson or Mary's Harbour. The estimated cost of energy remains low for an interconnection to either town. In addition, the proposed plant size could possibly be increased to accommodate an interconnection to the third town.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the existing weather data, it is reasonable to confirm that Labrador possesses alternative energy resources that, under the right economic conditions, could be developed to reduce the usage of diesel generation in many communities. In general, the most promising potential lies with wind and hydro power.

The wind data collected indicates that reasonable amounts of resource potential exist in Nain, Hopedale, Makkovik, and Cartwright. Based on the load profiles for each of these communities, the best fits for wind energy are in Nain, Hopedale, and Makkovik.

The solar data collected indicates that resource potential exists across Labrador, however due to the extremely high cost of solar energy and its relative energy conversion inefficiency solar energy is not recommended for further consideration at this time.

Hatch's Review of Hydraulic Potential of Coastal Labrador identified numerous potential sites with estimated cost of energy less than that of diesel generation. In addition, some opportunities were identified that possessed sufficient energy at low cost to completely replace one or more diesel plants. With the identified opportunity for the interconnection of Charlottetown, Port Hope Simpson, and Mary's Harbour it is possible that three plants could be eliminated, making a larger plant more viable.

6.2 Recommendations

Based on the detailed analysis of all data, the following actions are recommended.

- Nain, Hopedale, Makkovik, and Cartwright should have wind energy prefeasibility investigations conducted. This would include a thorough wind farm site selection process and collection of hub height data for analysis (minimum one year).

- Prefeasibility hydro investigations should be conducted at hydro sites that have potentially low energy costs relative to energy produced from burning diesel fuel, as well as those sites that are potentially low cost energy relative to energy from a diesel plant and are large enough to completely replace one or more diesel plants. The list below identifies the sites with a low energy cost relative to diesel fuel:
  - Site 4
  - Site MK S-1
  - Site 1
  - Site 5
  - Site MH S-2A
  - Site 2
  - Site MK S-2
  - Site MH S-4
  - Site PHS S-1
  - Site CH S-3
  - Site 12
  - Site PHS S-3
  - Site PHS S-5

- There is little high resolution mapping available for Labrador. This limits the accuracy of the resource assessment. More detailed mapping should be produced to further delineate the wind and hydro sites. This could be accomplished through a LIDAR Survey covering the sites identified in the study, and could be extended to the whole coast. Such data could potentially yield a greater number of sites, and provide the data necessary to move forward with investigations.

- The diesel plant weather stations should continue to be monitored and recorded on an ongoing basis to collect as much information as possible. In sites where a discrepancy exists between diesel plant data and Environment Canada data, investigations begin into moving the weather station to a more optimally sited location. These sites include:
    - Cartwright
    - Hopedale
    - Makkovik
    - Nain
    - Mary's Harbour

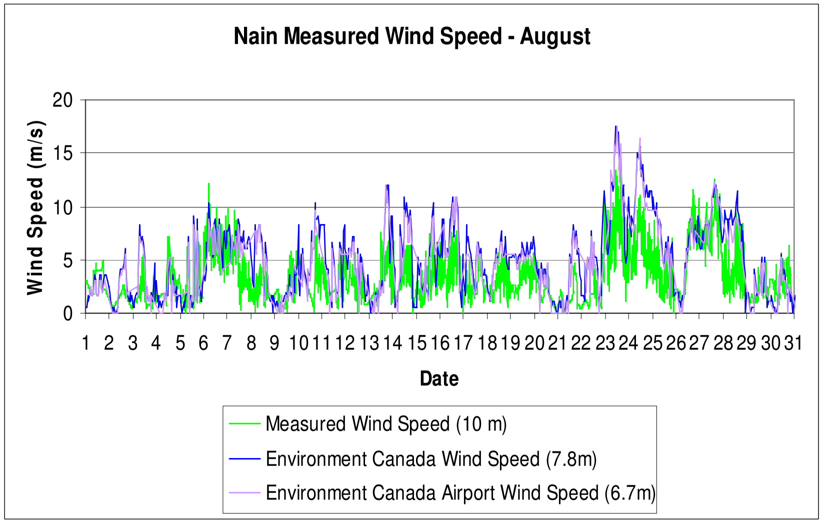
7 REFERENCES

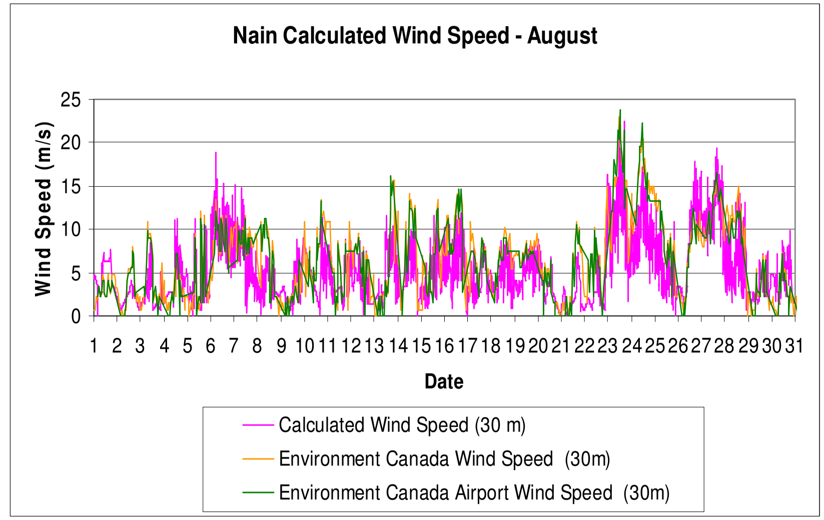
1. Population by Census Subdivision Newfoundland and Labrador 2006 Census Updated March 13, 2007. Newfoundland and Labrador Statistics Agency. Visited December 23, 2009. http://www.stats.gov.nl.ca/Statistics/Census2006/PDF/POP_CSD_Alphabetical_2006.pdf

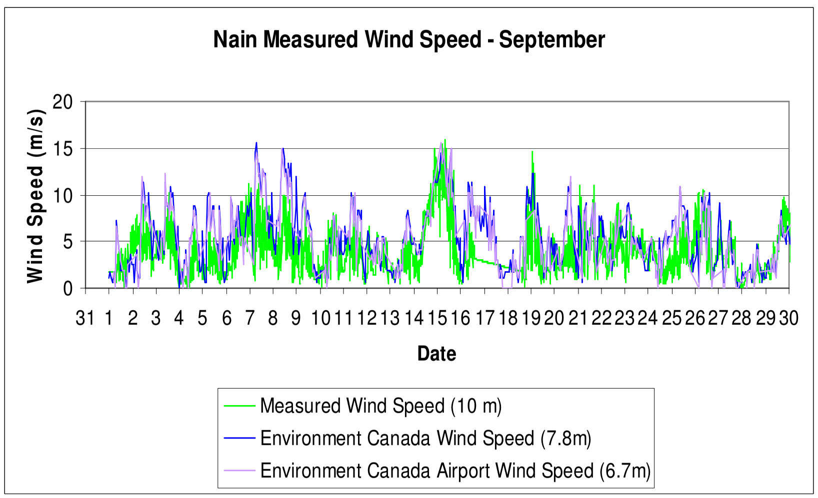
2. Canadian Wind Energy Atlas Updated August 21, 2008. Visited December 23, 2009. http://www.windatlas.ca/en/methodology.php

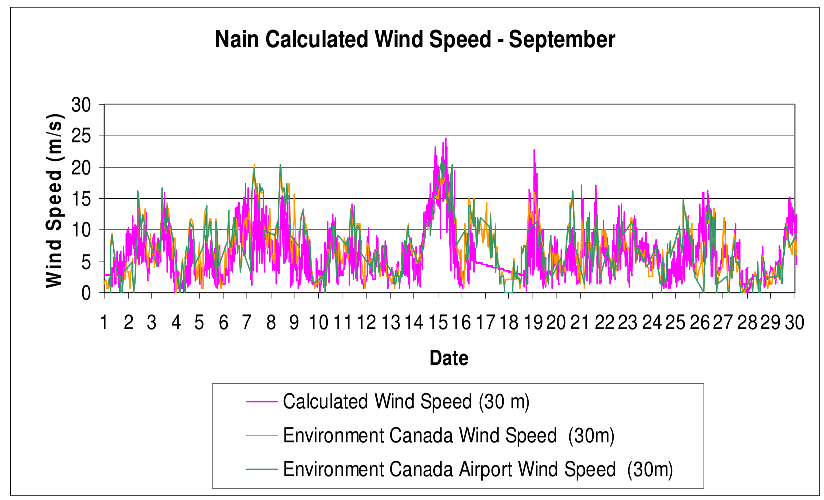
3. Surface Meteorology and Solar Energy Updated December 23, 2009. Atmospheric Science Data Center. Visited December 23, 2009. http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s01

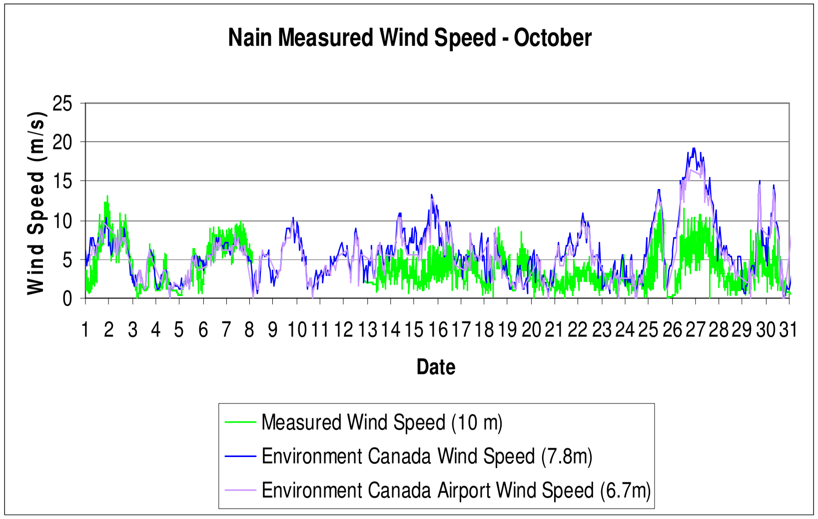
APPENDIX A - NAIN


Nain Measured Wind Speed - August
Wind Speed (m/s)
Date
Measured Wind Speed (10 m)
Environment Canada Wind Speed (7.8m)
Environment Canada Airport Wind Speed (6.7m)

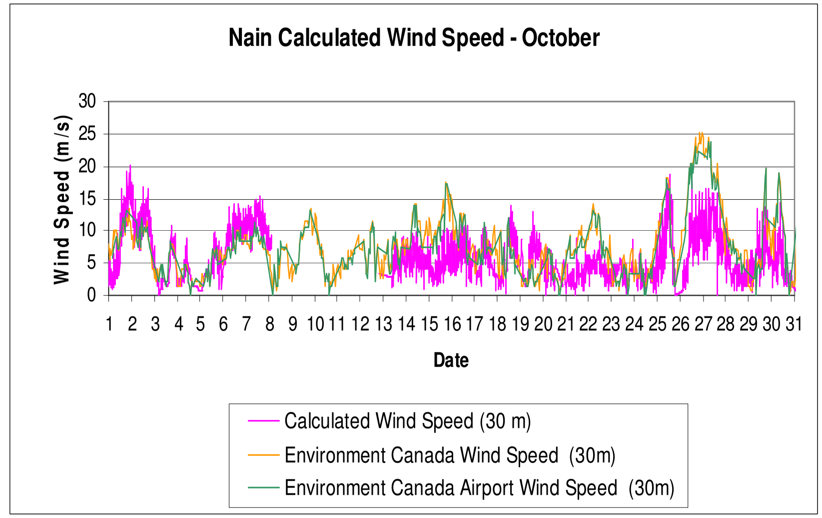

Nain Calculated Wind Speed - August
Wind Speed (m/s)
Date
Calculated Wind Speed (30 m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30m)


Nain Measured Wind Speed - September
Wind Speed (m/s)
Date
Measured Wind Speed (10 m)
Environment Canada Wind Speed (7.8m)
Environment Canada Airport Wind Speed (6.7m)

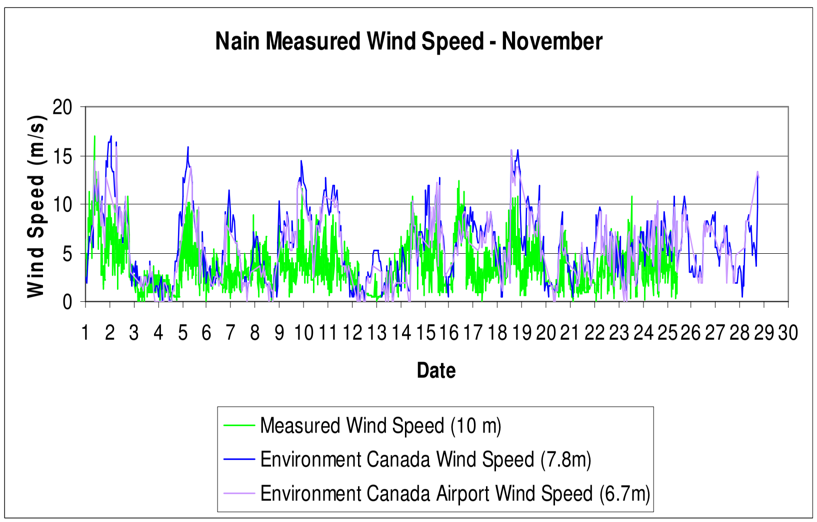

Nain Calculated Wind Speed - September
Wind Speed (m/s)
Date
Calculated Wind Speed (30 m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30m)



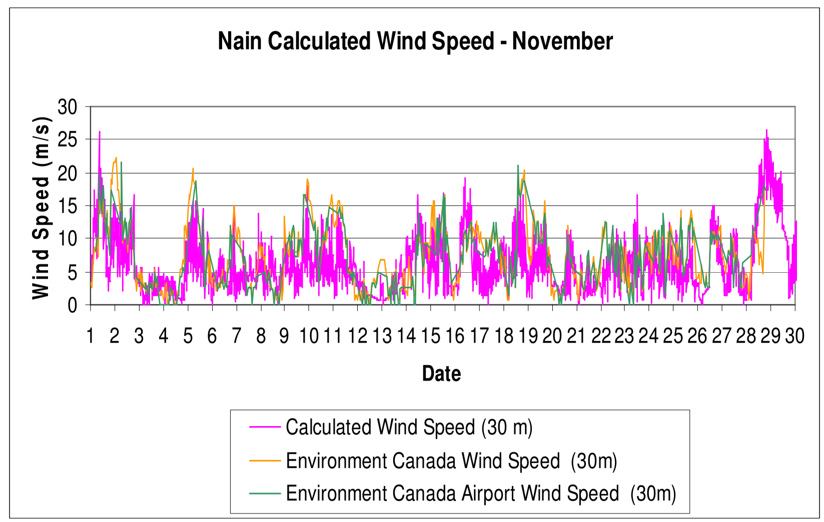
Nain Measured Wind Speed - October
Wind Speed (m/s)
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (10 m)
Environment Canada Wind Speed (7.8m)
Environment Canada Airport Wind Speed (6.7m)



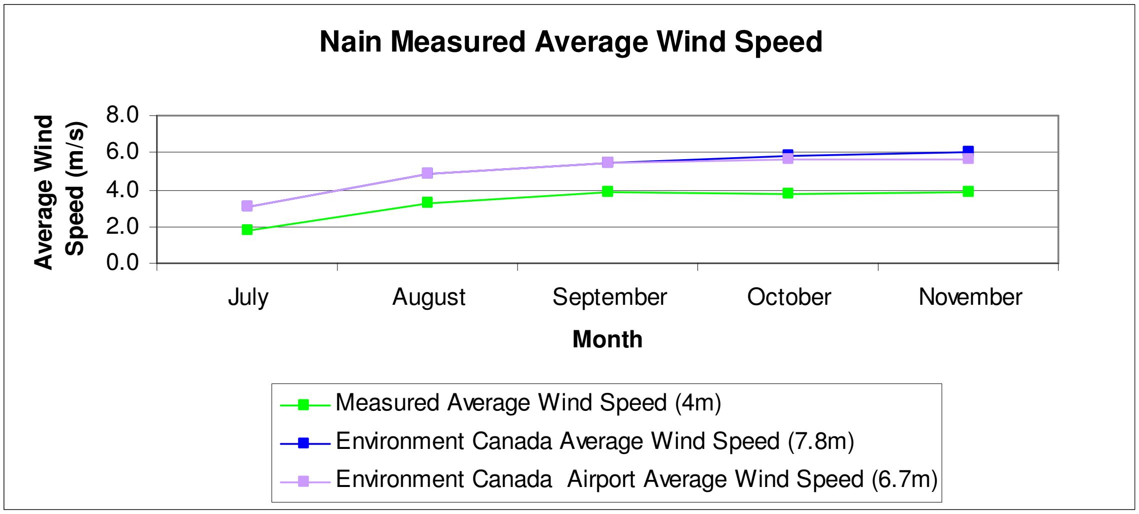
Nain Calculated Wind Speed - October
Wind Speed (m/s)
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Calculated Wind Speed (30 m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30m)



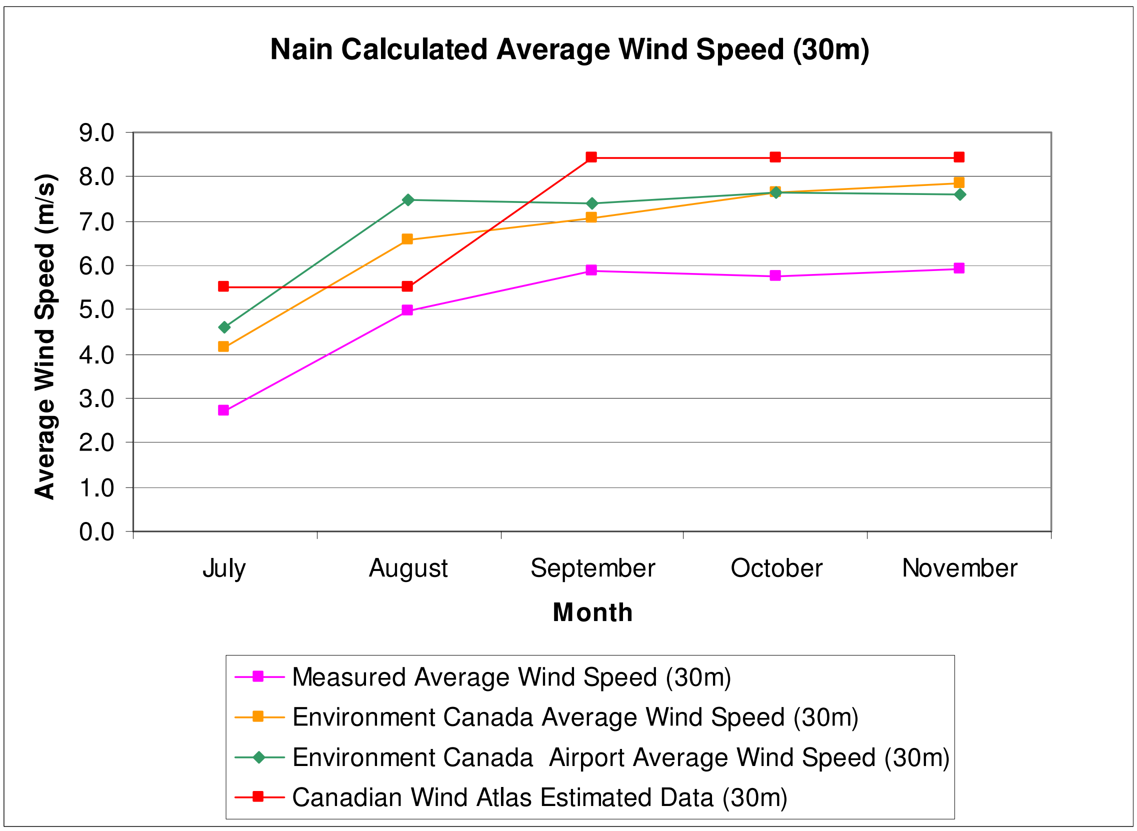
Nain Measured Wind Speed - November
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (10 m)
Environment Canada Wind Speed (7.8m)
Environment Canada Airport Wind Speed (6.7m)



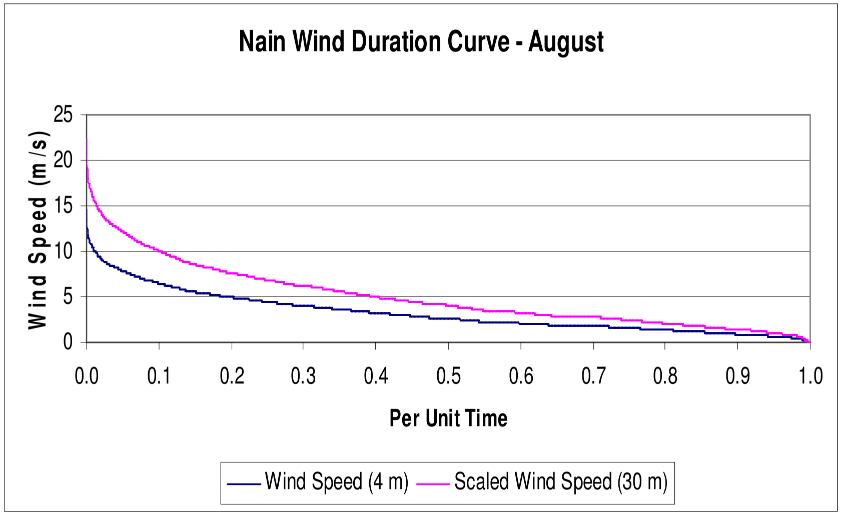
Nain Calculated Wind Speed - November
Wind Speed (m/s)
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Calculated Wind Speed (30 m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30m)

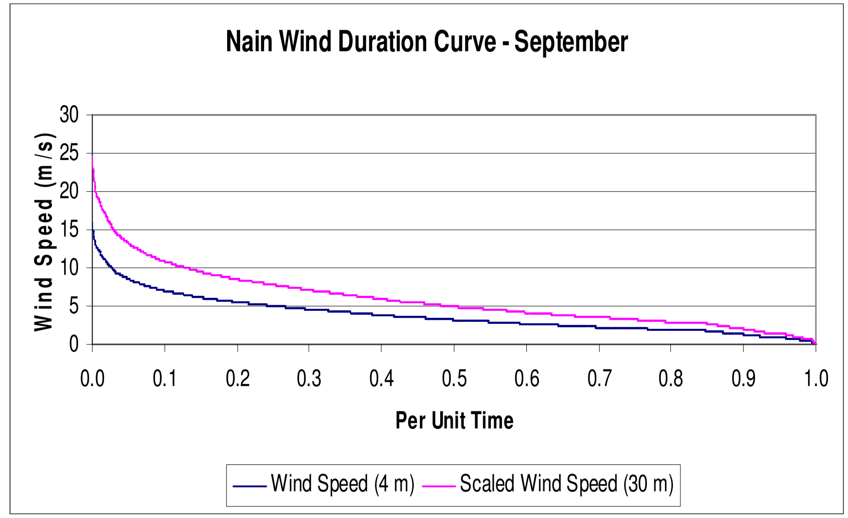


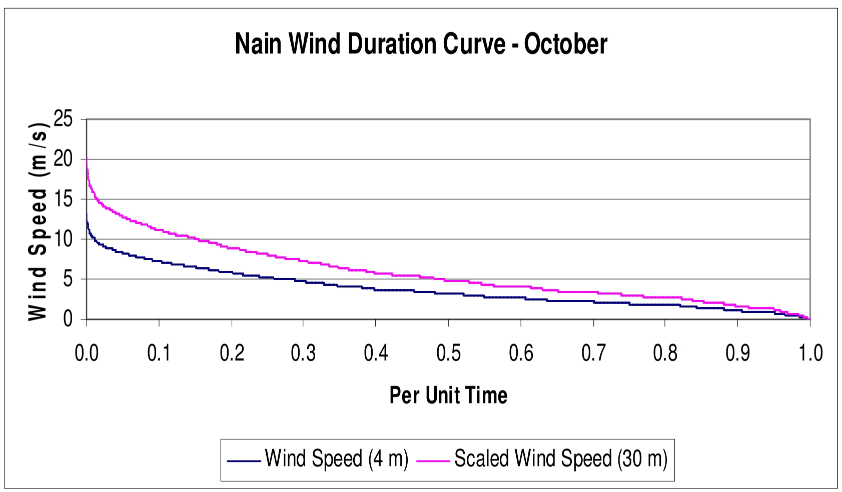
Nain Measured Average Wind Speed
Average Wind Speed (m/s)
8.0
6.0
4.0
2.0
0.0
July
August
September
October
November
Month
Measured Average Wind Speed (4m)
Environment Canada Average Wind Speed (7.8m)
Environment Canada Airport Average Wind Speed (6.7m)

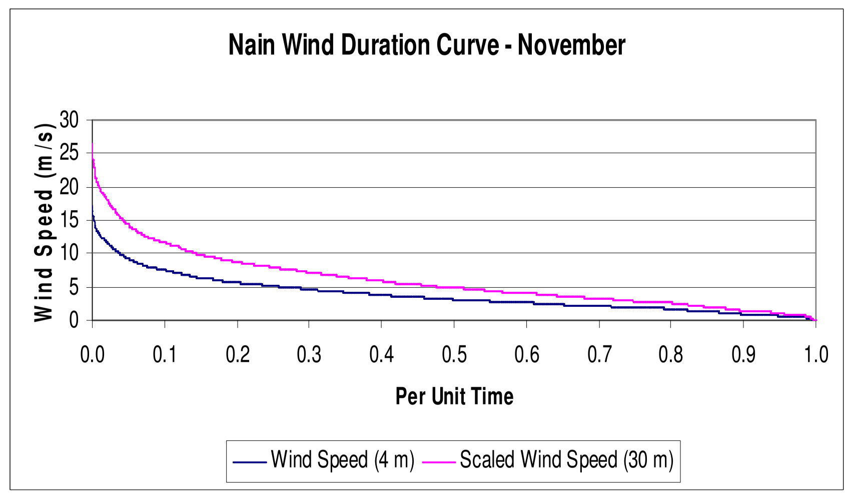


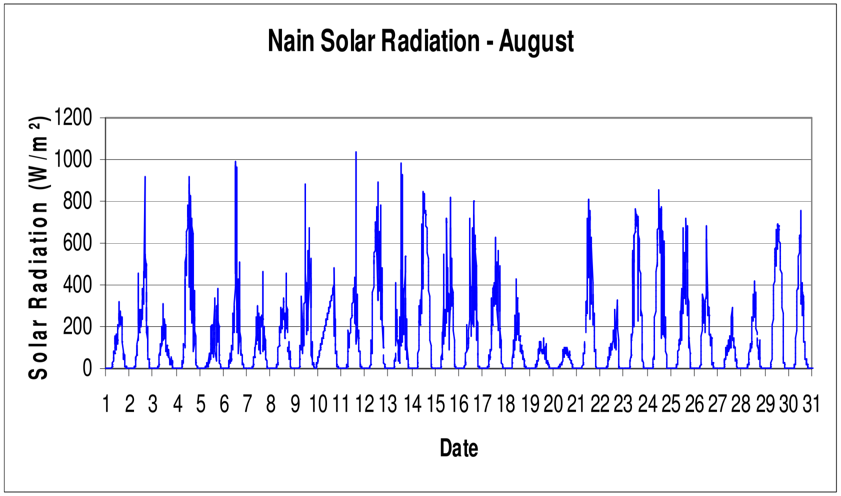
Nain Calculated Average Wind Speed (30m)
Average Wind Speed (m/s)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
July
August
September
October
November
Month
Measured Average Wind Speed (30m)
Environment Canada Average Wind Speed (30m)
Environment Canada Airport Average Wind Speed (30m)
Canadian Wind Atlas Estimated Data (30m)

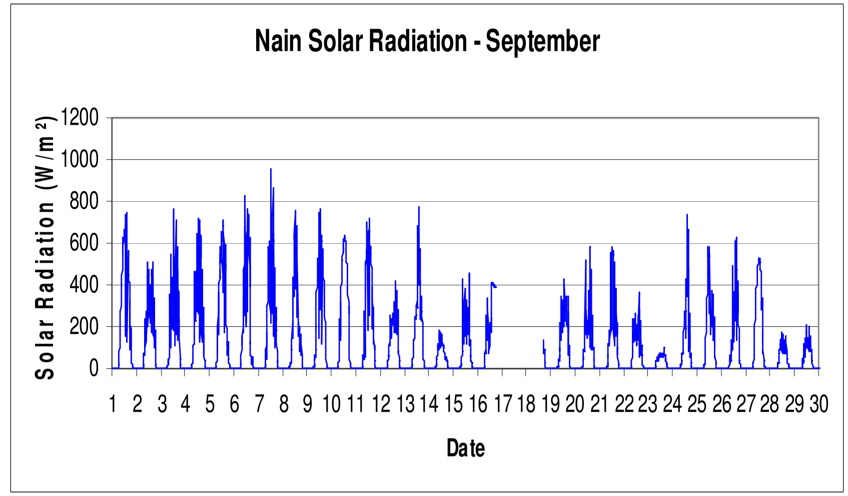

Nain Wind Duration Curve - August
Wind Speed (m/s)
0
5
10
15
20
25
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (4 m)
Scaled Wind Speed (30 m)

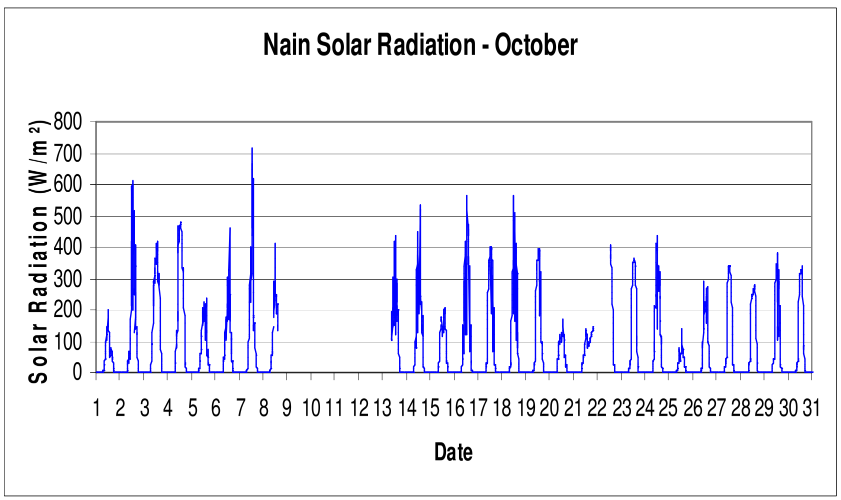

Nain Wind Duration Curve - September
Wind Speed (m/s)
0
5
10
15
20
25
30
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (4 m)
Scaled Wind Speed (30 m)

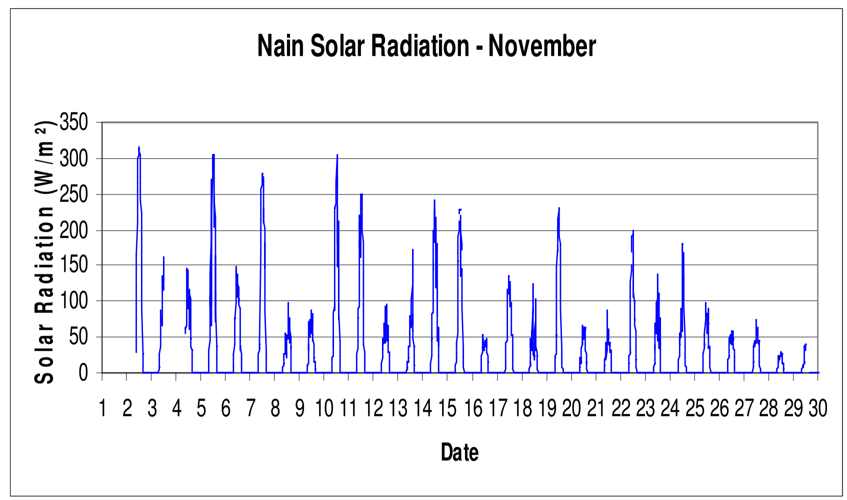

Nain Wind Duration Curve - October
Wind Speed (m/s)
0
5
10
15
20
25
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (4 m)
Scaled Wind Speed (30 m)

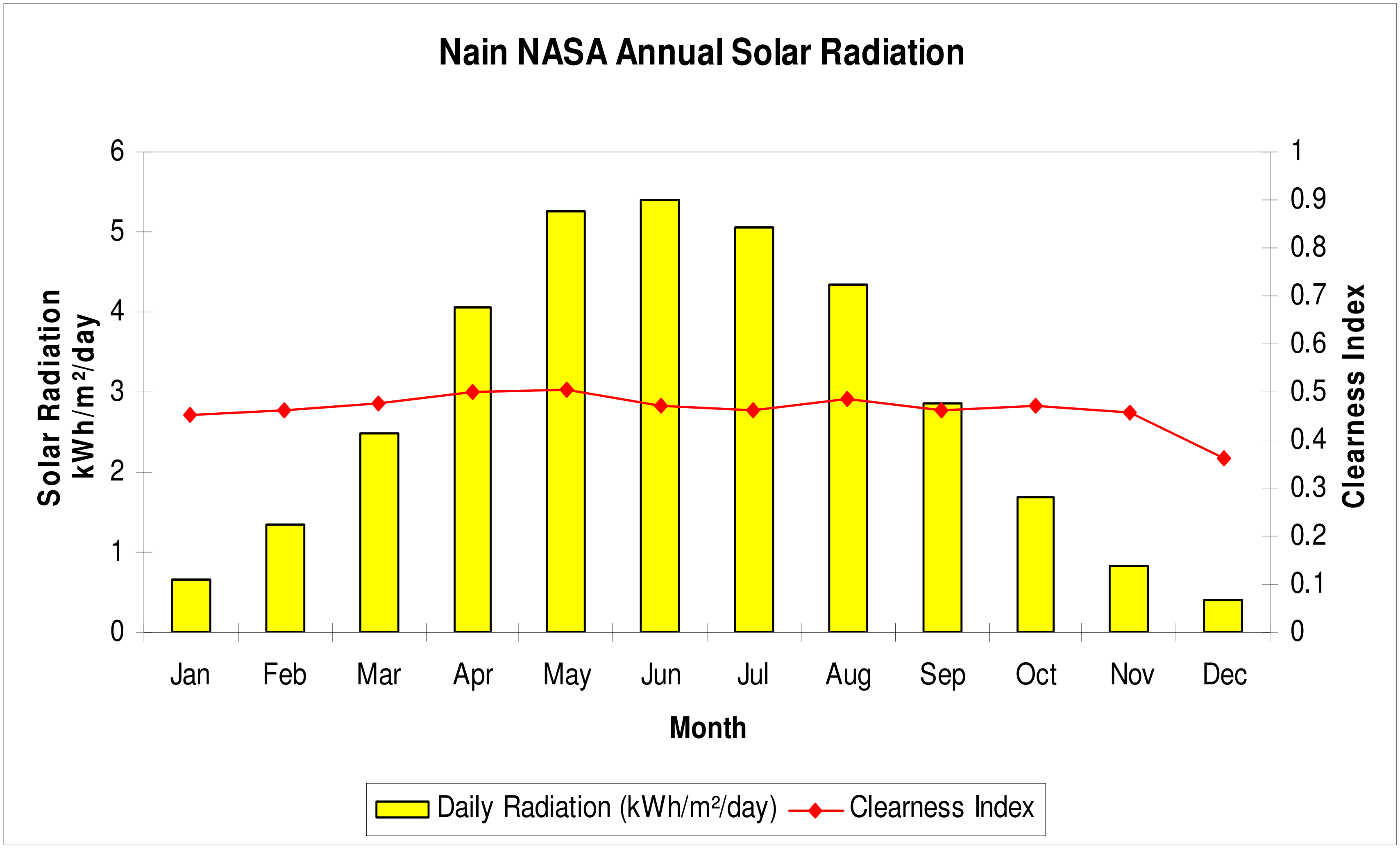

Nain Wind Duration Curve - November
Wind Speed (m/s)
0
5
10
15
20
25
30
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (4 m)
Scaled Wind Speed (30 m)


Nain Solar Radiation - August
Solar Radiation (W/m²)
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date

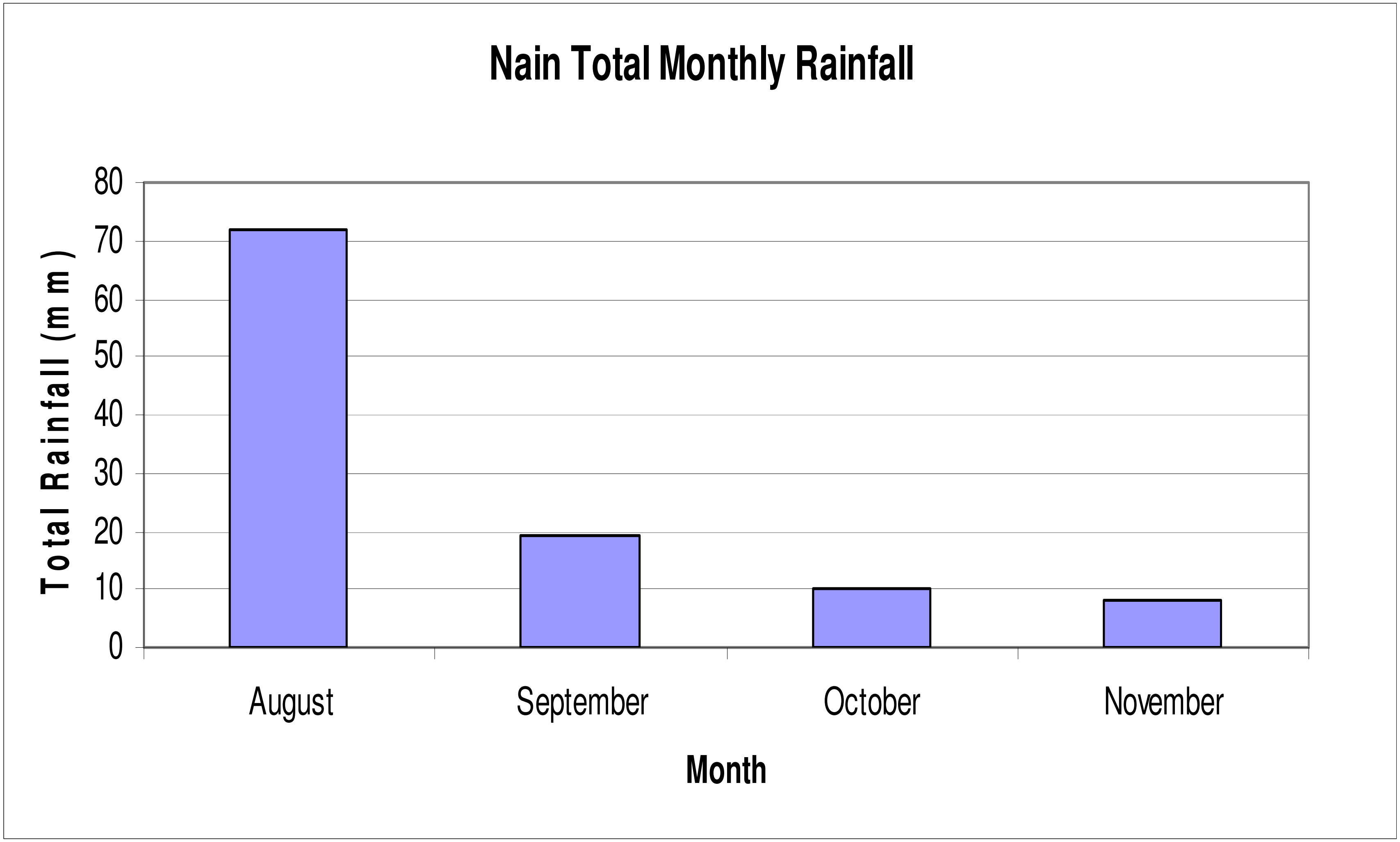

Nain Solar Radiation - September
Solar Radiation (W/m²)
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Nain Solar Radiation - October
Solar Radiation (W/m²)
800
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Nain Solar Radiation - November
Solar Radiation (W/m²)
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date



Nain NASA Annual Solar Radiation
Solar Radiation kWh/m²/day
6
5
4
3
2
1
0
Clearness Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Daily Radiation (kWh/m²/day)
Clearness Index

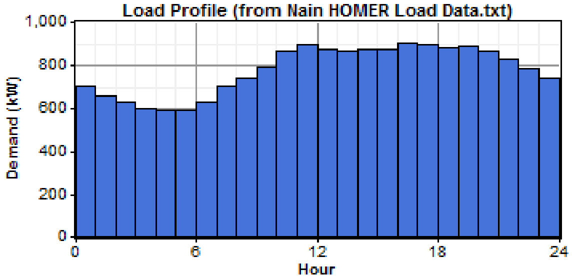

Nain Total Monthly Rainfall
Total Rainfall (mm)
80
70
60
50
40
30
20
10
0
August
September
October
November
Month

HOMER Input Summary

File name: Nain.hmr
File version: 2.67 beta
Author:

AC Load: Nain Net System Load

Data source: Nain HOMER Load Data.txt
Daily noise: 8.91%
Hourly noise: 8.19%
Scaled annual average: 21,000, 21,414, 21,830, 22,247, 22,668 kWh/d
Scaled peak load: 1,699, 1,733, 1,766, 1,800, 1,834 kW
Load factor: 0.515



PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
50.000	400,000	400,000	10,000
100.000	750,000	750,000	15,000

Sizes to consider: 0, 50, 100 kW
Lifetime: 20 yr
Derating factor: 80%
Tracking system: No Tracking
Slope: 56.5 deg
Azimuth: 0 deg
Ground reflectance: 20%

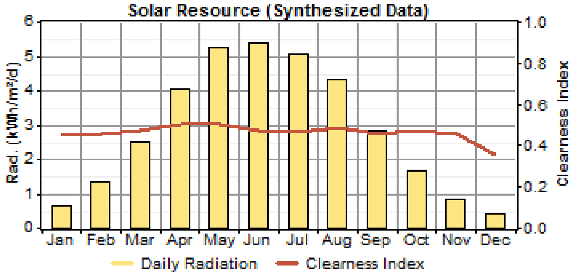
Solar Resource

Latitude: 56 degrees 32 minutes North
Longitude: 61 degrees 41 minutes West
Time zone: GMT -4:00

Data source: Synthetic

Month	Clearness Index	Average Radiation
		(kWh/m^2/day)
Jan	0.451	0.670
Feb	0.460	1.330
Mar	0.474	2.490
Apr	0.502	4.050
May	0.507	5.260
Jun	0.472	5.400
Jul	0.464	5.050
Aug	0.486	4.330
Sep	0.460	2.850
Oct	0.470	1.680
Nov	0.459	0.820
Dec	0.360	0.400

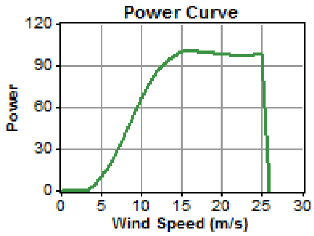
Scaled annual average: 2.86 kWh/m²/d



AC Wind Turbine: Northern Power NW100/21

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	500,000	400,000	10,000

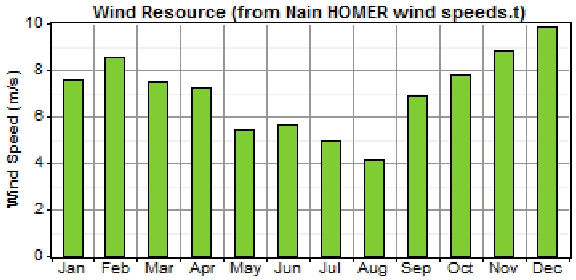
Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Lifetime: 20 yr
Hub height: 37 m



Wind Resource

Data source: Nain HOMER wind speeds.txt

Month	Wind Speed (m/s)
Jan	7.58
Feb	8.52
Mar	7.54
Apr	7.21
May	5.44
Jun	5.67
Jul	4.98
Aug	4.13
Sep	6.90
Oct	7.78
Nov	8.86
Dec	9.90



Weibull k: 1.28
Autocorrelation factor: 0.879
Diurnal pattern strength: 0.127
Hour of peak wind speed: 16
Scaled annual average: 7.03 m/s
Anemometer height: 4 m
Altitude: 29 m

Wind shear profile: Logarithmic
Surface roughness length: 0.01 m

AC Hydro:

Capital cost:	$ 64,892,000, 5,378,000
Replacement cost:	$ 0
O&M cost:	$ 533,650, 6,840/yr
Lifetime:	60 yr
Available head:	45, 30 m
Design flow rate:	12,890, 430 L/s
Min. flow ratio:	5, 15%
Max. flow ratio:	100%
Turbine efficiency:	85%
Pipe head loss:	0, 1%

Consider systems without hydro: Yes

Hydro Resource

Data source: Synthetic

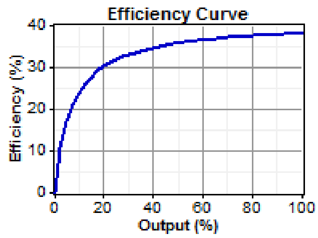
Month	Stream Flow (L/s)
Jan	1,824
Feb	1,471
Mar	1,706
Apr	1,647
May	4,706
Jun	4,588
Jul	4,706
Aug	4,706
Sep	4,588
Oct	4,706
Nov	4,588
Dec	3,412

Residual flow: 0 L/s
Scaled annual average: 3,568, 79 L/s

AC Generator: #574

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
865.000	0	600,000	2.489

Sizes to consider:	865 kW
Lifetime:	100,000 hrs
Min. load ratio:	30%
Heat recovery ratio:	0%
Fuel used:	#1 Diesel Arctic Grade
Fuel curve intercept:	0.0167 L/hr/kW
Fuel curve slope:	0.238 L/hr/kW

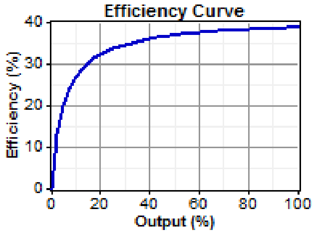


AC Generator: #576

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)

865.000	0	600,000	2.489

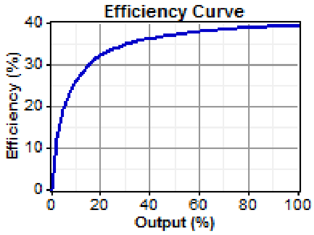
Sizes to consider: 865 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0124 L/hr/kW
Fuel curve slope: 0.238 L/hr/kW



AC Generator: #2085

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
1,275.000	0	1,120,000	3.069

Sizes to consider: 1,275 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0139 L/hr/kW
Fuel curve slope: 0.233 L/hr/kW



Fuel: #1 Diesel Arctic Grade

Price: $ 0.95, 0.95, 0.97, 1.00, 1.00/L
Lower heating value: 45.8 MJ/kg
Density: 809 kg/m3
Carbon content: 88.0%
Sulfur content: 0.0500%

Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
100.000	64,000	64,000	6,400

Sizes to consider: 0, 100 kW
Lifetime: 15 yr
Inverter efficiency: 90%
Inverter can parallel with AC generator: Yes
Rectifier relative capacity: 100%
Rectifier efficiency: 85%

Economics

Annual real interest rate: 8%
Project lifetime: 60 yr
Capacity shortage penalty: $ 0/kWh
System fixed capital cost: $ 0

System fixed O&M cost:	$ 0/yr

Generator control

Check load following:	Yes
Check cycle charging:	No

Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	No

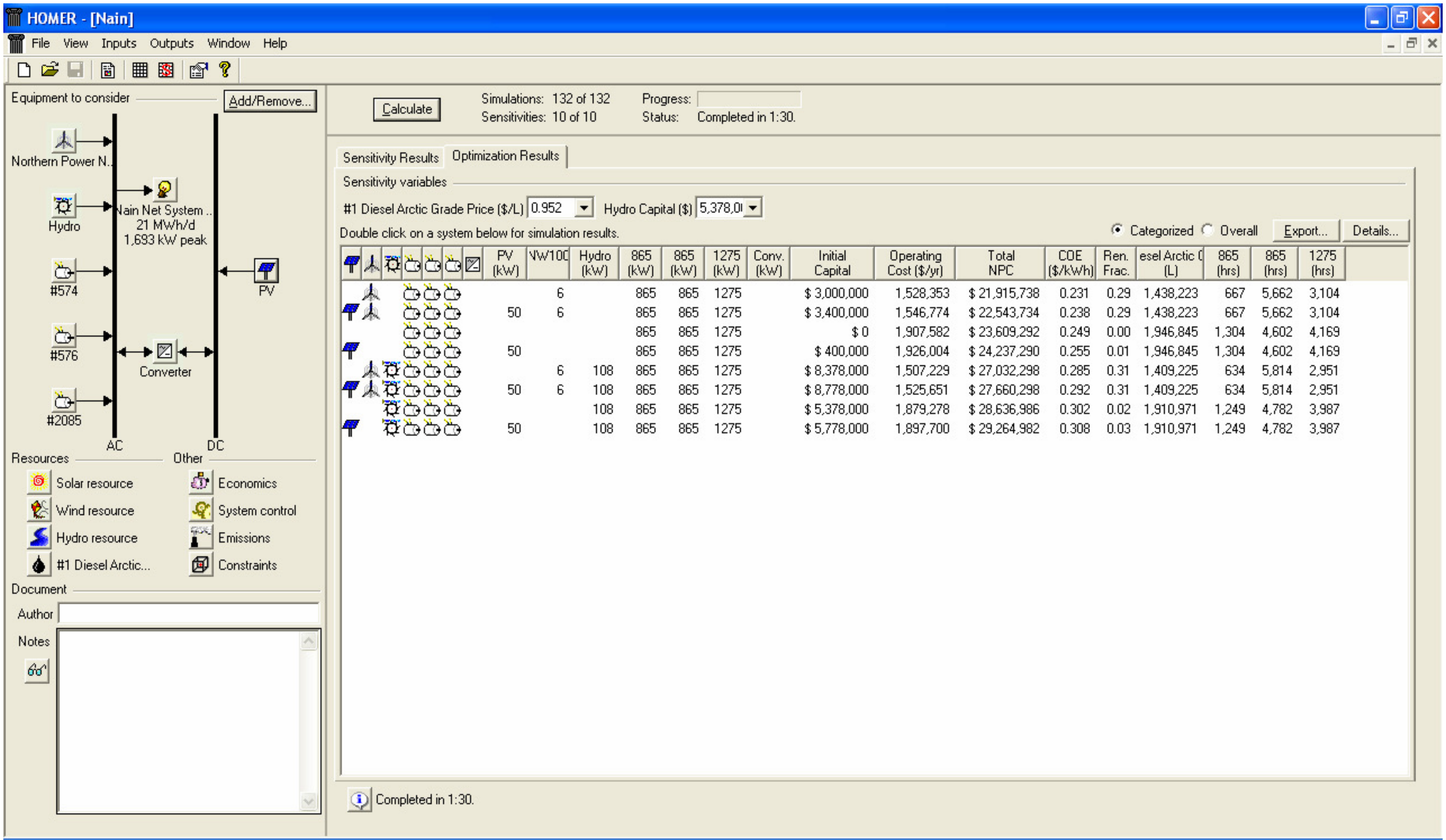
Emissions

Carbon dioxide penalty:	$ 0/t
Carbon monoxide penalty:	$ 0/t
Unburned hydrocarbons penalty:	$ 0/t
Particulate matter penalty:	$ 0/t
Sulfur dioxide penalty:	$ 0/t
Nitrogen oxides penalty:	$ 0/t

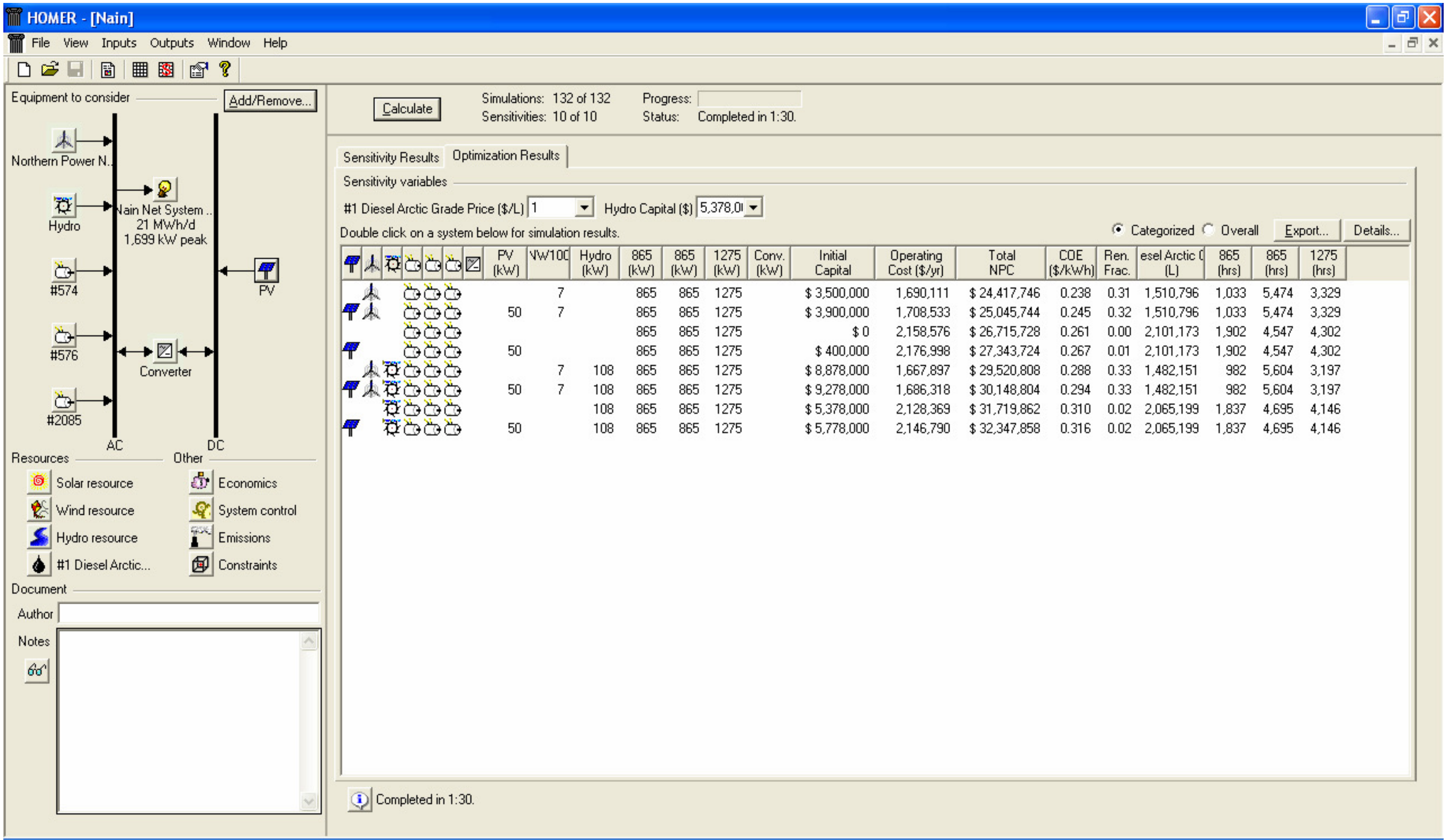
Constraints

Maximum annual capacity shortage:	0%
Minimum renewable fraction:	0%

Operating reserve as percentage of hourly load:	10%
Operating reserve as percentage of peak load:	0%
Operating reserve as percentage of solar power output:	25%
Operating reserve as percentage of wind power output:	50%



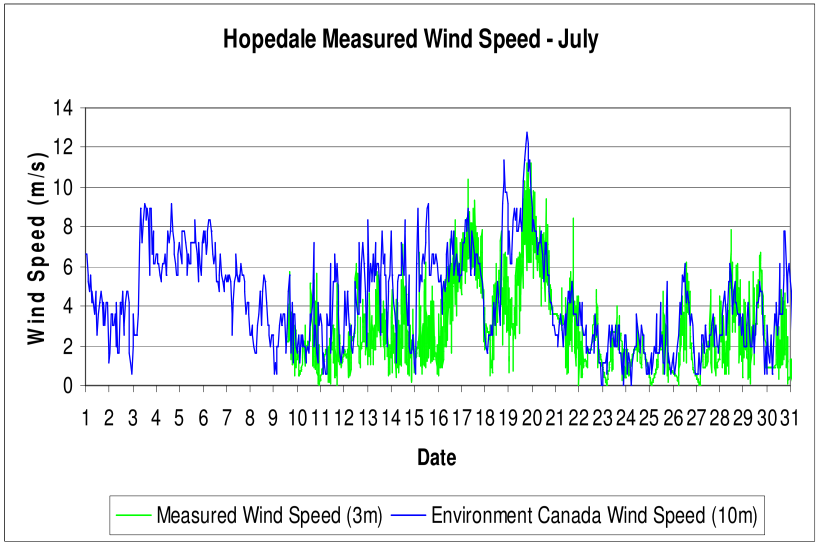
Nain HOMER Results – 2011 System Load



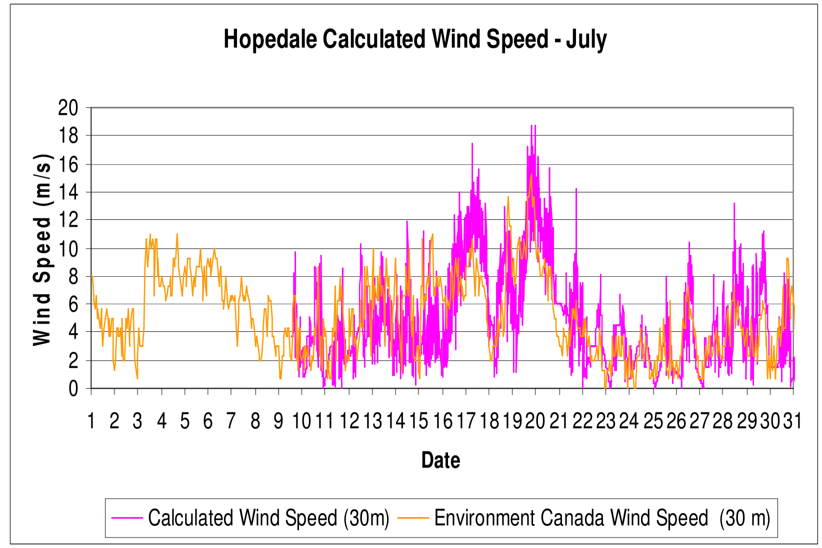
PV (kW)	NW100	Hydro (kW)	865 (kW)	865 (kW)	1275 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic ((L)	865 (hrs)	865 (hrs)	1275 (hrs)
	7		865	865	1275		$ 3,500,000	1,690,111	$ 24,417,746	0.238	0.31	1,510,796	1,033	5,474	3,329
50	7		865	865	1275		$ 3,900,000	1,708,533	$ 25,045,744	0.245	0.32	1,510,796	1,033	5,474	3,329
			865	865	1275		$ 0	2,158,576	$ 26,715,728	0.261	0.00	2,101,173	1,902	4,547	4,302
50			865	865	1275		$ 400,000	2,176,998	$ 27,343,724	0.267	0.01	2,101,173	1,902	4,547	4,302
	7	108	865	865	1275		$ 8,878,000	1,667,897	$ 29,520,808	0.288	0.33	1,482,151	982	5,604	3,197
50	7	108	865	865	1275		$ 9,278,000	1,686,318	$ 30,148,804	0.294	0.33	1,482,151	982	5,604	3,197
		108	865	865	1275		$ 5,378,000	2,128,369	$ 31,719,862	0.310	0.02	2,065,199	1,837	4,695	4,146
50		108	865	865	1275		$ 5,778,000	2,146,790	$ 32,347,858	0.316	0.02	2,065,199	1,837	4,695	4,146

Nain HOMER Results – 2015 System Load

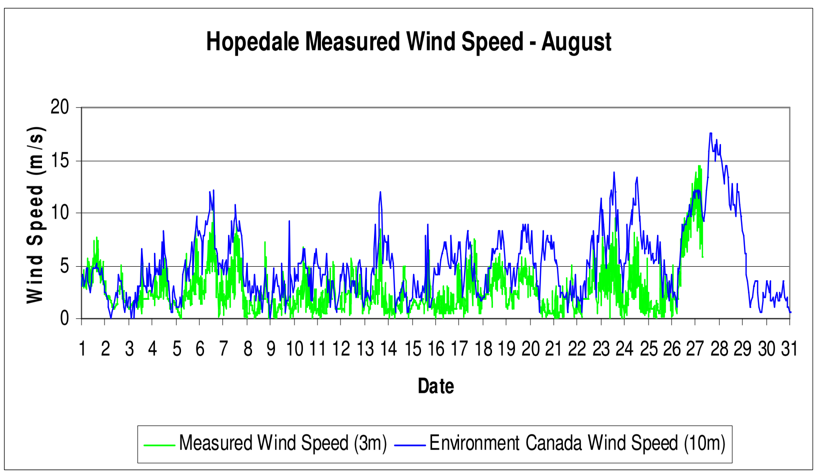
APPENDIX B - HOPEDALE



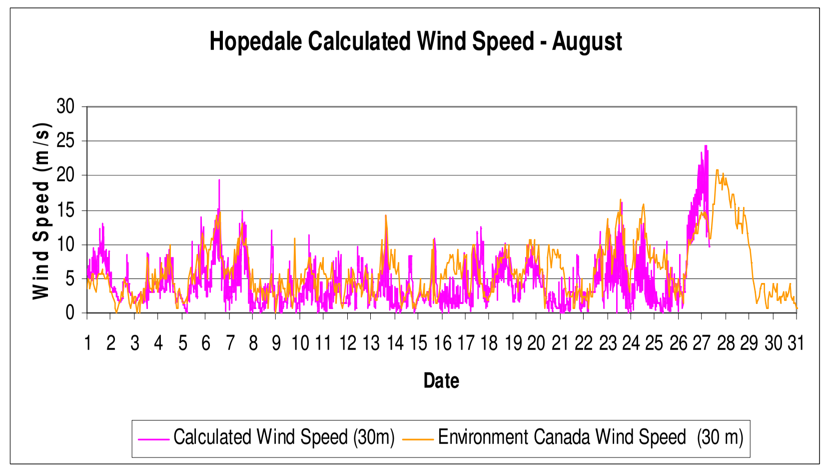
Hopedale Measured Wind Speed - July
Wind Speed (m/s)
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (3m)
Environment Canada Wind Speed (10m)



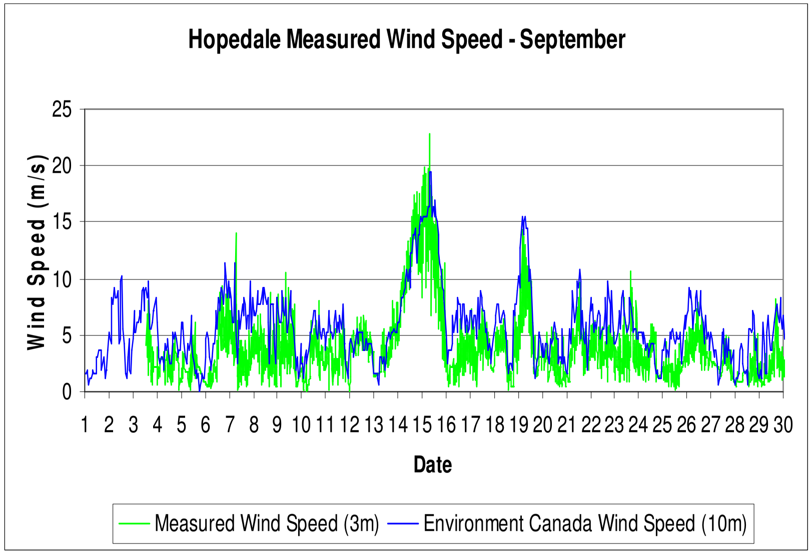
Hopedale Calculated Wind Speed - July
Wind Speed (m/s)
20
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Calculated Wind Speed (30m)
Environment Canada Wind Speed (30 m)

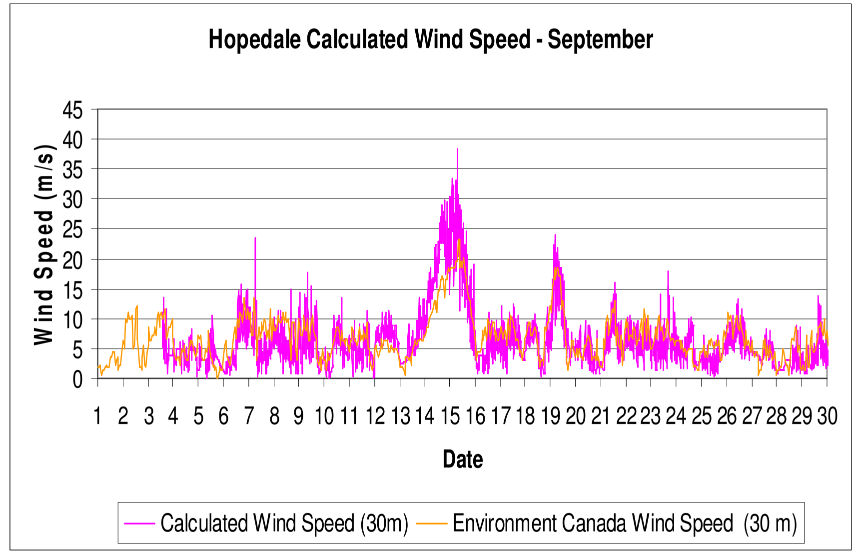


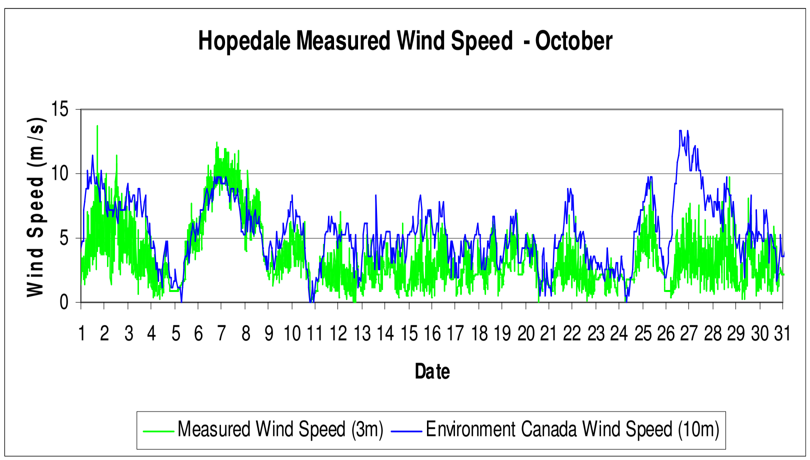
Hopedale Measured Wind Speed - August
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (3m)
Environment Canada Wind Speed (10m)

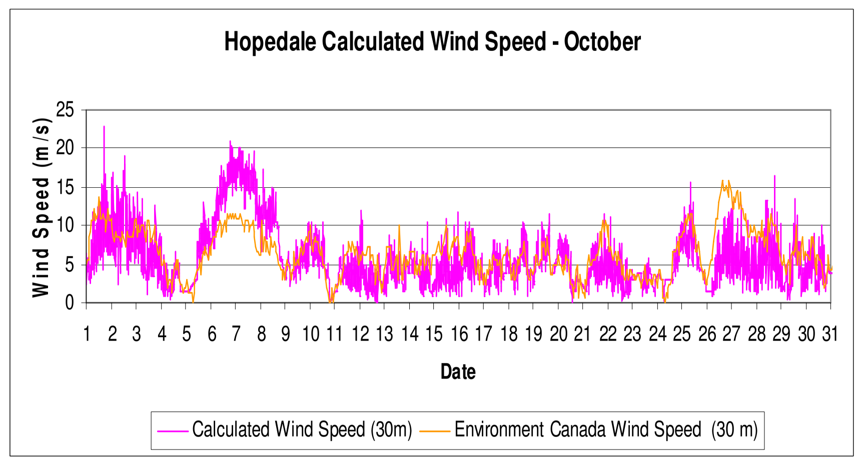


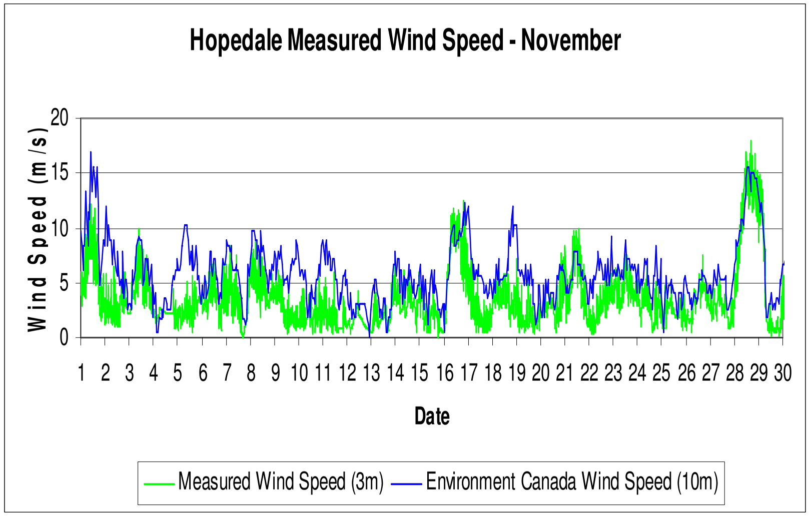
Hopedale Calculated Wind Speed - August
Wind Speed (m/s)
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Calculated Wind Speed (30m)
Environment Canada Wind Speed (30 m)

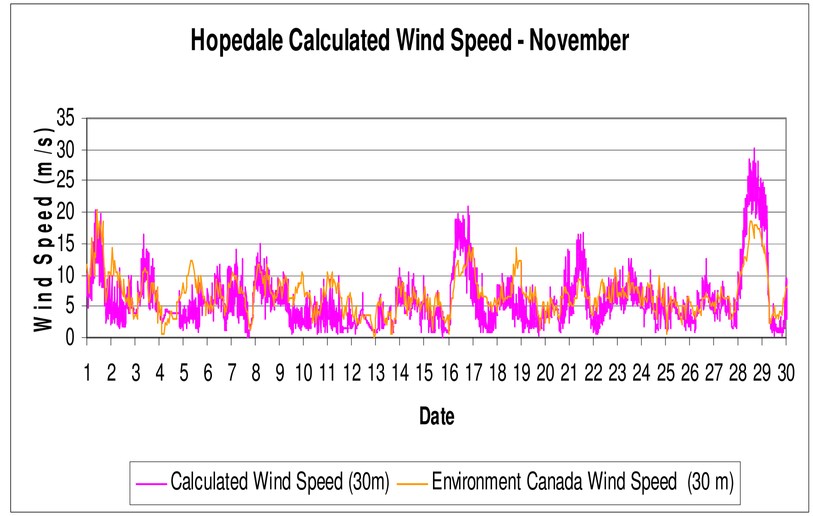

Hopedale Measured Wind Speed - September
Wind Speed (m/s)
Date
Measured Wind Speed (3m)
Environment Canada Wind Speed (10m)

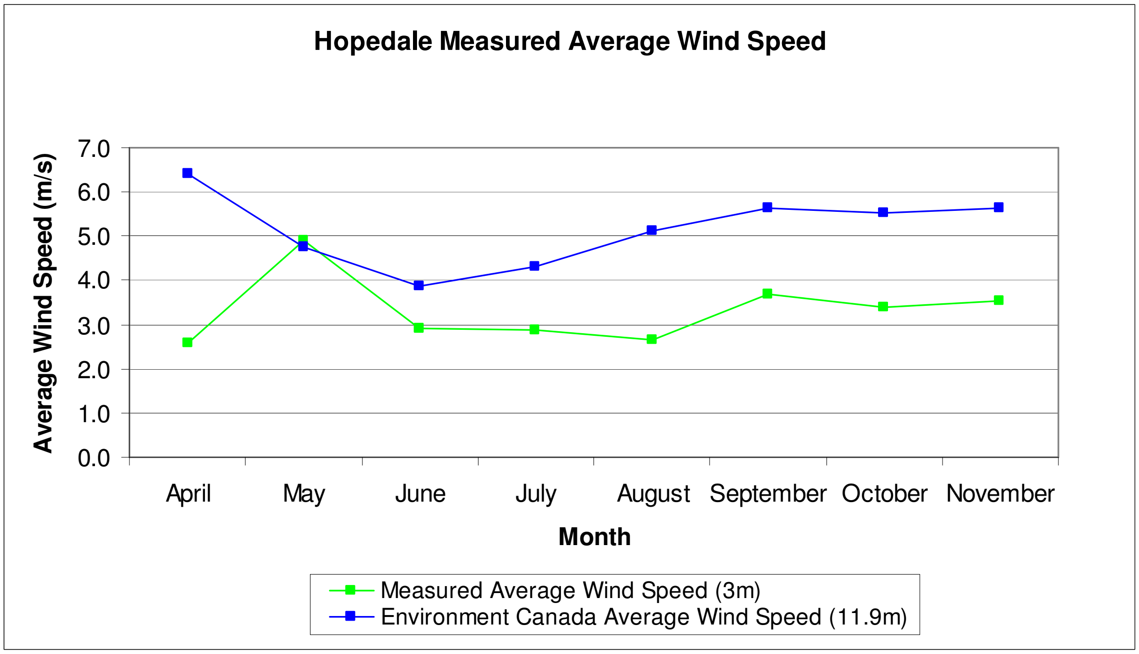

Hopedale Calculated Wind Speed - September
Wind Speed (m/s)
Date
Calculated Wind Speed (30m)
Environment Canada Wind Speed (30 m)

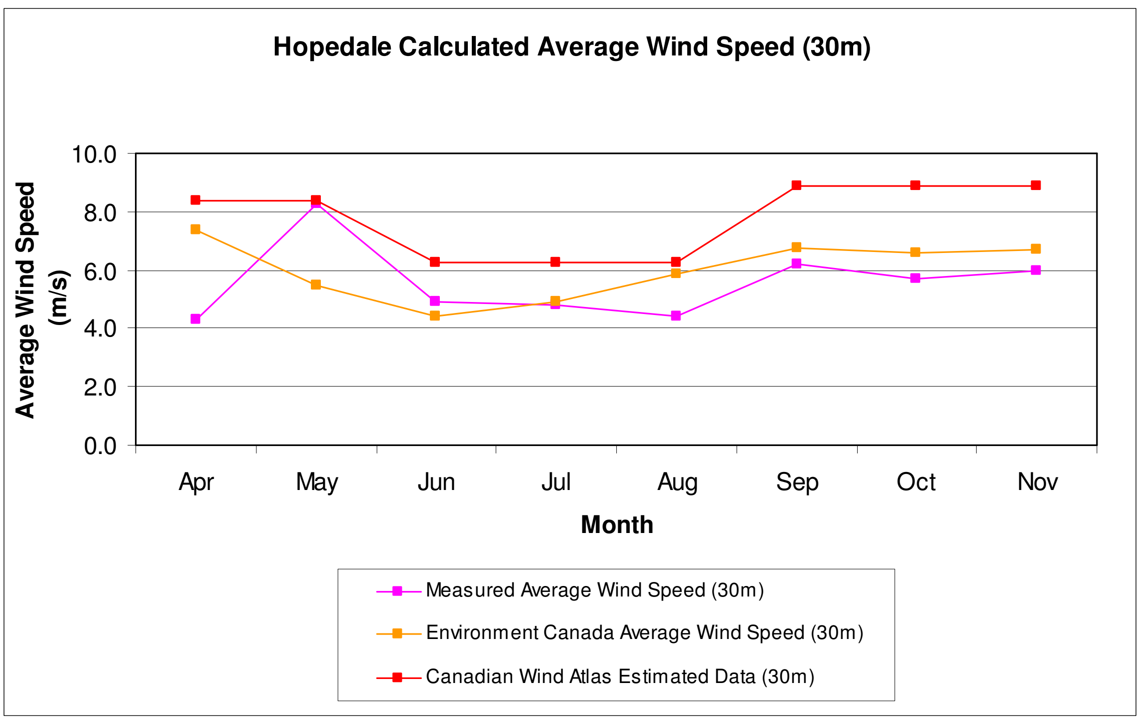

Hopedale Measured Wind Speed - October
Wind Speed (m/s)
Date
Measured Wind Speed (3m)
Environment Canada Wind Speed (10m)

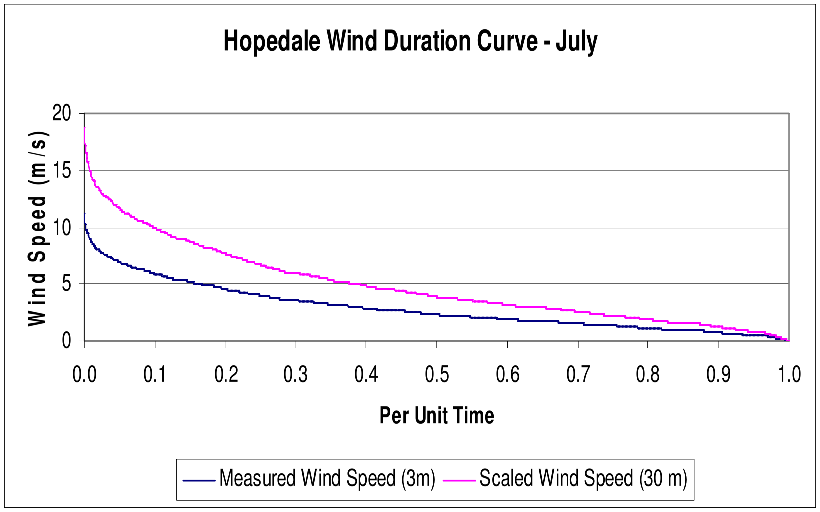

Hopedale Calculated Wind Speed - October
Wind Speed (m/s)
Date
Calculated Wind Speed (30m)
Environment Canada Wind Speed (30 m)


Hopedale Measured Wind Speed - November
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (3m)
Environment Canada Wind Speed (10m)

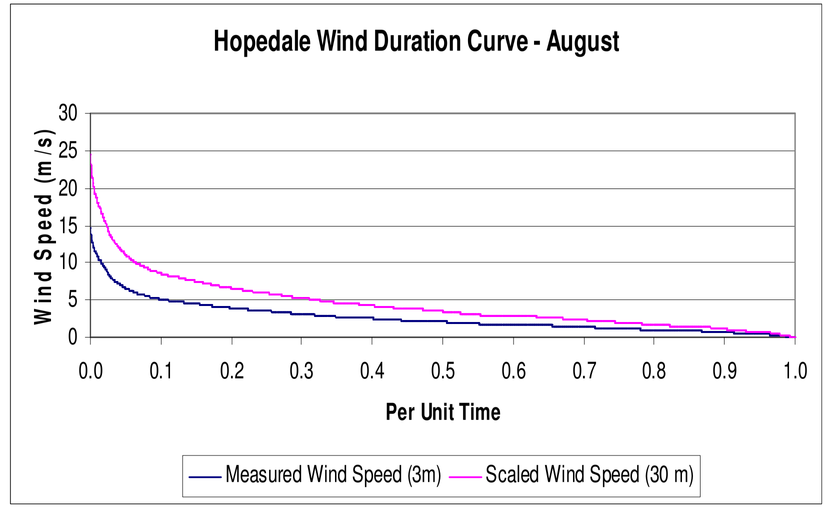

Hopedale Calculated Wind Speed - November
Wind Speed (m/s)
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Calculated Wind Speed (30m)
Environment Canada Wind Speed (30 m)


Hopedale Measured Average Wind Speed
Average Wind Speed (m/s)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
April
May
June
July
August
September
October
November
Month
Measured Average Wind Speed (3m)
Environment Canada Average Wind Speed (11.9m)

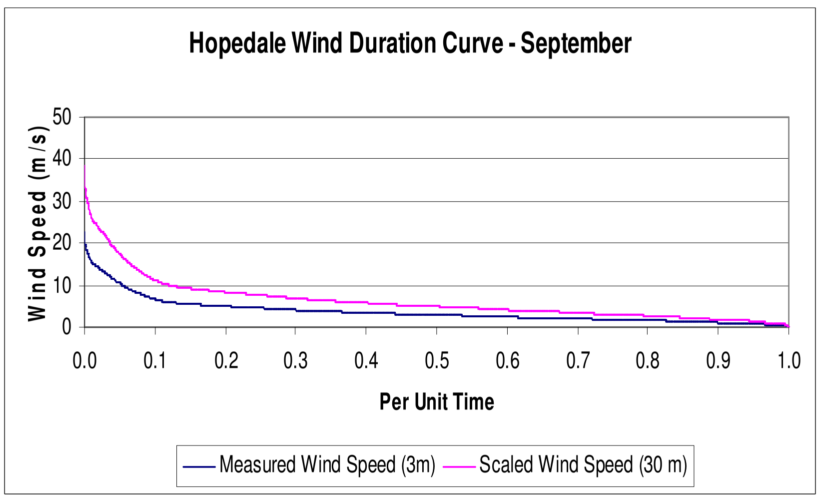

Hopedale Calculated Average Wind Speed (30m)
Average Wind Speed (m/s)
10.0
8.0
6.0
4.0
2.0
0.0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Month
Measured Average Wind Speed (30m)
Environment Canada Average Wind Speed (30m)
Canadian Wind Atlas Estimated Data (30m)



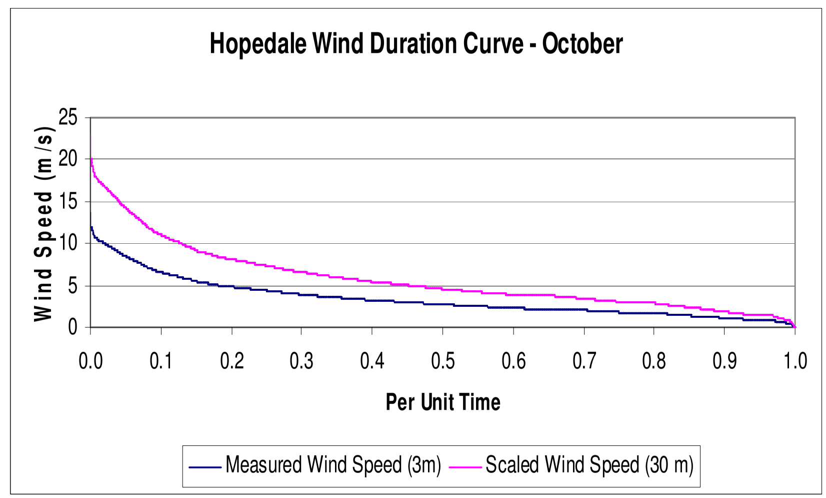
Hopedale Wind Duration Curve - July
Wind Speed (m/s)
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (3m)
Scaled Wind Speed (30 m)



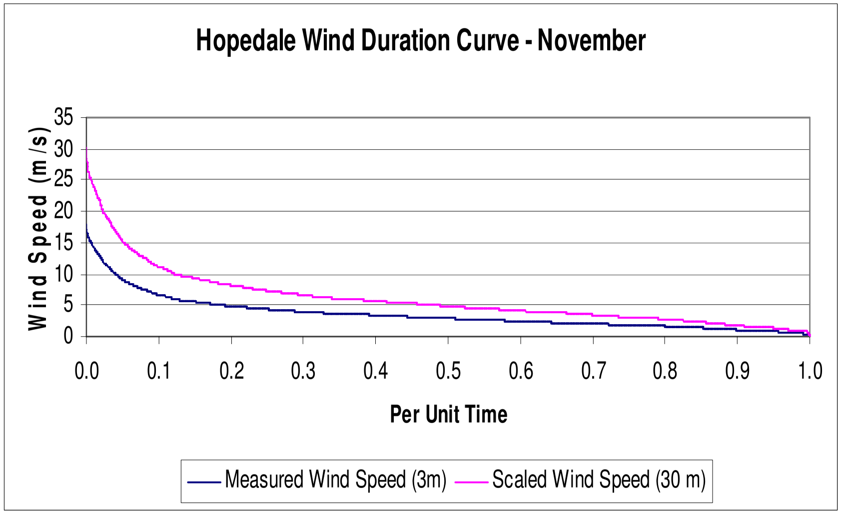
Hopedale Wind Duration Curve - August
Wind Speed (m/s)
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (3m)
Scaled Wind Speed (30 m)



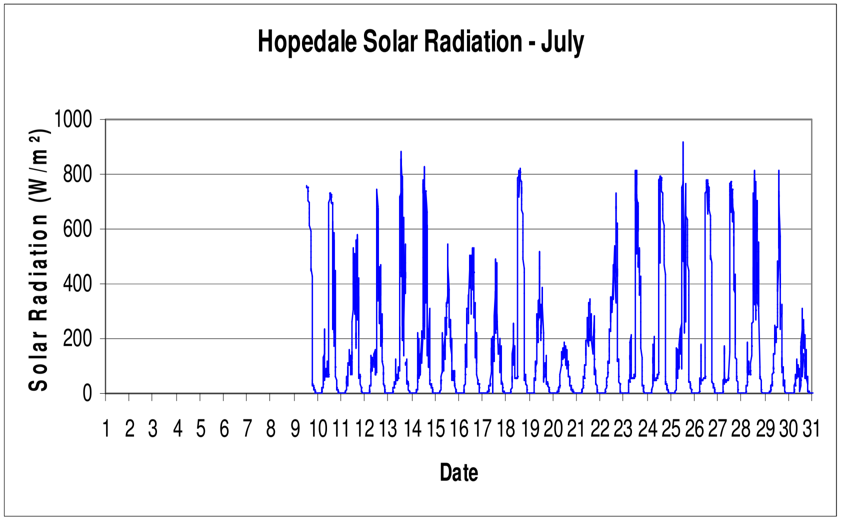
Hopedale Wind Duration Curve - September
Wind Speed (m/s)
50
40
30
20
10
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (3m)
Scaled Wind Speed (30 m)

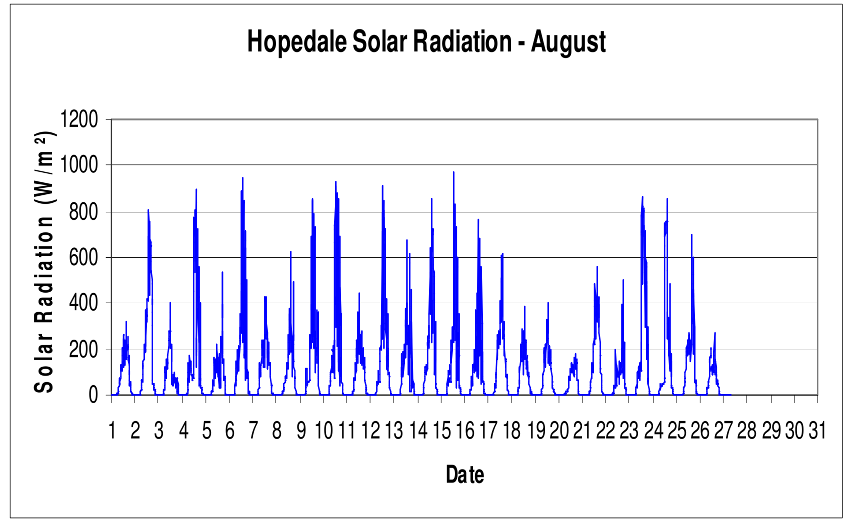


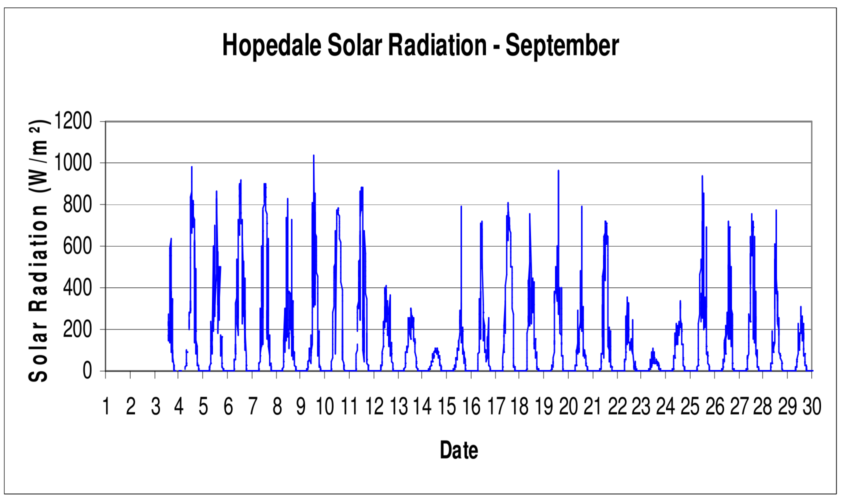
Hopedale Wind Duration Curve - October
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (3m)
Scaled Wind Speed (30 m)

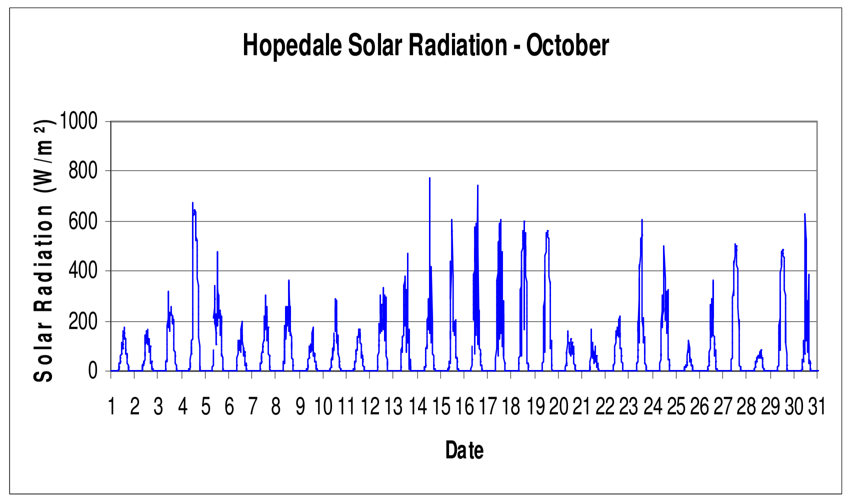


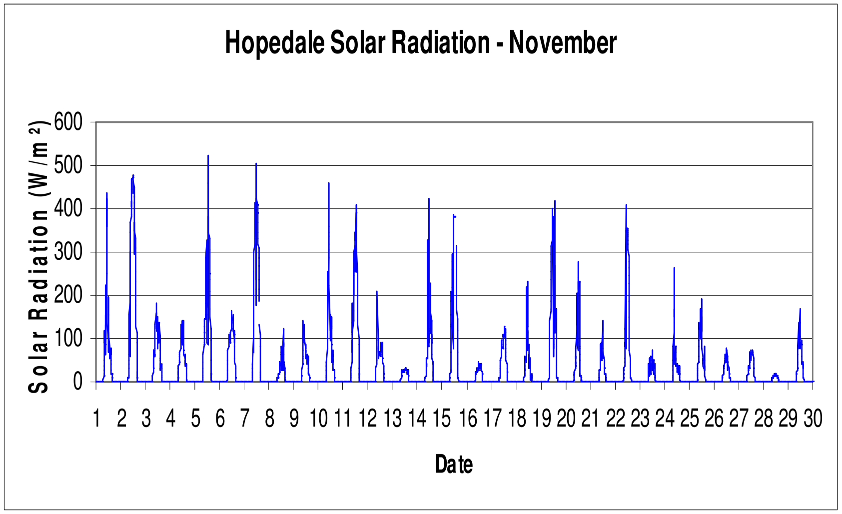
Hopedale Wind Duration Curve - November
Wind Speed (m/s)
35
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (3m)
Scaled Wind Speed (30 m)

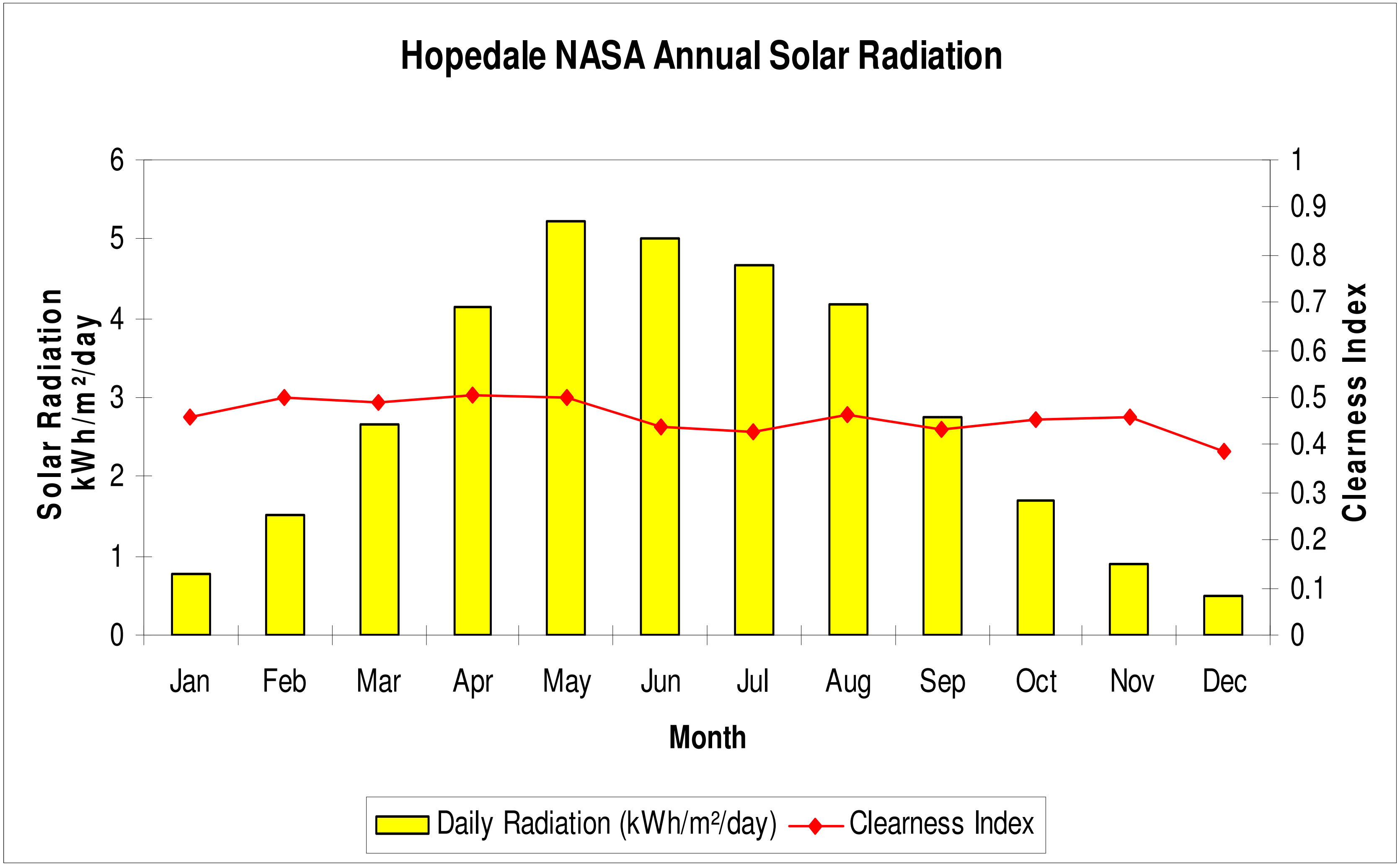

Hopedale Solar Radiation - July
Solar Radiation (W/m²)
0
200
400
600
800
1000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date

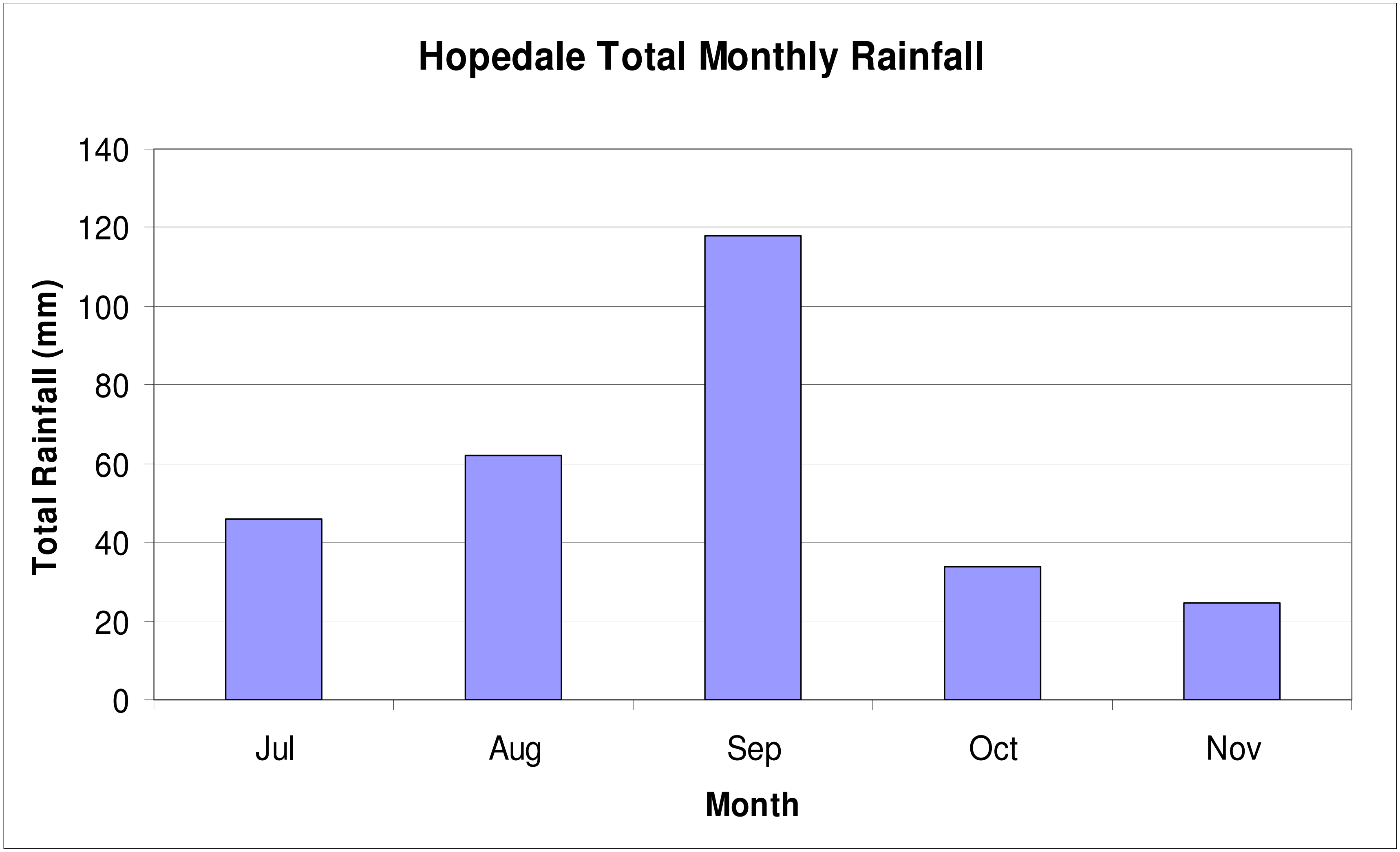

Hopedale Solar Radiation - August
Solar Radiation (W/m²)
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Hopedale Solar Radiation - September
Solar Radiation (W/m²)
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Hopedale Solar Radiation - October
Solar Radiation (W/m²)
0
200
400
600
800
1000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Hopedale Solar Radiation - November
Solar Radiation (W/m²)
0
100
200
300
400
500
600
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Hopedale NASA Annual Solar Radiation
Solar Radiation kWh/m²/day
6
5
4
3
2
1
0
Clearness Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Daily Radiation (kWh/m²/day)
Clearness Index

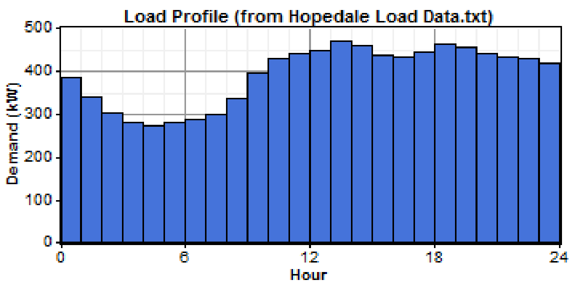

Hopedale Total Monthly Rainfall
Total Rainfall (mm)
140
120
100
80
60
40
20
0
Jul
Aug
Sep
Oct
Nov
Month

HOMER Input Summary

File name: Hopedale.hmr
File version: 2.67 beta
Author:
Notes:

AC Load: Hopedale Net System Load

Data source: Hopedale Load Data.txt
Daily noise: 16.9%
Hourly noise: 22.5%
Scaled annual average: 11,616, 11,959, 12,252, 12,540, 12,805 kWh/d
Scaled peak load: 991, 1,020, 1,045, 1,070, 1,092 kW
Load factor: 0.488



PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
50.000	400,000	400,000	10,000
100.000	750,000	750,000	15,000

Sizes to consider: 0, 50, 100 kW
Lifetime: 20 yr
Derating factor: 80%
Tracking system: No Tracking
Slope: 55.5 deg
Azimuth: 0 deg
Ground reflectance: 20%

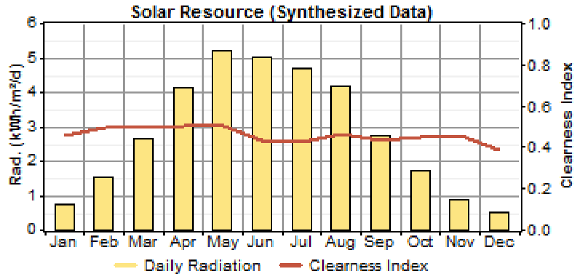
Solar Resource

Latitude: 55 degrees 27 minutes North
Longitude: 60 degrees 11 minutes West
Time zone: GMT -4:00

Data source: Synthetic

Month	Clearness Index	Average Radiation
		($kWh/m^2/day$)
Jan	0.460	0.760
Feb	0.498	1.530
Mar	0.492	2.670
Apr	0.506	4.140
May	0.501	5.220
Jun	0.437	5.010
Jul	0.428	4.680
Aug	0.463	4.170
Sep	0.432	2.740
Oct	0.453	1.700
Nov	0.459	0.900
Dec	0.386	0.490

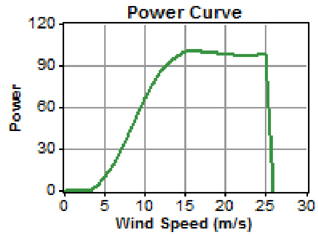
Scaled annual average: 2.83 $kWh/m^2/d$



AC Wind Turbine: Northern Power NW100/21

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	500,000	400,000	10,000

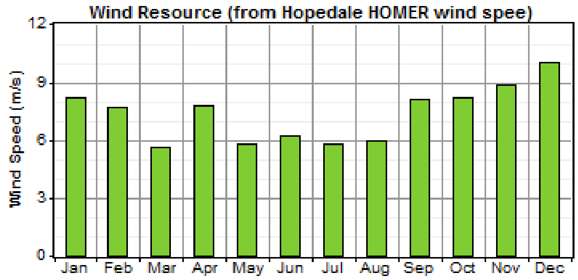
Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Lifetime: 20 yr
Hub height: 37 m



Wind Resource

Data source: Hopedale HOMER wind speed.txt

Month	Wind Speed (m/s)
Jan	8.2
Feb	7.7
Mar	5.6
Apr	7.8
May	5.8
Jun	6.2
Jul	5.8
Aug	6.0
Sep	8.1
Oct	8.2
Nov	8.9
Dec	10.0



Weibull k: 1.55
Autocorrelation factor: 0.902
Diurnal pattern strength: 0.113
Hour of peak wind speed: 14
Scaled annual average: 7.34 m/s
Anemometer height: 3 m
Altitude: 6 m

Wind shear profile: Logarithmic
Surface roughness length: 0.1 m

AC Hydro:

Capital cost:	$ 41,975,000, 31,690,000, 21,230,000, 11,810,000
Replacement cost:	$ 0
O&M cost:	$ 516,880, 516,880, 516,880, 37,220/yr
Lifetime:	60 yr
Available head:	20, 14, 14, 45 m
Design flow rate:	63,280, 63,280, 31,110, 1,410 L/s
Min. flow ratio:	15, 15, 15, 10%
Max. flow ratio:	100%
Turbine efficiency:	85%
Pipe head loss:	0%

Consider systems without hydro: Yes

Hydro Resource

Data source: Synthetic

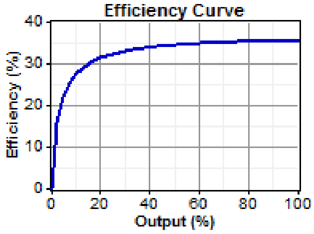
Month	Stream Flow (L/s)
Jan	3,470
Feb	2,235
Mar	2,000
Apr	2,471
May	9,294
Jun	8,941
Jul	9,294
Aug	9,294
Sep	8,941
Oct	9,294
Nov	8,941
Dec	5,765

Residual flow: 0 L/s
Scaled annual average: 6,691, 4,652, 4,652, 327 L/s

AC Generator: #2074

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
569.000	0	600,000	1.850

Sizes to consider:	569 kW
Lifetime:	100,000 hrs
Min. load ratio:	30%
Heat recovery ratio:	0%
Fuel used:	#1 Diesel Arctic Grade
Fuel curve intercept:	0.00881 L/hr/kW
Fuel curve slope:	0.264 L/hr/kW

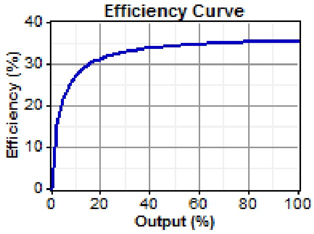


AC Generator: #2053

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)

545.000	0	400,000	1.684

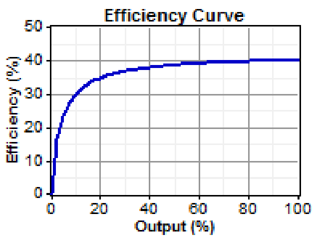
Sizes to consider: 545 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0092 L/hr/kW
Fuel curve slope: 0.264 L/hr/kW



AC Generator: #2054

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
475.000	0	400,000	1.684

Sizes to consider: 475 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.00921 L/hr/kW
Fuel curve slope: 0.233 L/hr/kW



Fuel: #1 Diesel Arctic Grade

Price: $ 0.97, 0.97, 0.99, 1.02, 1.02/L
Lower heating value: 45.8 MJ/kg
Density: 809 kg/m3
Carbon content: 88.0%
Sulfur content: 0.0500%

Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
100.000	64,000	64,000	6,400

Sizes to consider: 0, 100 kW
Lifetime: 15 yr
Inverter efficiency: 90%
Inverter can parallel with AC generator: Yes
Rectifier relative capacity: 100%
Rectifier efficiency: 85%

Economics

Annual real interest rate: 8%
Project lifetime: 60 yr
Capacity shortage penalty: $ 0/kWh
System fixed capital cost: $ 0

System fixed O&M cost: $ 0/yr

Generator control

Check load following: Yes
Check cycle charging: No

Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	No

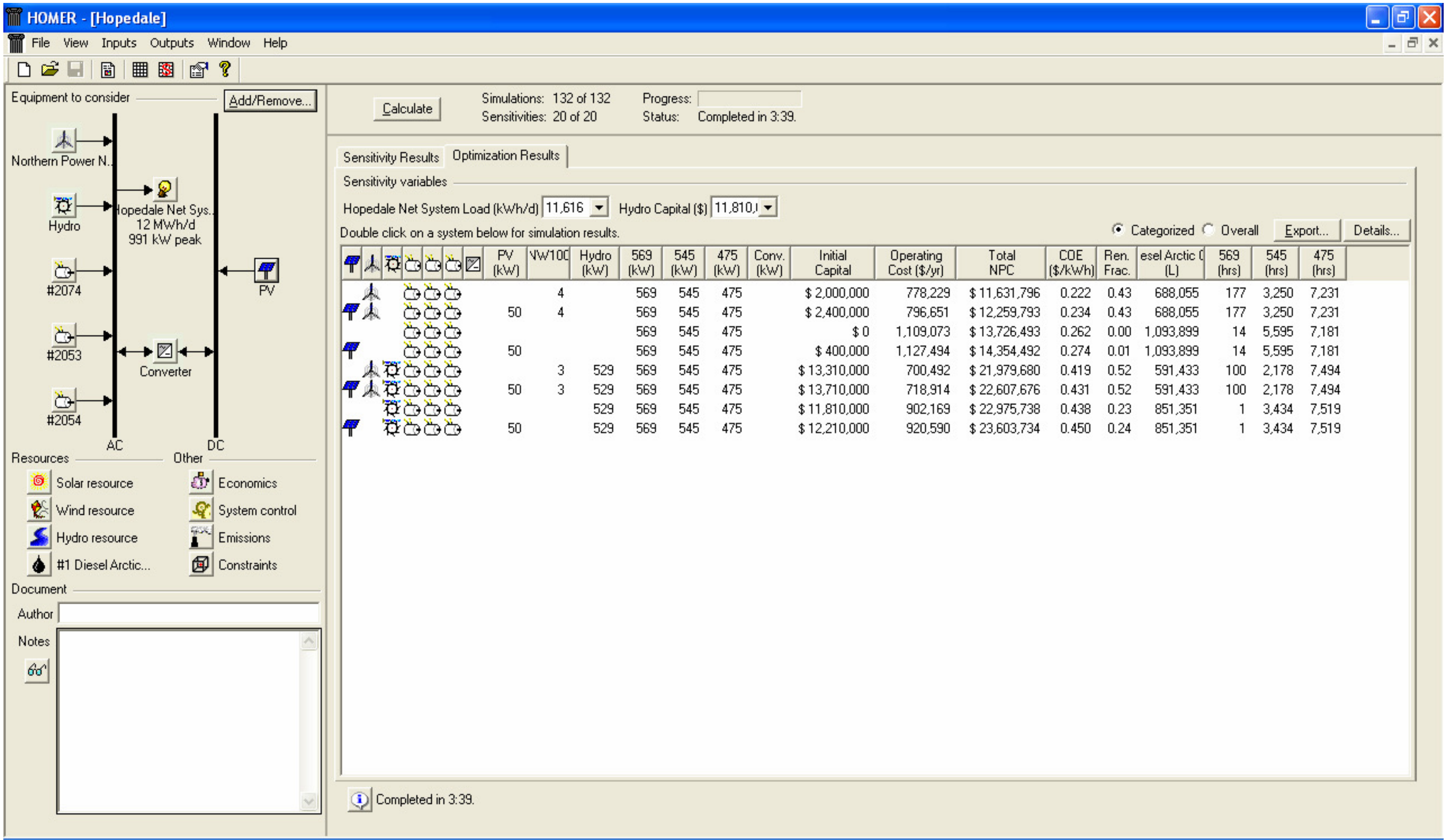
Emissions

Carbon dioxide penalty:	$ 0/t
Carbon monoxide penalty:	$ 0/t
Unburned hydrocarbons penalty:	$ 0/t
Particulate matter penalty:	$ 0/t
Sulfur dioxide penalty:	$ 0/t
Nitrogen oxides penalty:	$ 0/t

Constraints

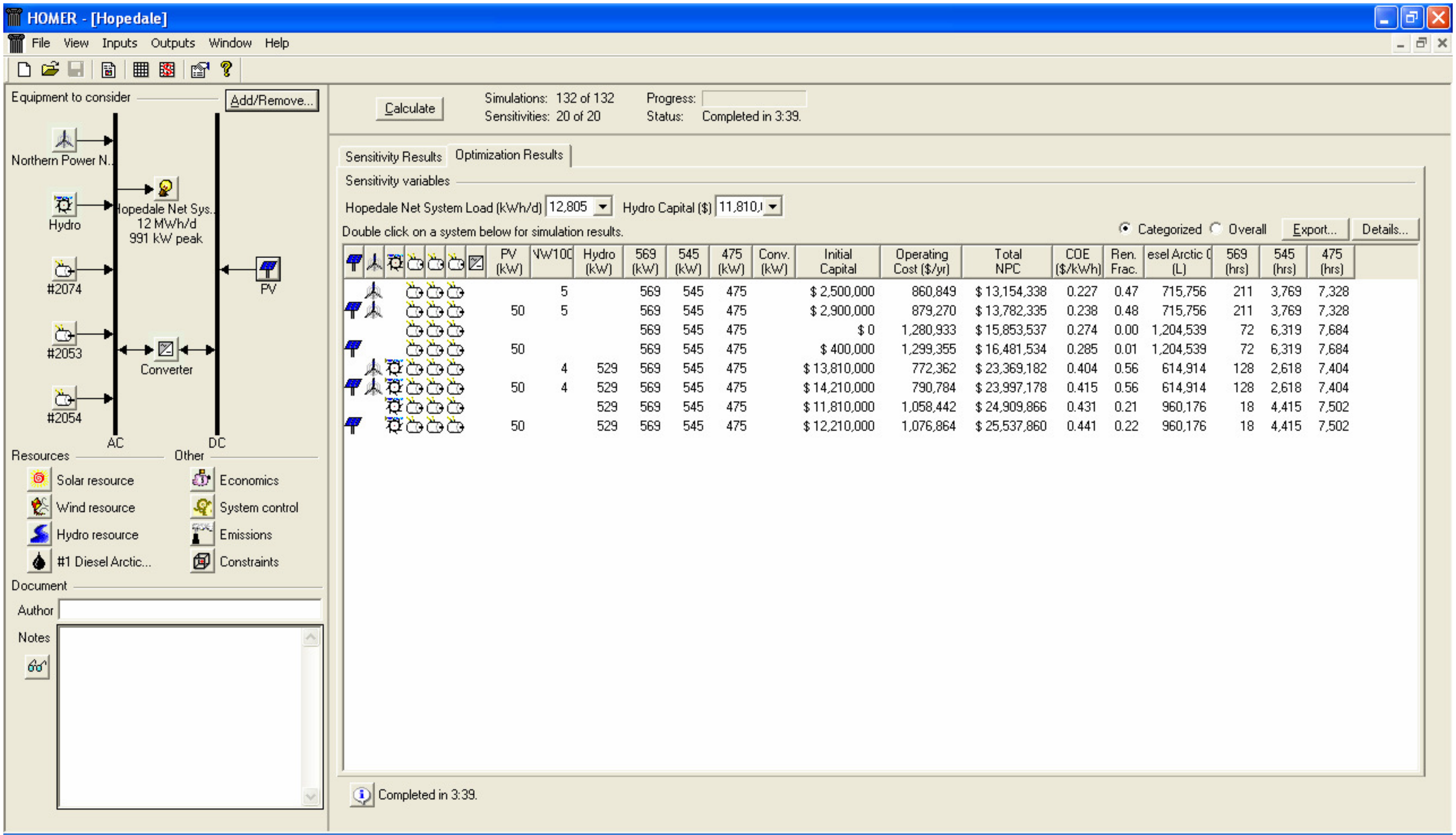
Maximum annual capacity shortage:	0%
Minimum renewable fraction:	0%

Operating reserve as percentage of hourly load:	10%
Operating reserve as percentage of peak load:	0%
Operating reserve as percentage of solar power output:	25%
Operating reserve as percentage of wind power output:	50%



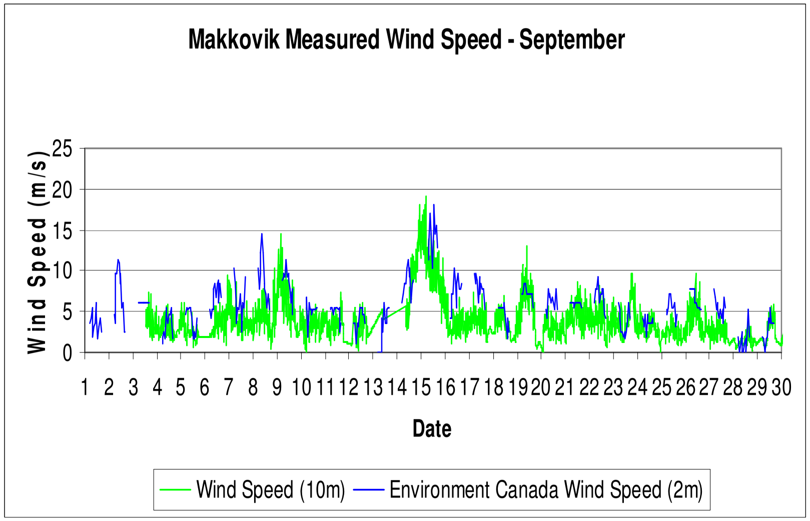
PV (kW)	NW100	Hydro (kW)	569 (kW)	545 (kW)	475 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic ((L)	569 (hrs)	545 (hrs)	475 (hrs)
	4		569	545	475		$ 2,000,000	778,229	$ 11,631,796	0.222	0.43	688,055	177	3,250	7,231
50	4		569	545	475		$ 2,400,000	796,651	$ 12,259,793	0.234	0.43	688,055	177	3,250	7,231
			569	545	475		$ 0	1,109,073	$ 13,726,493	0.262	0.00	1,093,899	14	5,595	7,181
50			569	545	475		$ 400,000	1,127,494	$ 14,354,492	0.274	0.01	1,093,899	14	5,595	7,181
	3	529	569	545	475		$ 13,310,000	700,492	$ 21,979,680	0.419	0.52	591,433	100	2,178	7,494
50	3	529	569	545	475		$ 13,710,000	718,914	$ 22,607,676	0.431	0.52	591,433	100	2,178	7,494
		529	569	545	475		$ 11,810,000	902,169	$ 22,975,738	0.438	0.23	851,351	1	3,434	7,519
50		529	569	545	475		$ 12,210,000	920,590	$ 23,603,734	0.450	0.24	851,351	1	3,434	7,519

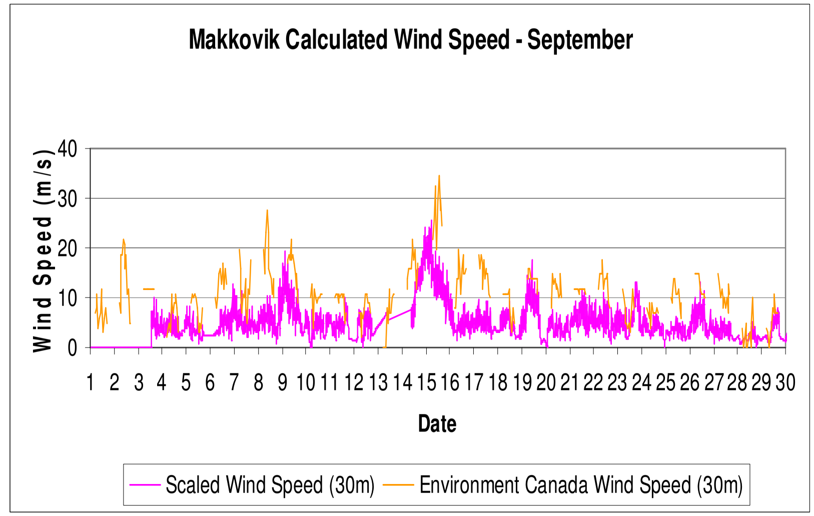
Hopedale HOMER Results – 2011 System Load

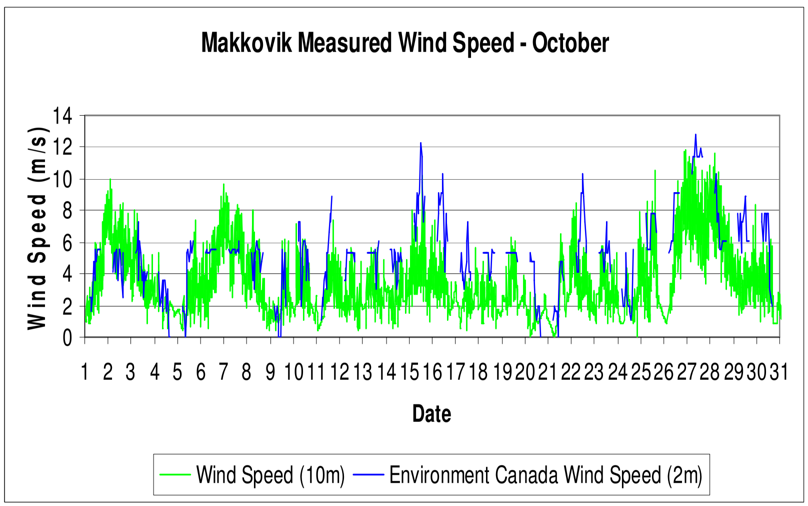


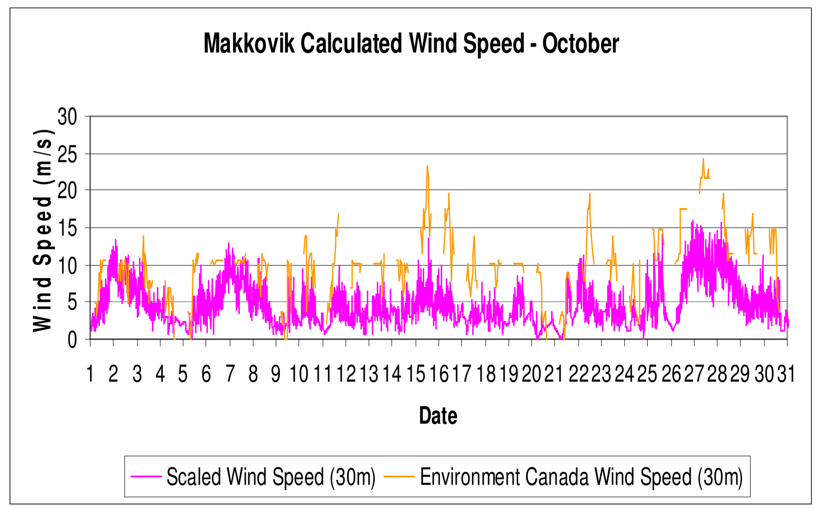
Hopedale HOMER Results – 2015 System Load

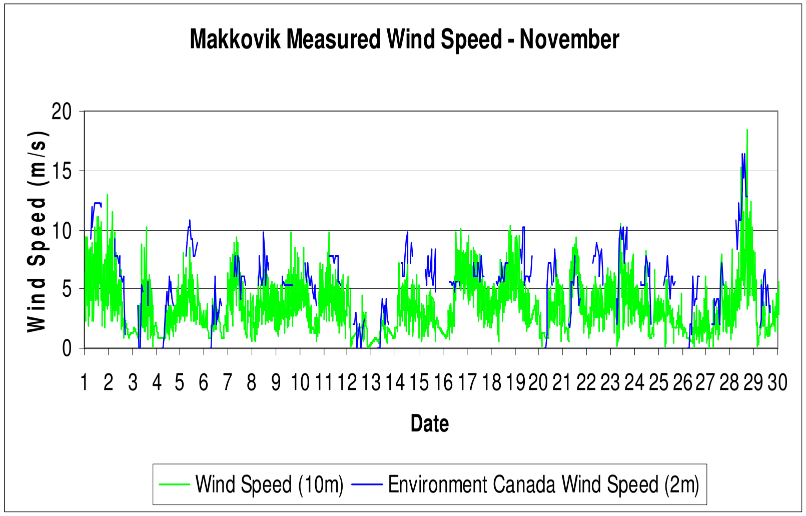
APPENDIX C - MAKKOVIK

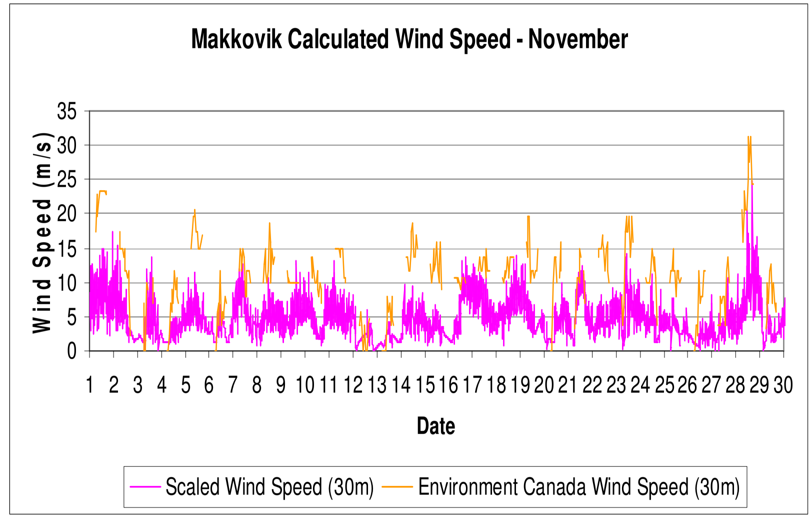

Makkovik Measured Wind Speed - September
Wind Speed (m/s)
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Wind Speed (10m)
Environment Canada Wind Speed (2m)

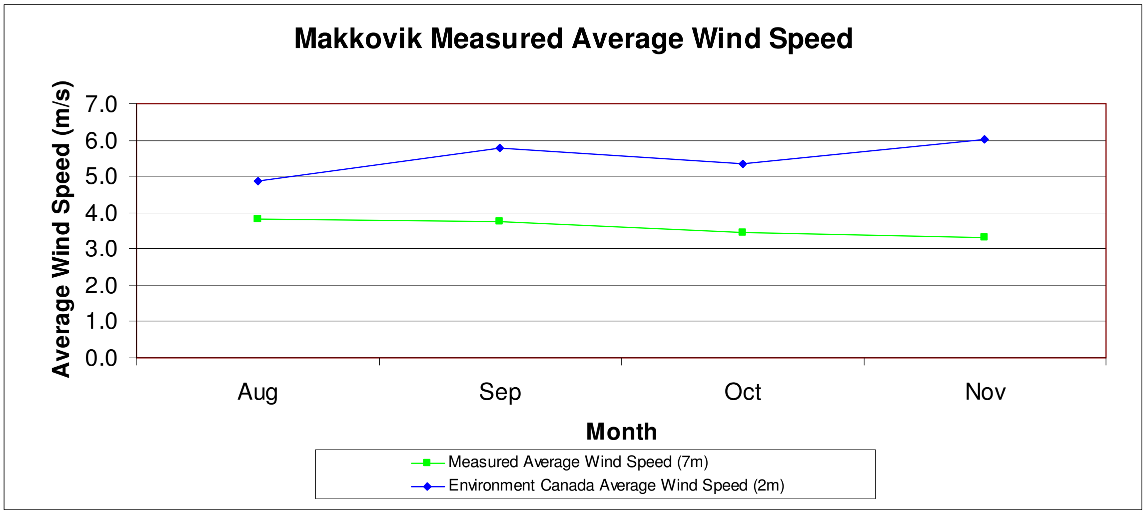

Makkovik Calculated Wind Speed - September
Wind Speed (m/s)
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

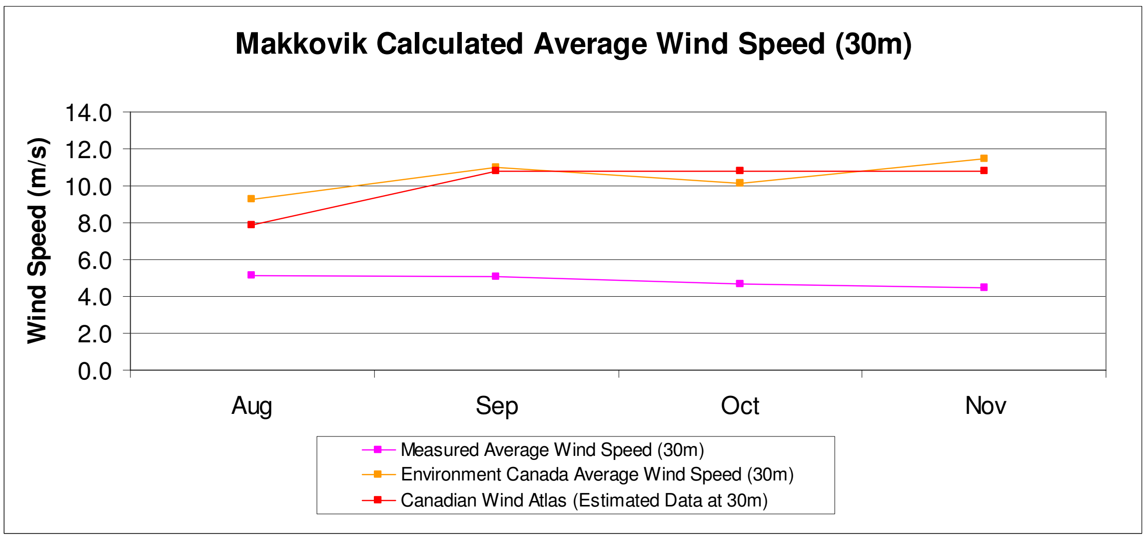

Makkovik Measured Wind Speed - October
Wind Speed (m/s)
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Wind Speed (10m)
Environment Canada Wind Speed (2m)

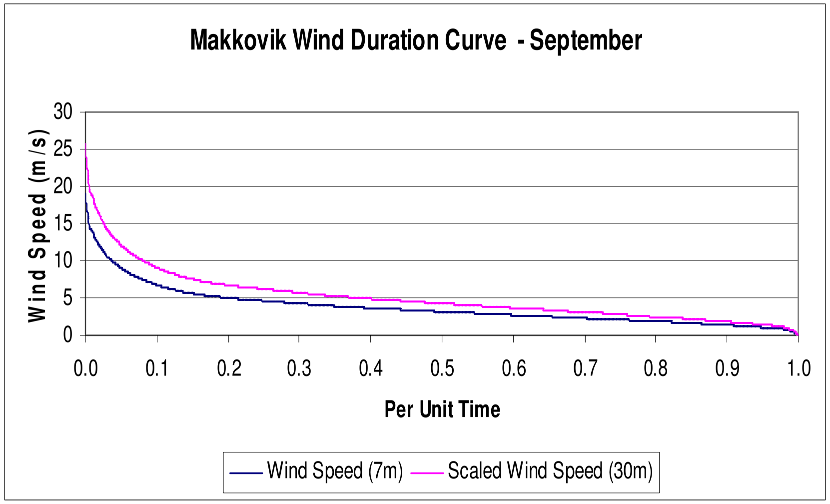

Makkovik Calculated Wind Speed - October
Wind Speed (m/s)
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

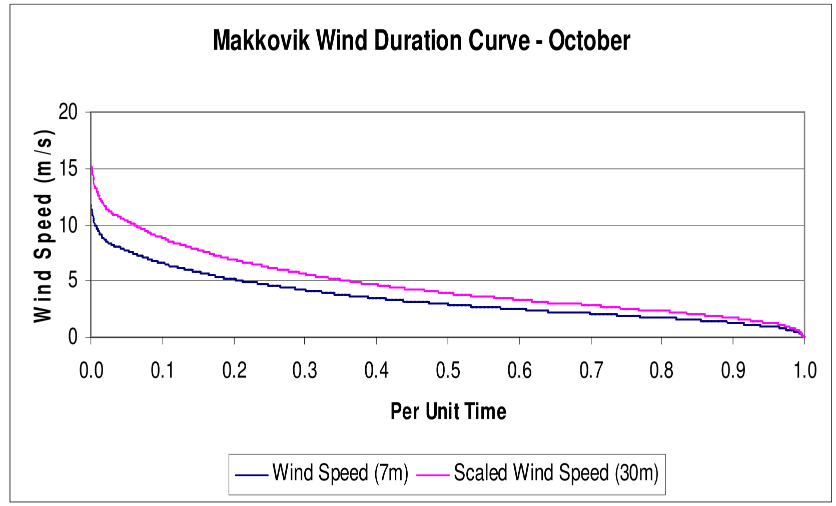

Makkovik Measured Wind Speed - November
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Wind Speed (10m)
Environment Canada Wind Speed (2m)

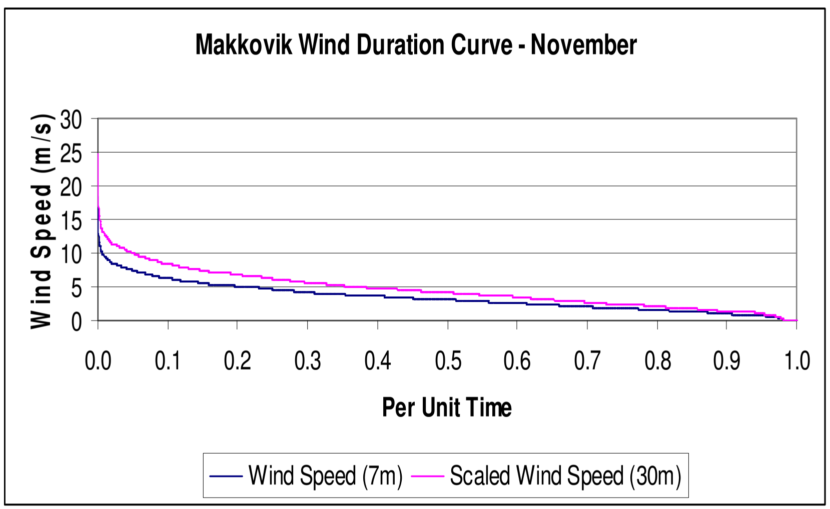

Makkovik Calculated Wind Speed - November
Wind Speed (m/s)
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

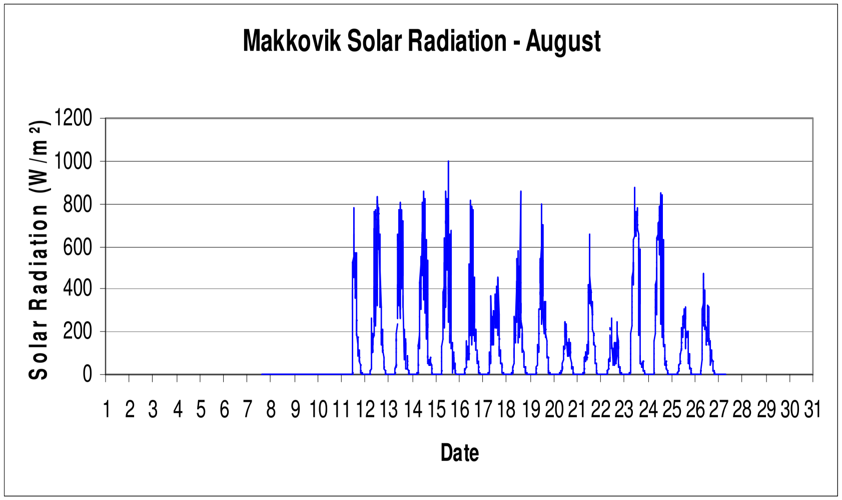

Makkovik Measured Average Wind Speed
Average Wind Speed (m/s)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Aug
Sep
Oct
Nov
Month
Measured Average Wind Speed (7m)
Environment Canada Average Wind Speed (2m)

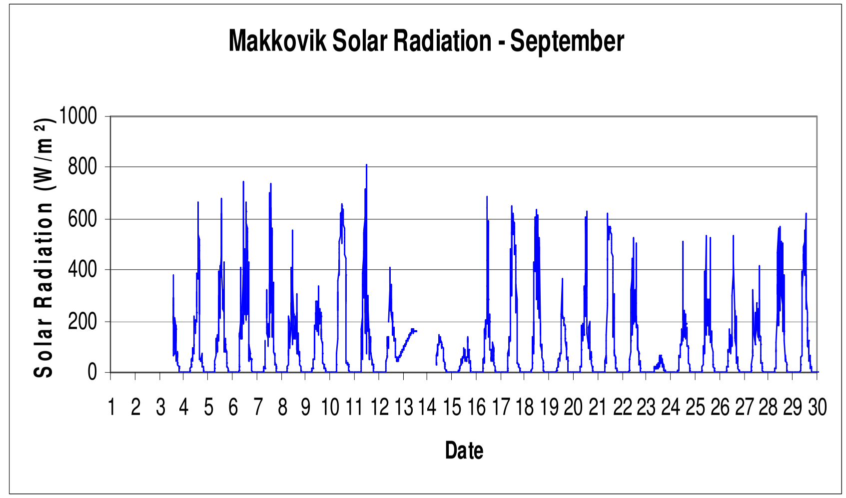

Makkovik Calculated Average Wind Speed (30m)
Wind Speed (m/s)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Aug
Sep
Oct
Nov
Measured Average Wind Speed (30m)
Environment Canada Average Wind Speed (30m)
Canadian Wind Atlas (Estimated Data at 30m)

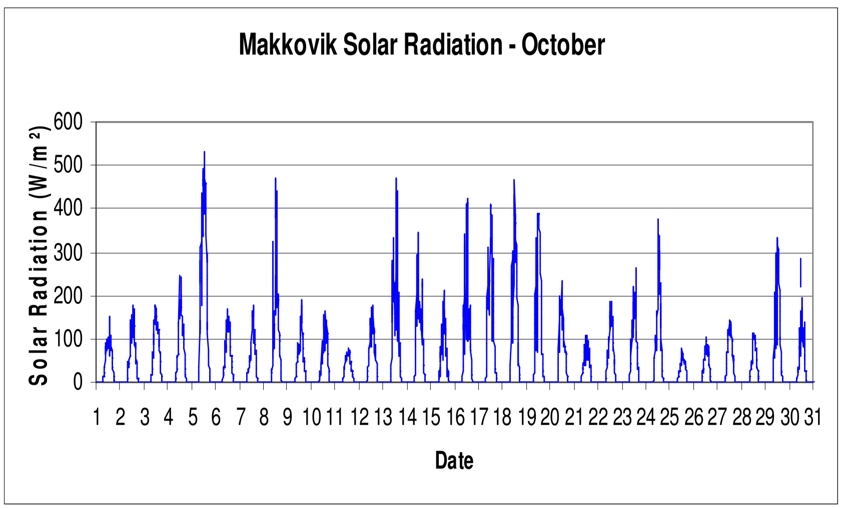

Makkovik Wind Duration Curve - September
Wind Speed (m/s)
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (7m)
Scaled Wind Speed (30m)

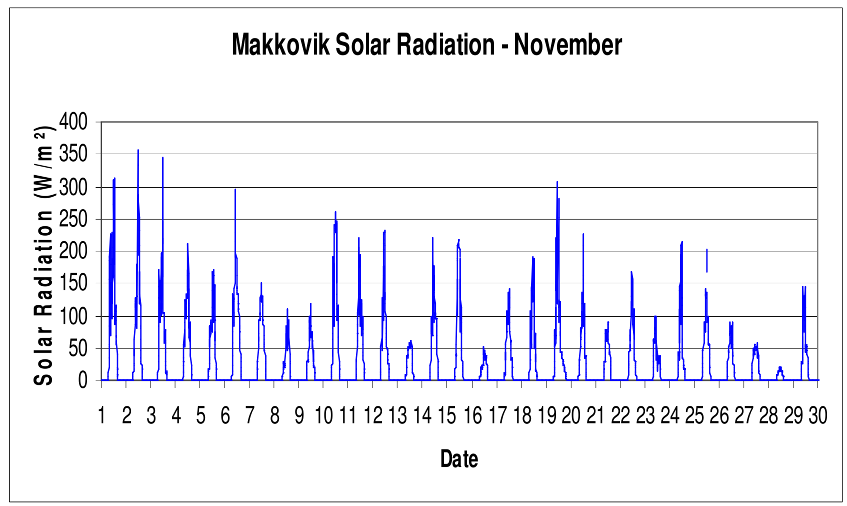

Makkovik Wind Duration Curve - October
Wind Speed (m/s)
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (7m)
Scaled Wind Speed (30m)

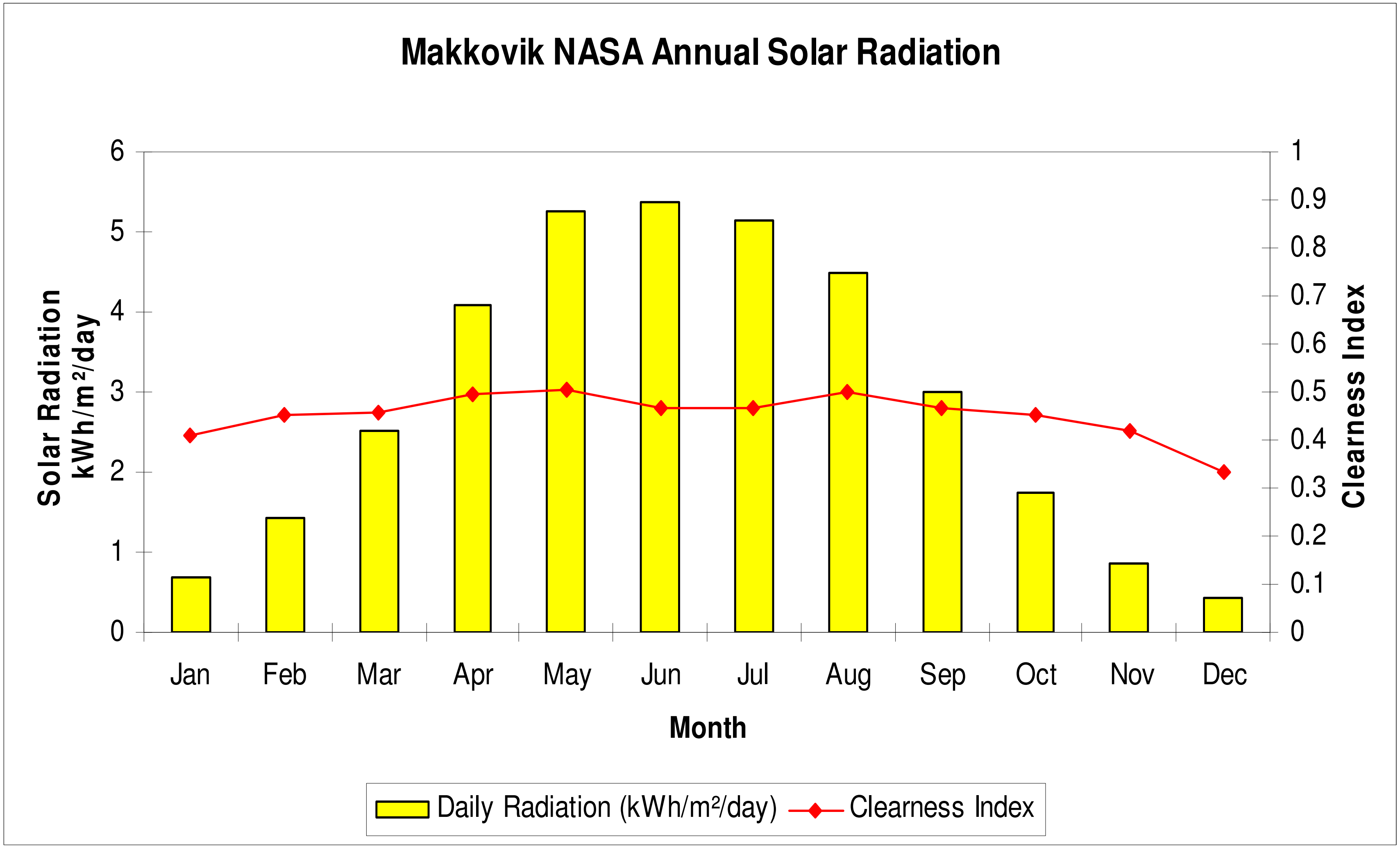

Makkovik Wind Duration Curve - November
Wind Speed (m/s)
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (7m)
Scaled Wind Speed (30m)


Makkovik Solar Radiation - August
Solar Radiation (W/m²)
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date

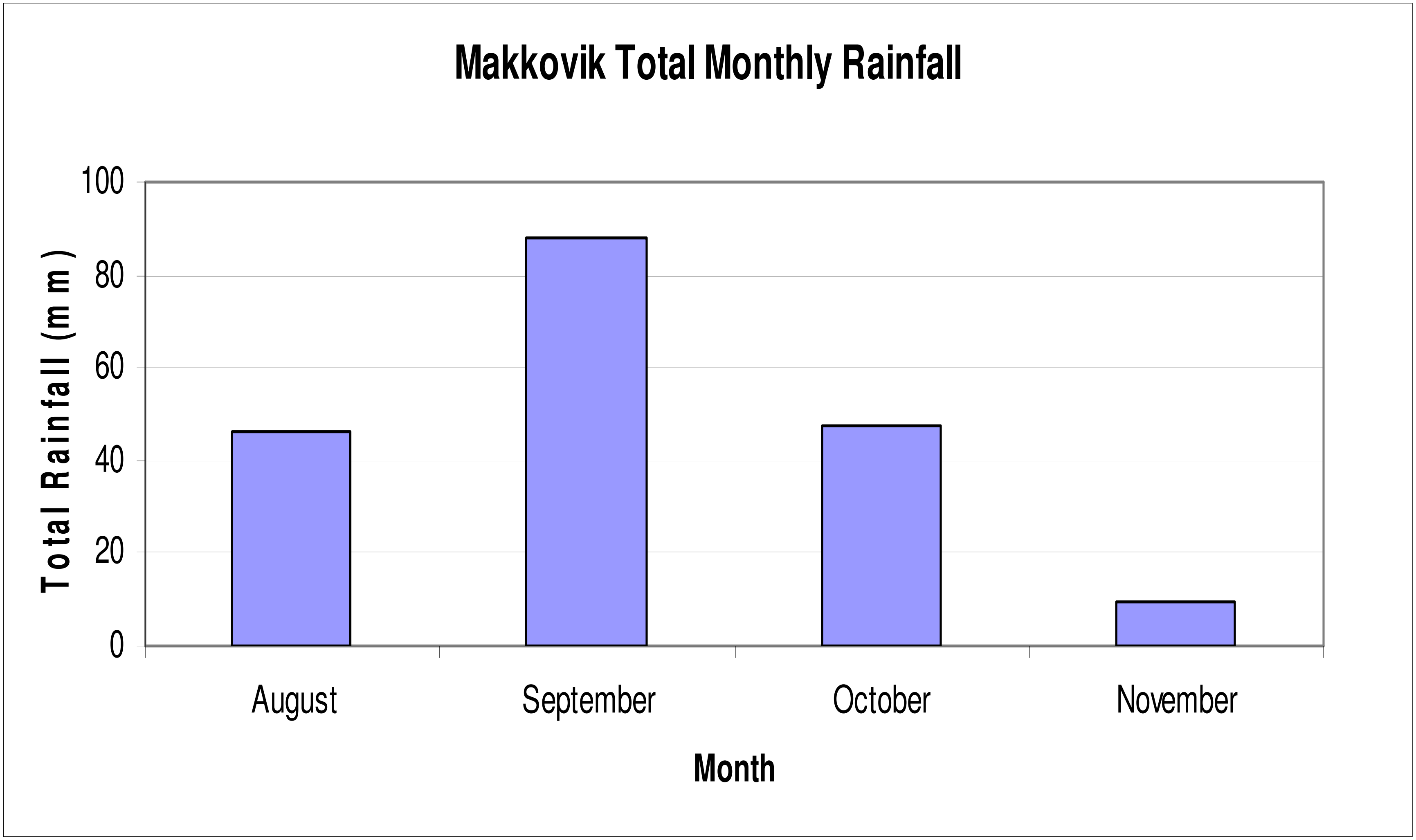

Makkovik Solar Radiation - September
Solar Radiation (W/m²)
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Makkovik Solar Radiation - October
Solar Radiation (W/m²)
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Makkovik Solar Radiation - November
Solar Radiation (W/m²)
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date



Makkovik NASA Annual Solar Radiation
Solar Radiation
kWh/m²/day
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Clearness Index
Daily Radiation (kWh/m²/day)
Clearness Index

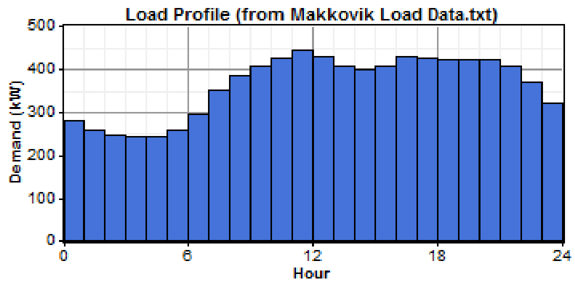

Makkovik Total Monthly Rainfall
Total Rainfall (mm)
100
80
60
40
20
0
August
September
October
November
Month

HOMER Input Summary

File name: Makkovik.hmr
File version: 2.67 beta
Author:

AC Load: Makkovik Net System Load

Data source:	Makkovik Load Data.txt
Daily noise:	7.08%
Hourly noise:	8.85%
Scaled annual average:	9,205, 9,370, 9,504, 9,767, 9,885 kWh/d
Scaled peak load:	749, 763, 774, 795, 805 kW
Load factor:	0.512



PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
50.000	400,000	400,000	10,000
100.000	750,000	750,000	15,000

Sizes to consider:	0, 50, 100 kW
Lifetime:	20 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	55.1 deg
Azimuth:	0 deg
Ground reflectance:	20%

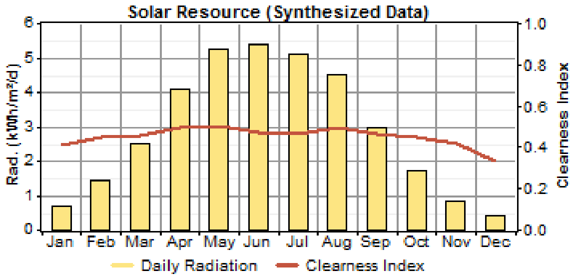
Solar Resource

Latitude: 55 degrees 4 minutes North
Longitude: 59 degrees 10 minutes West
Time zone: GMT -4:00

Data source: Synthetic

Month	Clearness Index	Average Radiation
		(kWh/m^2/day)
Jan	0.408	0.700
Feb	0.452	1.420
Mar	0.458	2.510
Apr	0.497	4.090
May	0.505	5.270
Jun	0.469	5.380
Jul	0.469	5.130
Aug	0.498	4.500
Sep	0.467	2.990
Oct	0.453	1.730
Nov	0.420	0.850
Dec	0.331	0.440

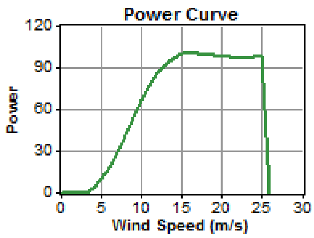
Scaled annual average: 2.91 kWh/m²/d



AC Wind Turbine: Northern Power NW100/21

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	500,000	400,000	10,000

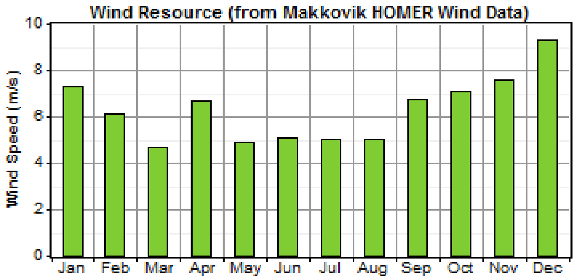
Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Lifetime: 20 yr
Hub height: 37 m



Wind Resource

Data source: Makkovik HOMER Wind Data.txt

Month	Wind Speed (m/s)
Jan	7.32
Feb	6.11
Mar	4.66
Apr	6.72
May	4.93
Jun	5.11
Jul	5.00
Aug	5.06
Sep	6.75
Oct	7.12
Nov	7.55
Dec	9.29



Weibull k: 1.53
Autocorrelation factor: 0.854
Diurnal pattern strength: 0.0568
Hour of peak wind speed: 20
Scaled annual average: 6.3 m/s
Anemometer height: 7 m
Altitude: 10 m

Wind shear profile: Logarithmic
Surface roughness length: 0.2 m

AC Hydro:

Capital cost: $ 2,222,000, 8,068,000, 3,858,000, 6,548,000
Replacement cost: $ 0
O&M cost: $ 17,160, 47,890, 15,890, 14,840/yr
Lifetime: 60 yr
Available head: 25, 99, 31, 34 m
Design flow rate: 1,140, 800, 850, 720 L/s
Min. flow ratio: 15, 10, 15, 15%
Max. flow ratio: 100%
Turbine efficiency: 85%
Pipe head loss: 0%

Consider systems without hydro: Yes

Hydro Resource

Data source: Synthetic

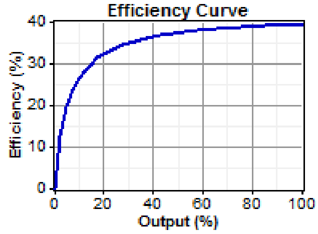
Month	Stream Flow (L/s)
Jan	235
Feb	165
Mar	153
Apr	212
May	582
Jun	565
Jul	582
Aug	582
Sep	565
Oct	582
Nov	565
Dec	347

Residual flow: 0 L/s
Scaled annual average: 153, 428, 141, 131 L/s

AC Generator: 3033

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
450.000	0	400,000	1.684

Sizes to consider: 450 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0133 L/hr/kW
Fuel curve slope: 0.233 L/hr/kW

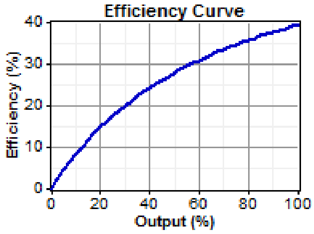


AC Generator: 2029

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)

620.000	0	600,000	1.850

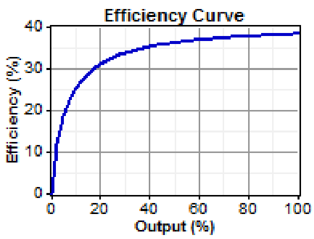
Sizes to consider: 620 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.102 L/hr/kW
Fuel curve slope: 0.144 L/hr/kW



AC Generator: 2059

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
635.000	0	600,000	1.850

Sizes to consider: 635 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0146 L/hr/kW
Fuel curve slope: 0.239 L/hr/kW



Fuel: #1 Diesel Arctic Grade

Price: $ 0.921, 0.920, 0.940, 0.969, 0.969/L
Lower heating value: 45.8 MJ/kg
Density: 809 kg/m3
Carbon content: 88.0%
Sulfur content: 0.0500%

Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
100.000	64,000	64,000	6,400

Sizes to consider: 0, 100 kW
Lifetime: 15 yr
Inverter efficiency: 90%
Inverter can parallel with AC generator: Yes
Rectifier relative capacity: 100%
Rectifier efficiency: 85%

Economics

Annual real interest rate: 8%
Project lifetime: 60 yr
Capacity shortage penalty: $ 0/kWh
System fixed capital cost: $ 0

System fixed O&M cost:	$ 0/yr

Generator control

Check load following:	Yes
Check cycle charging:	No

Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	No

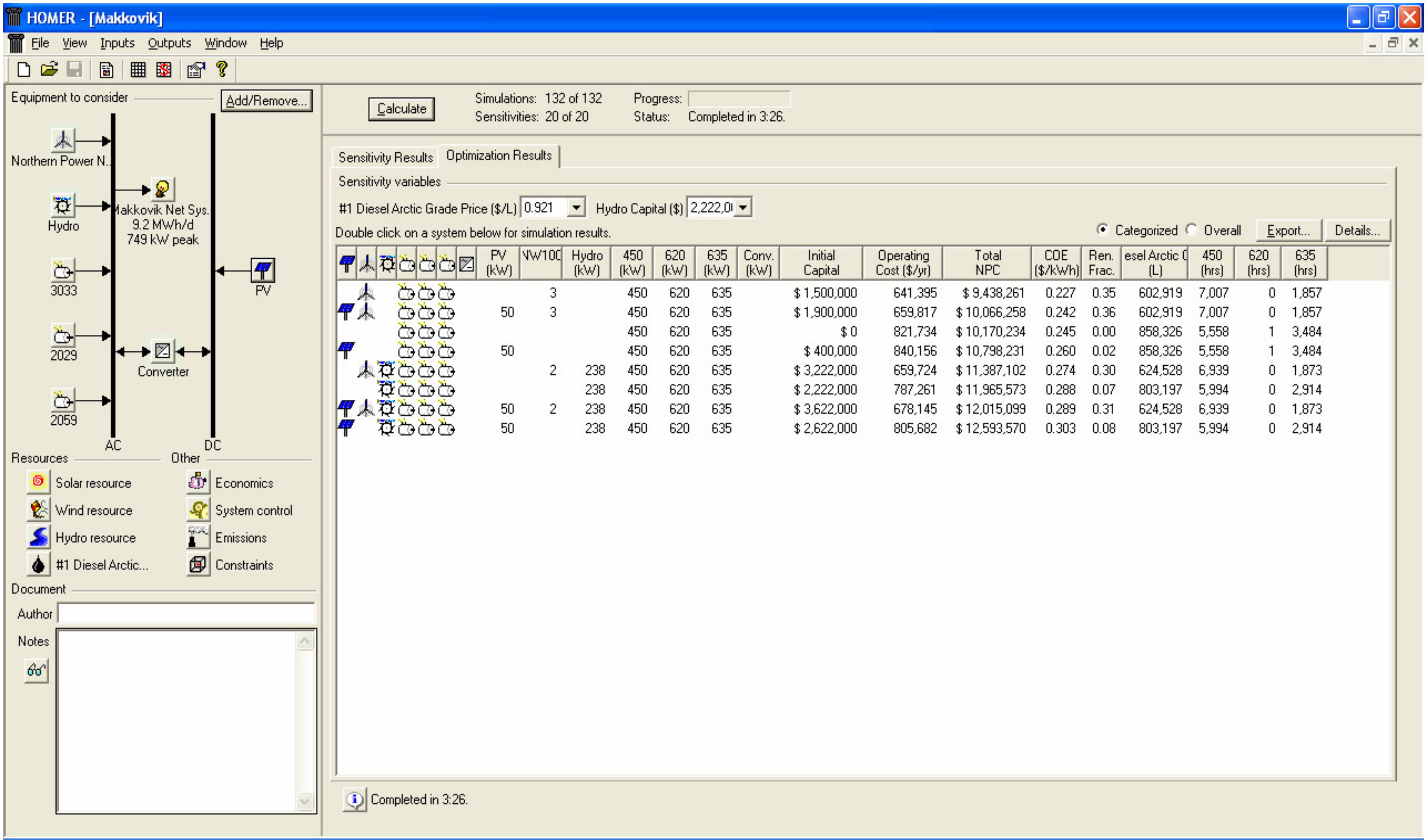
Emissions

Carbon dioxide penalty:	$ 0/t
Carbon monoxide penalty:	$ 0/t
Unburned hydrocarbons penalty:	$ 0/t
Particulate matter penalty:	$ 0/t
Sulfur dioxide penalty:	$ 0/t
Nitrogen oxides penalty:	$ 0/t

Constraints

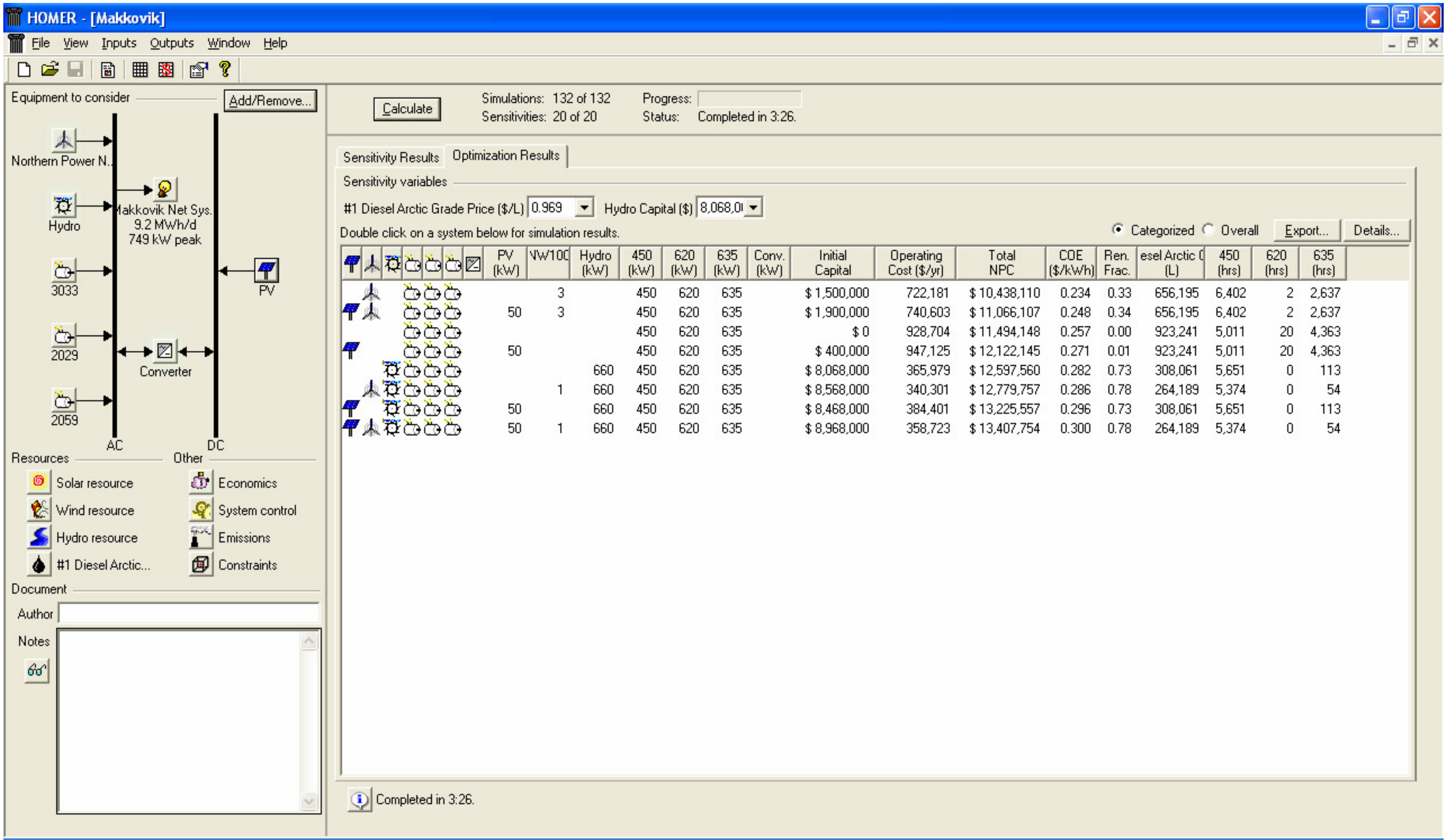
Maximum annual capacity shortage:	0%
Minimum renewable fraction:	0%

Operating reserve as percentage of hourly load:	10%
Operating reserve as percentage of peak load:	0%
Operating reserve as percentage of solar power output:	25%
Operating reserve as percentage of wind power output:	50%



PV (kW)	NW100	Hydro (kW)	450 (kW)	620 (kW)	635 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic (L)	450 (hrs)	620 (hrs)	635 (hrs)
	3		450	620	635		$ 1,500,000	641,395	$ 9,438,261	0.227	0.35	602,919	7,007	0	1,857
50	3		450	620	635		$ 1,900,000	659,817	$ 10,066,258	0.242	0.36	602,919	7,007	0	1,857
			450	620	635		$ 0	821,734	$ 10,170,234	0.245	0.00	858,326	5,558	1	3,484
50			450	620	635		$ 400,000	840,156	$ 10,798,231	0.260	0.02	858,326	5,558	1	3,484
	2	238	450	620	635		$ 3,222,000	659,724	$ 11,387,102	0.274	0.30	624,528	6,939	0	1,873
		238	450	620	635		$ 2,222,000	787,261	$ 11,965,573	0.288	0.07	803,197	5,994	0	2,914
50	2	238	450	620	635		$ 3,622,000	678,145	$ 12,015,099	0.289	0.31	624,528	6,939	0	1,873
50		238	450	620	635		$ 2,622,000	805,682	$ 12,593,570	0.303	0.08	803,197	5,994	0	2,914

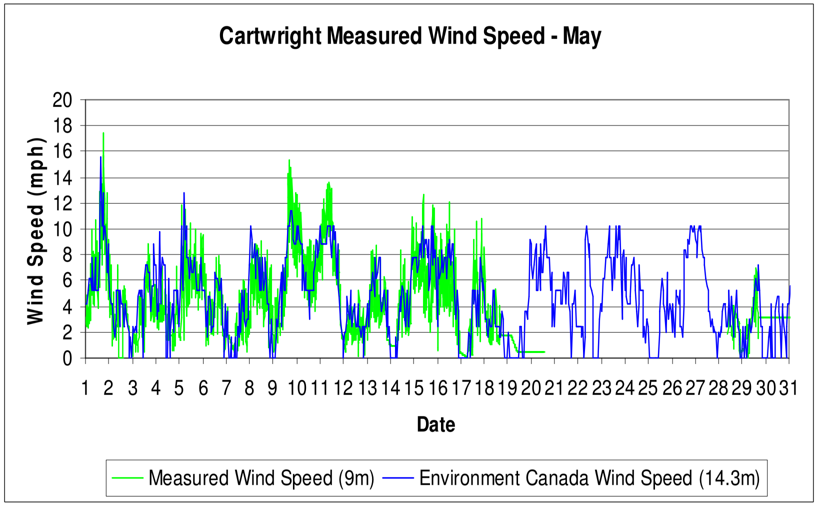
Makkovik HOMER Results – 2011 System Load

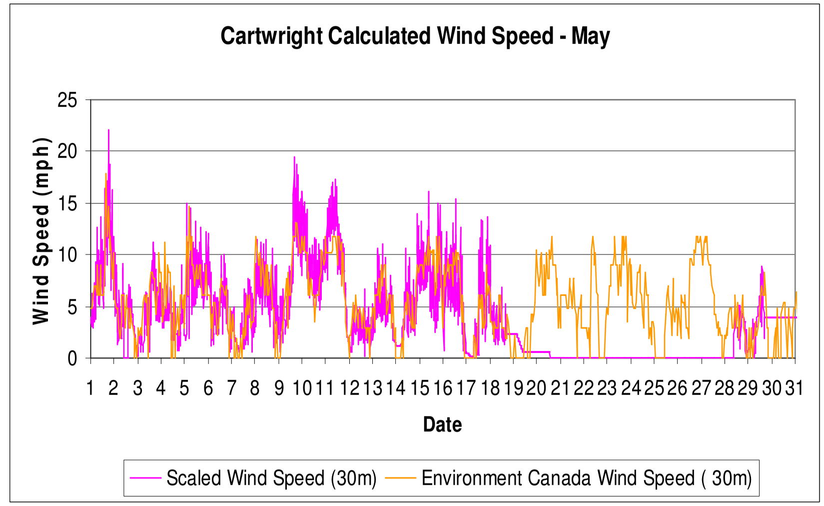


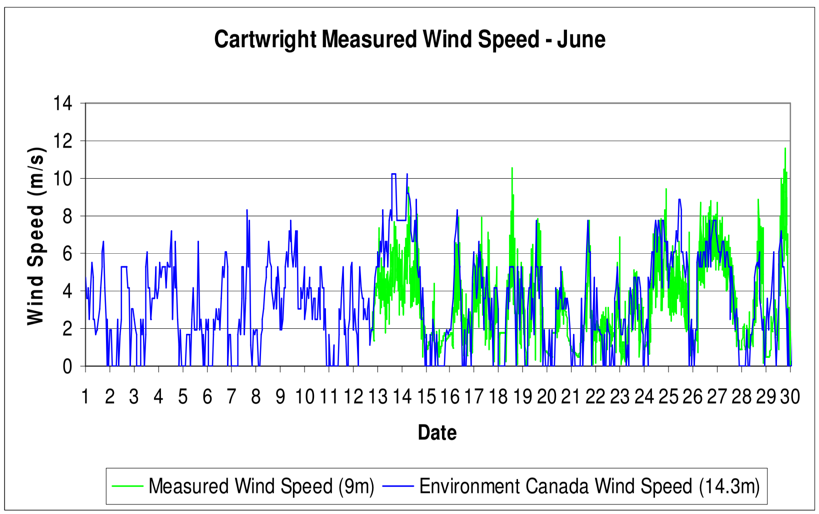
PV (kW)	NW100	Hydro (kW)	450 (kW)	620 (kW)	635 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic ((L)	450 (hrs)	620 (hrs)	635 (hrs)
	3		450	620	635		$ 1,500,000	722,181	$ 10,438,110	0.234	0.33	656,195	6,402	2	2,637
50	3		450	620	635		$ 1,900,000	740,603	$ 11,066,107	0.248	0.34	656,195	6,402	2	2,637
			450	620	635		$ 0	928,704	$ 11,494,148	0.257	0.00	923,241	5,011	20	4,363
50			450	620	635		$ 400,000	947,125	$ 12,122,145	0.271	0.01	923,241	5,011	20	4,363
		660	450	620	635		$ 8,068,000	365,979	$ 12,597,560	0.282	0.73	308,061	5,651	0	113
	1	660	450	620	635		$ 8,568,000	340,301	$ 12,779,757	0.286	0.78	264,189	5,374	0	54
50		660	450	620	635		$ 8,468,000	384,401	$ 13,225,557	0.296	0.73	308,061	5,651	0	113
50	1	660	450	620	635		$ 8,968,000	358,723	$ 13,407,754	0.300	0.78	264,189	5,374	0	54

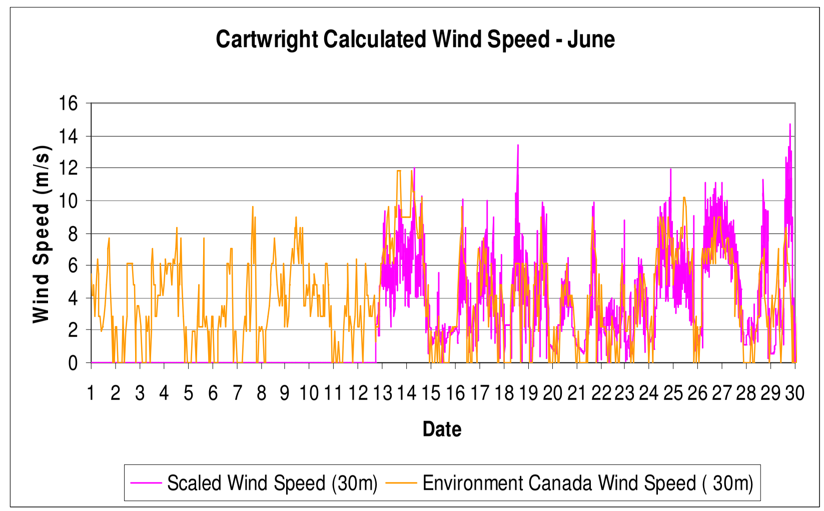
Makkovik HOMER Results – 2015 System Load

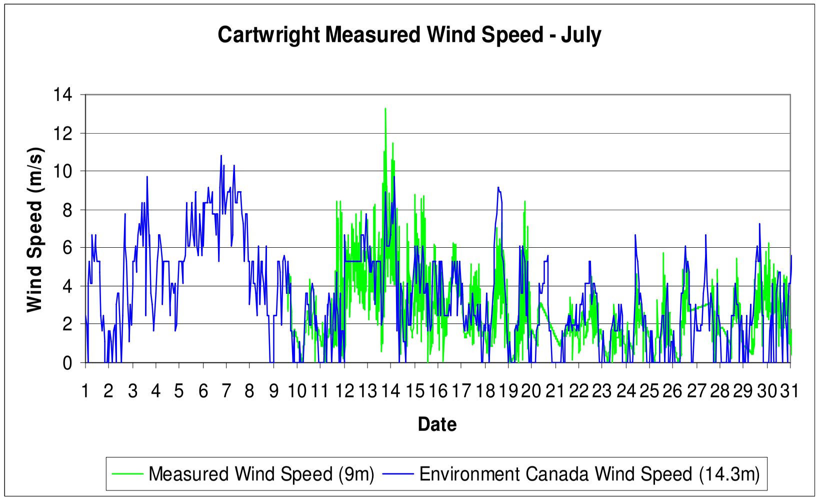
APPENDIX D - CARTWRIGHT

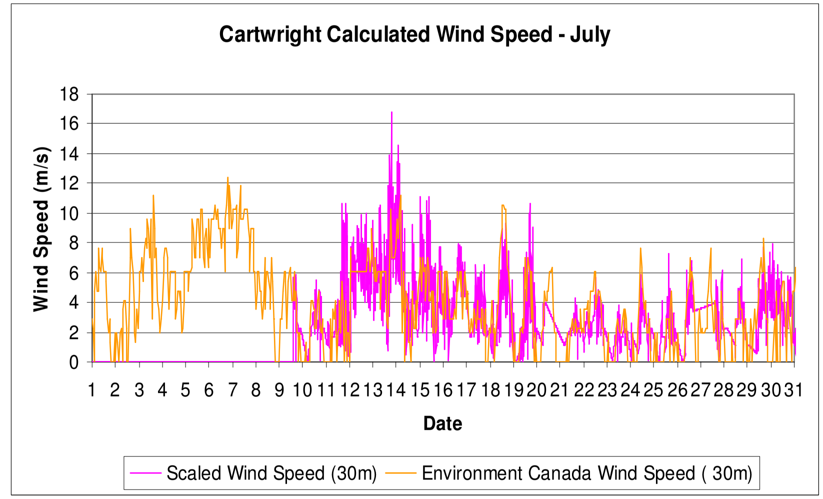

Cartwright Measured Wind Speed - May
Wind Speed (mph)
0 2 4 6 8 10 12 14 16 18 20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (9m)
Environment Canada Wind Speed (14.3m)

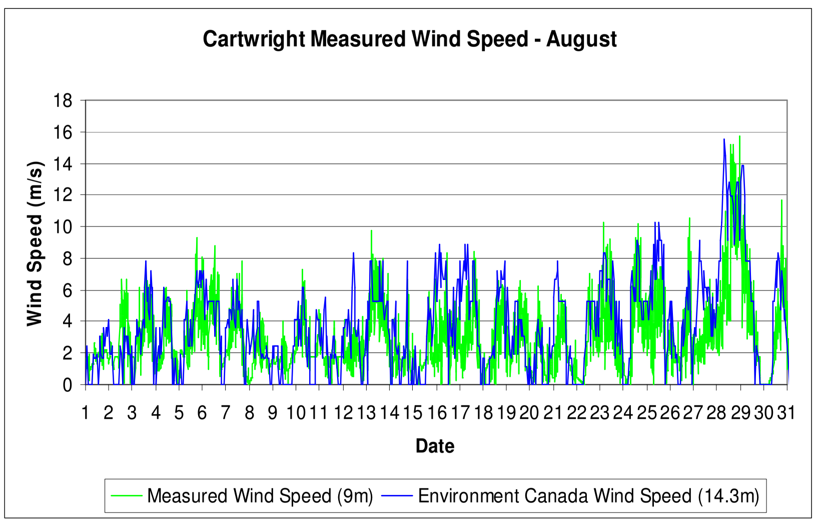

Cartwright Calculated Wind Speed - May
Wind Speed (mph)
0 5 10 15 20 25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

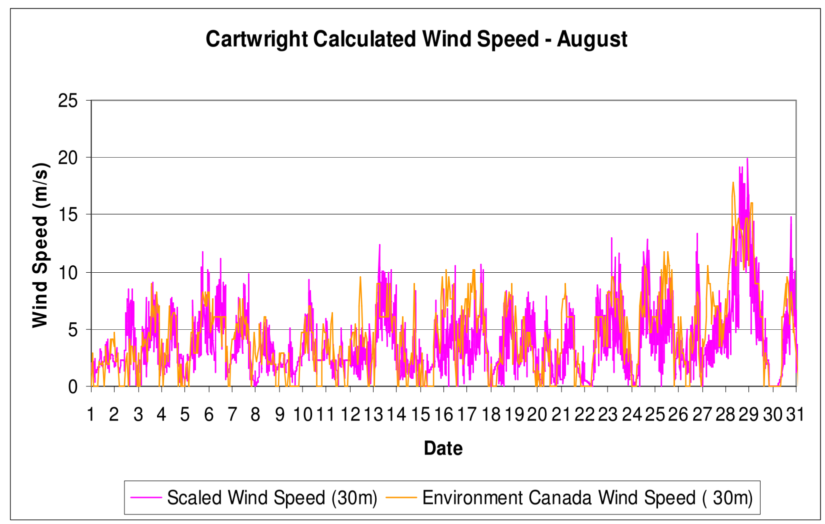

Cartwright Measured Wind Speed - June
Wind Speed (m/s)
0 2 4 6 8 10 12 14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (9m)
Environment Canada Wind Speed (14.3m)

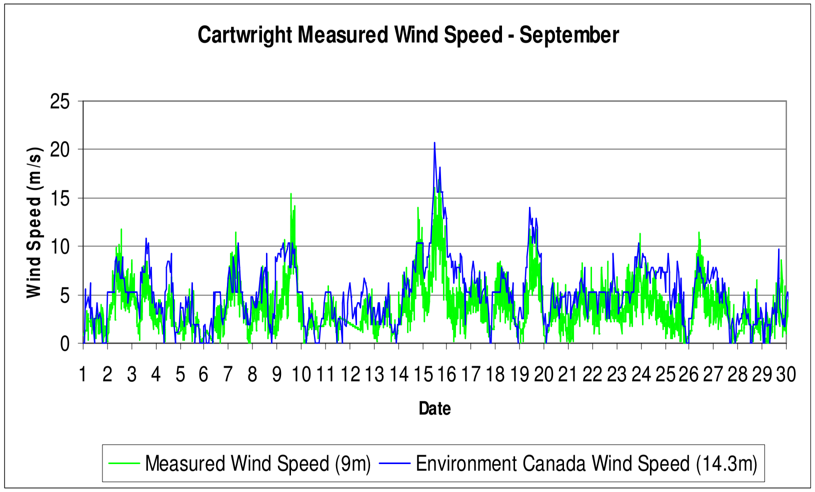

Cartwright Calculated Wind Speed - June
Wind Speed (m/s)
0 2 4 6 8 10 12 14 16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

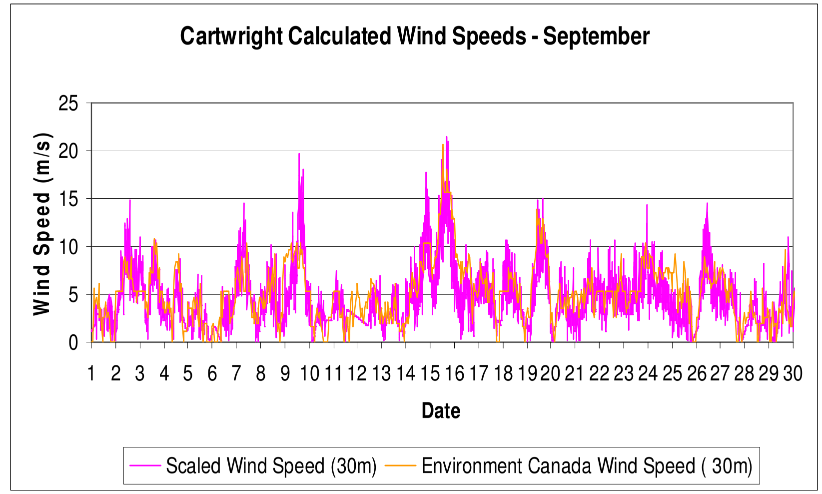

Cartwright Measured Wind Speed - July
Wind Speed (m/s)
Date
Measured Wind Speed (9m)
Environment Canada Wind Speed (14.3m)

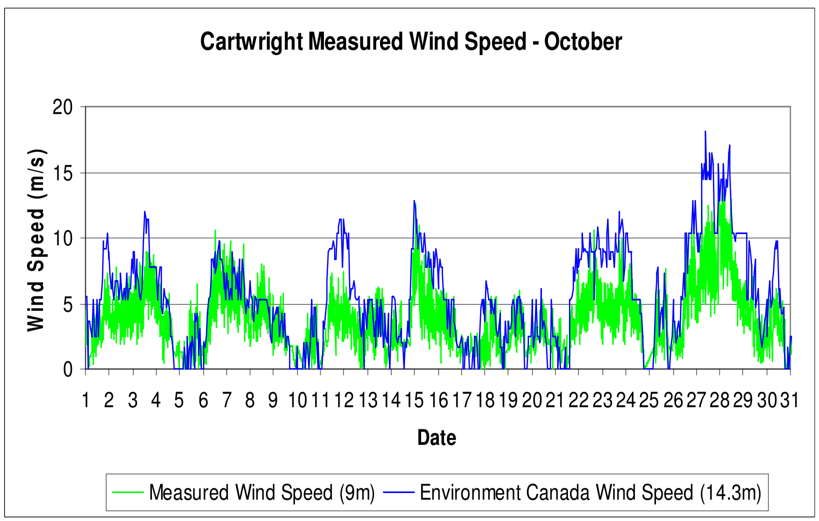

Cartwright Calculated Wind Speed - July
Wind Speed (m/s)
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

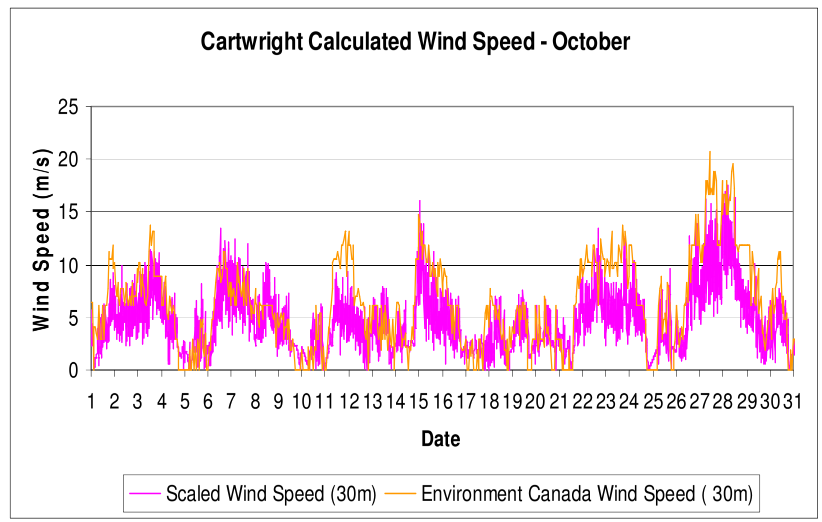

Cartwright Measured Wind Speed - August
Wind Speed (m/s)
Date
Measured Wind Speed (9m)
Environment Canada Wind Speed (14.3m)

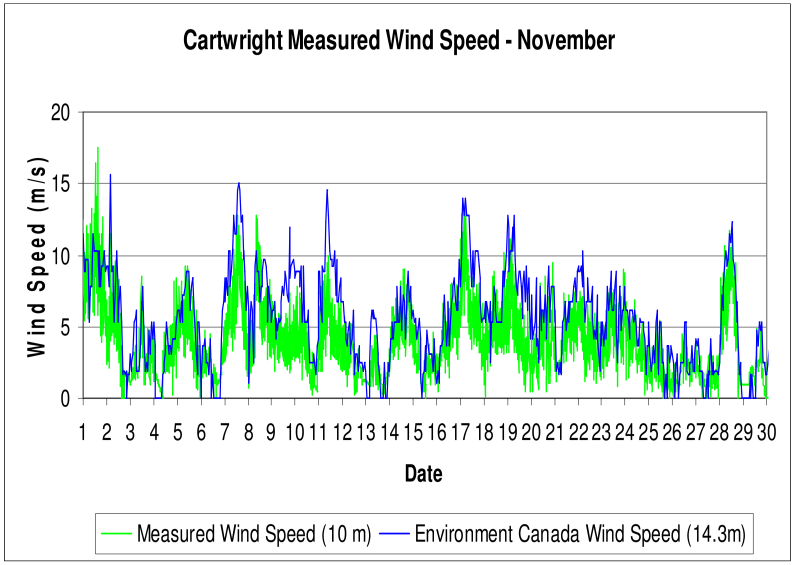

Cartwright Calculated Wind Speed - August
Wind Speed (m/s)
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

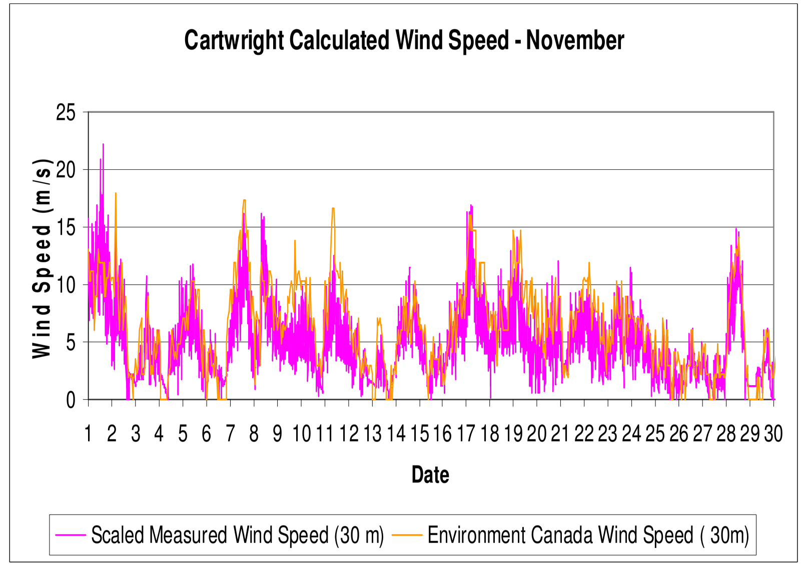

Cartwright Measured Wind Speed - September
Wind Speed (m/s)
Date
Measured Wind Speed (9m)
Environment Canada Wind Speed (14.3m)

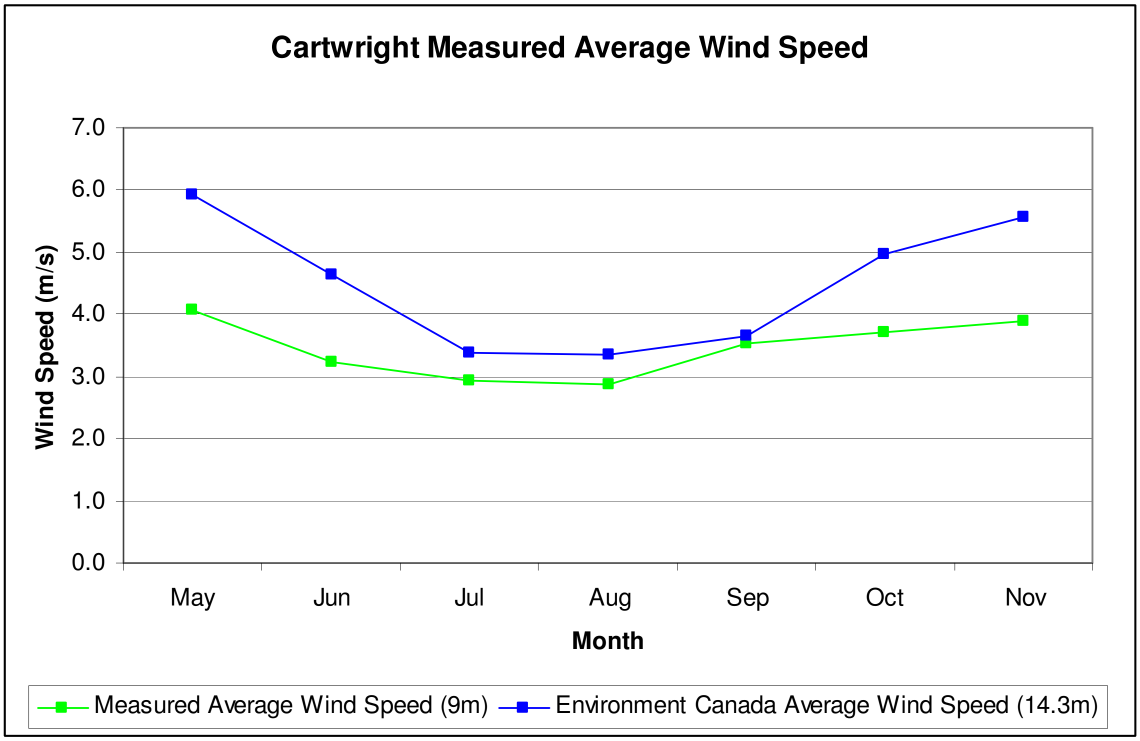

Cartwright Calculated Wind Speeds - September
Wind Speed (m/s)
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

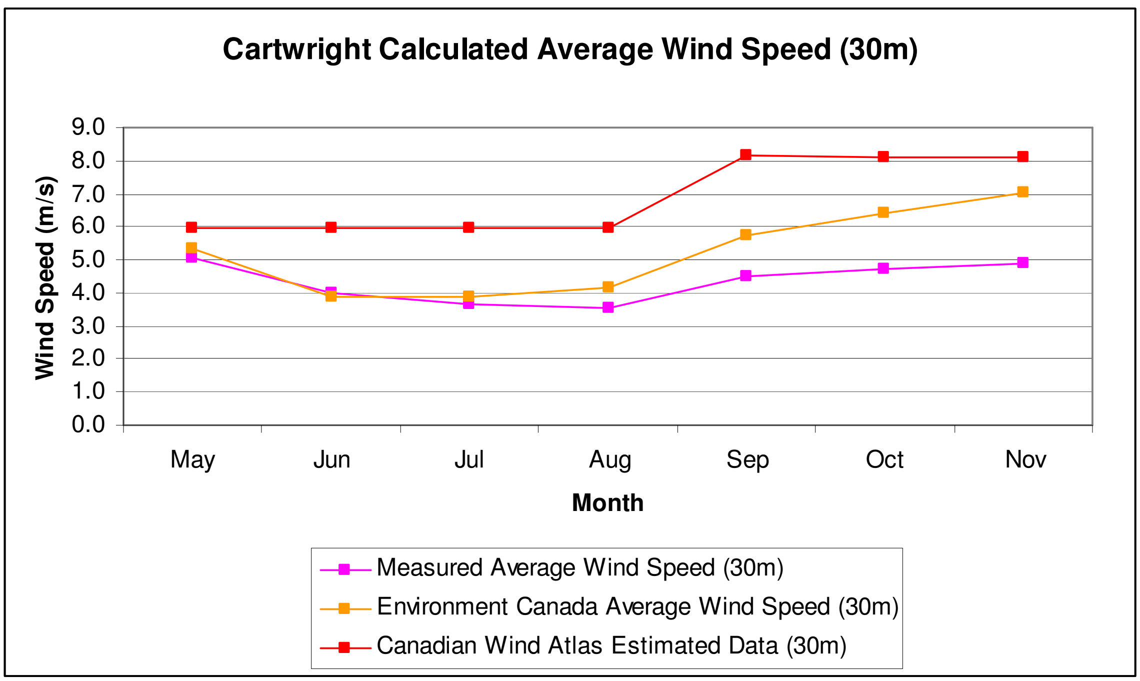

Cartwright Measured Wind Speed - October
Wind Speed (m/s)
Date
Measured Wind Speed (9m)
Environment Canada Wind Speed (14.3m)

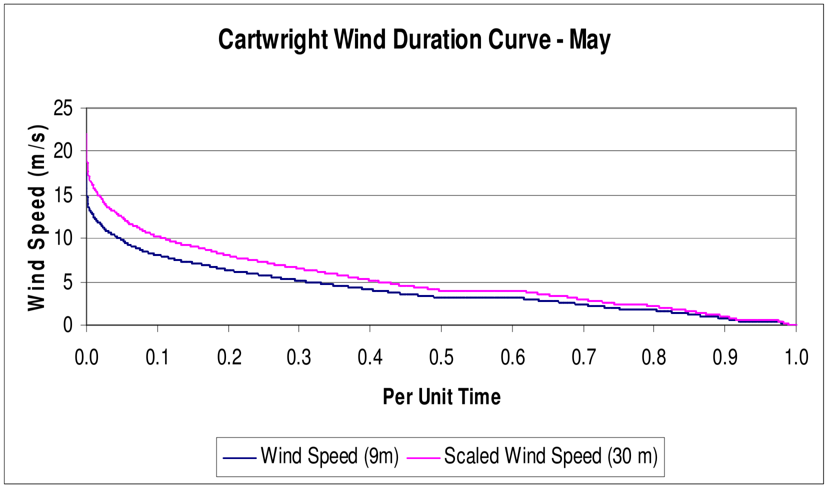

Cartwright Calculated Wind Speed - October
Wind Speed (m/s)
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)

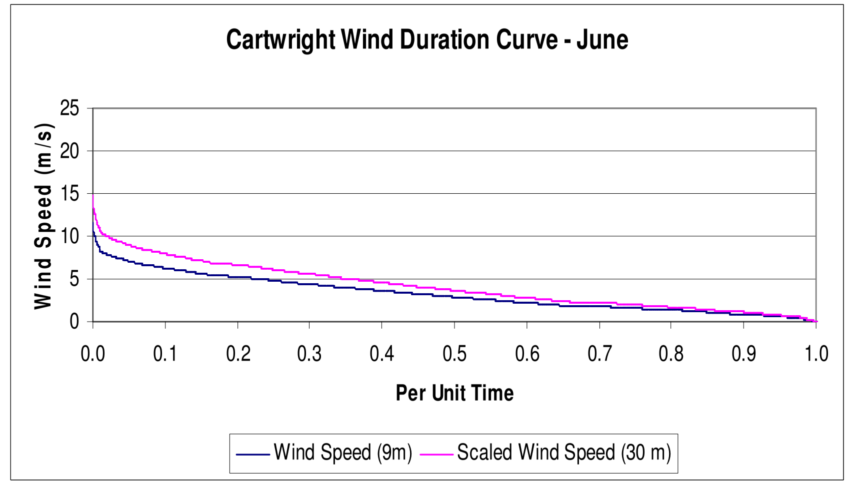

Cartwright Measured Wind Speed - November
Wind Speed (m/s)
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (10 m)
Environment Canada Wind Speed (14.3m)

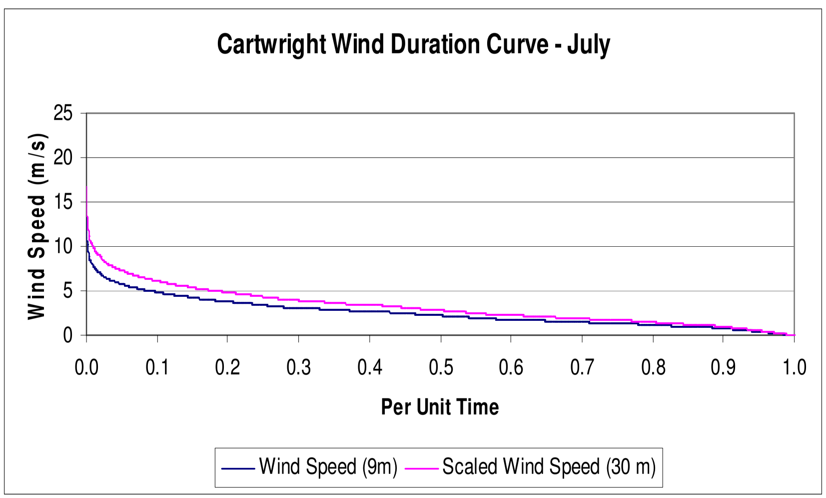

Cartwright Calculated Wind Speed - November
Wind Speed (m/s)
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Measured Wind Speed (30 m)
Environment Canada Wind Speed (30m)

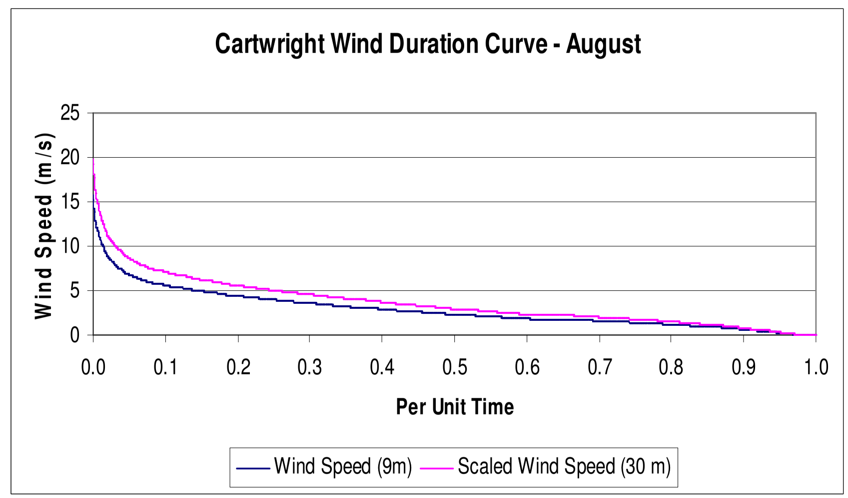

Cartwright Measured Average Wind Speed
Wind Speed (m/s)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
Month
Measured Average Wind Speed (9m)
Environment Canada Average Wind Speed (14.3m)

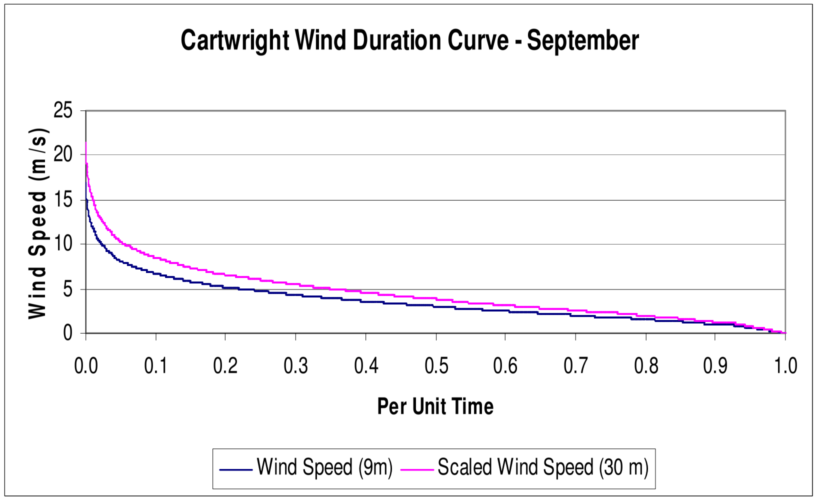

Cartwright Calculated Average Wind Speed (30m)
Wind Speed (m/s)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
Month
Measured Average Wind Speed (30m)
Environment Canada Average Wind Speed (30m)
Canadian Wind Atlas Estimated Data (30m)


Cartwright Wind Duration Curve - May
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (9m)
Scaled Wind Speed (30 m)

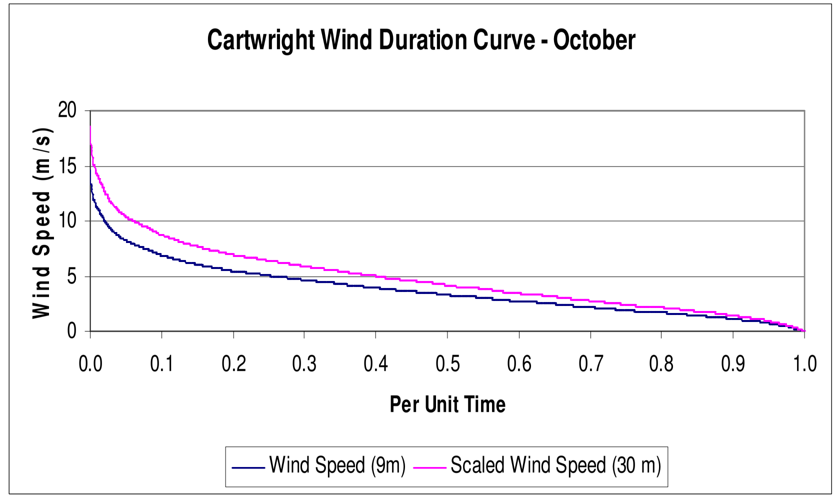

Cartwright Wind Duration Curve - June
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (9m)
Scaled Wind Speed (30 m)


Cartwright Wind Duration Curve - July
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (9m)
Scaled Wind Speed (30 m)

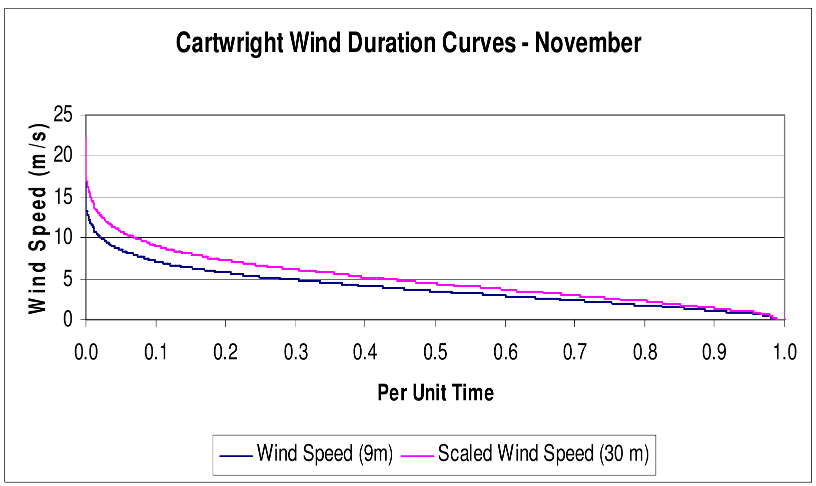

Cartwright Wind Duration Curve - August
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (9m)
Scaled Wind Speed (30 m)



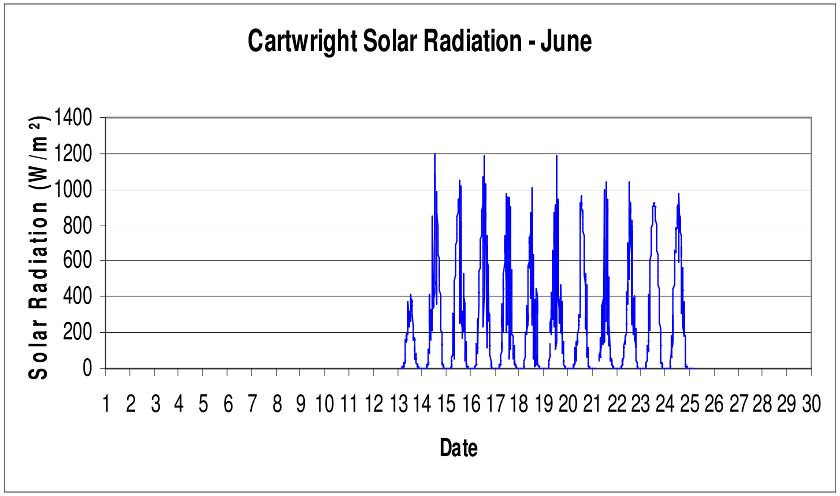
Cartwright Wind Duration Curve - September
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (9m)
Scaled Wind Speed (30 m)



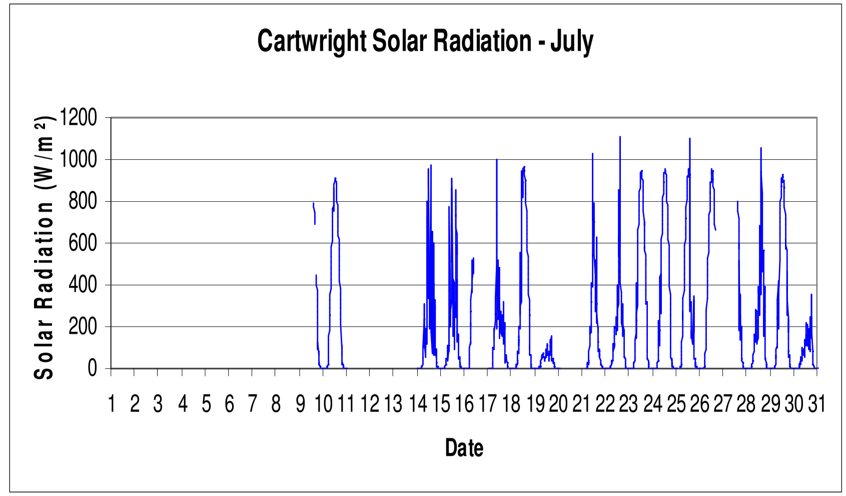
Cartwright Wind Duration Curve - October
Wind Speed (m/s)
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (9m)
Scaled Wind Speed (30 m)



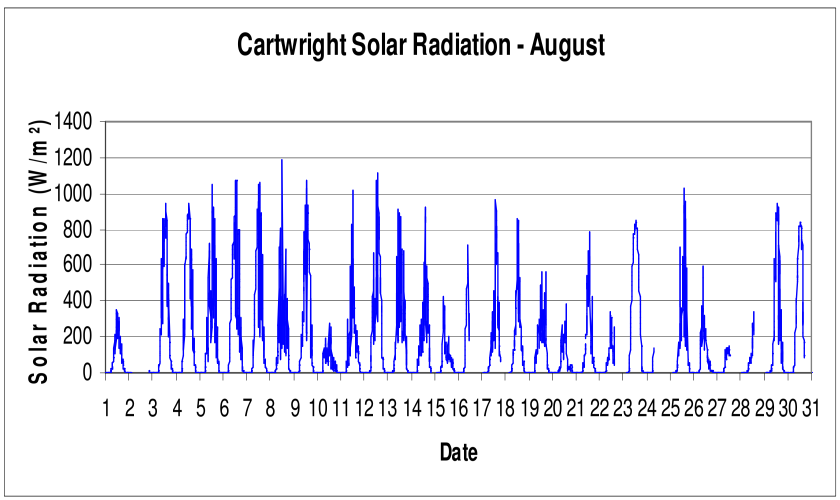
Cartwright Wind Duration Curves - November
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (9m)
Scaled Wind Speed (30 m)



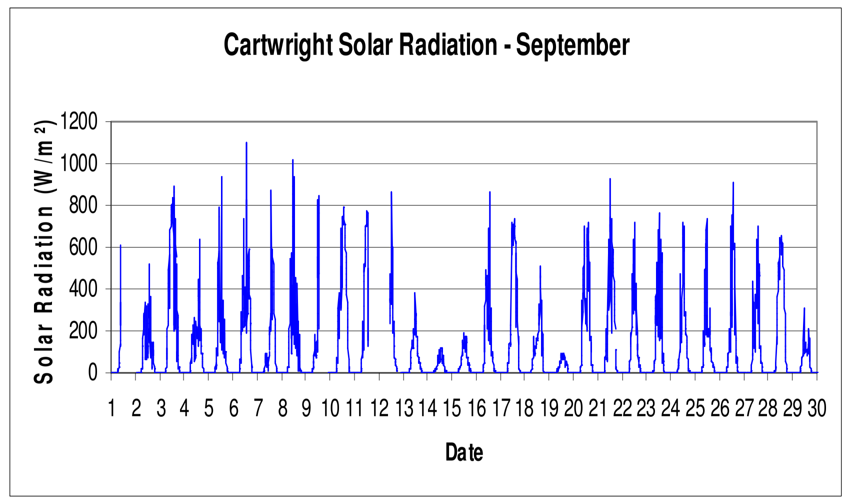
Cartwright Solar Radiation - June
Solar Radiation (W/m 2)
0
200
400
600
800
1000
1200
1400
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date



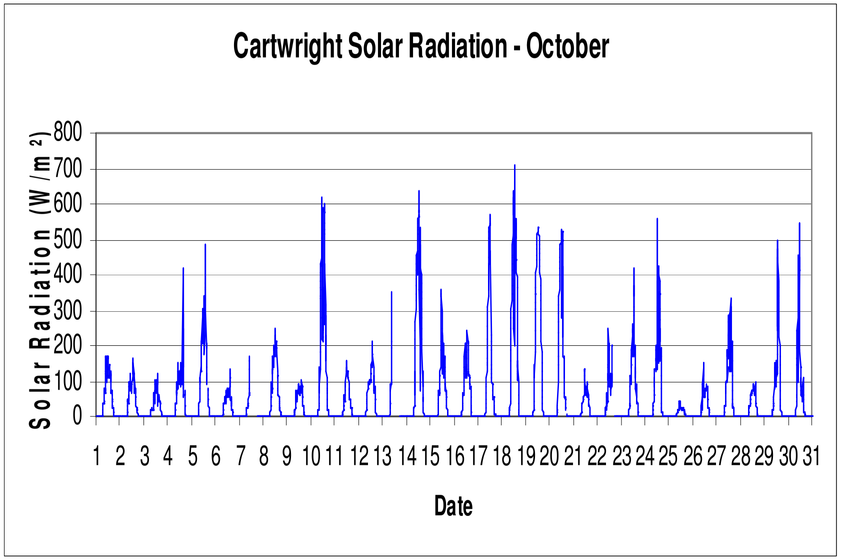
Cartwright Solar Radiation - July
Solar Radiation (W/m 2)
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date

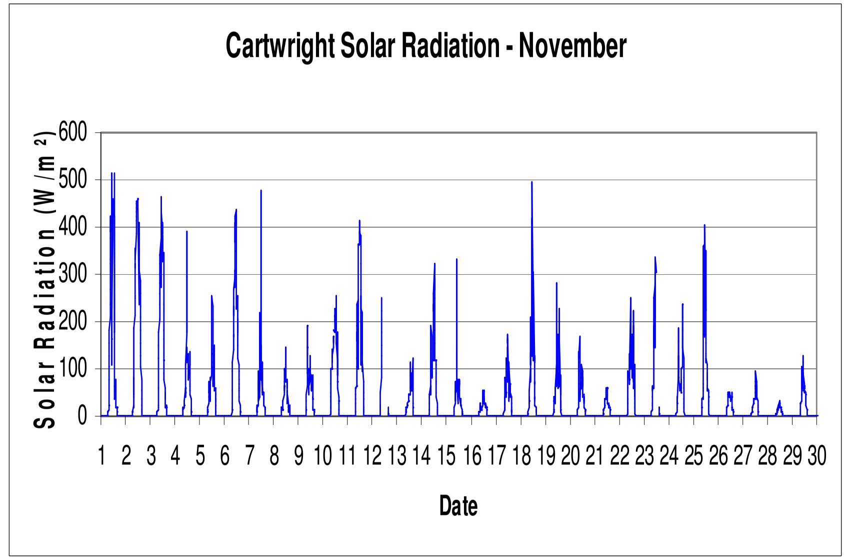


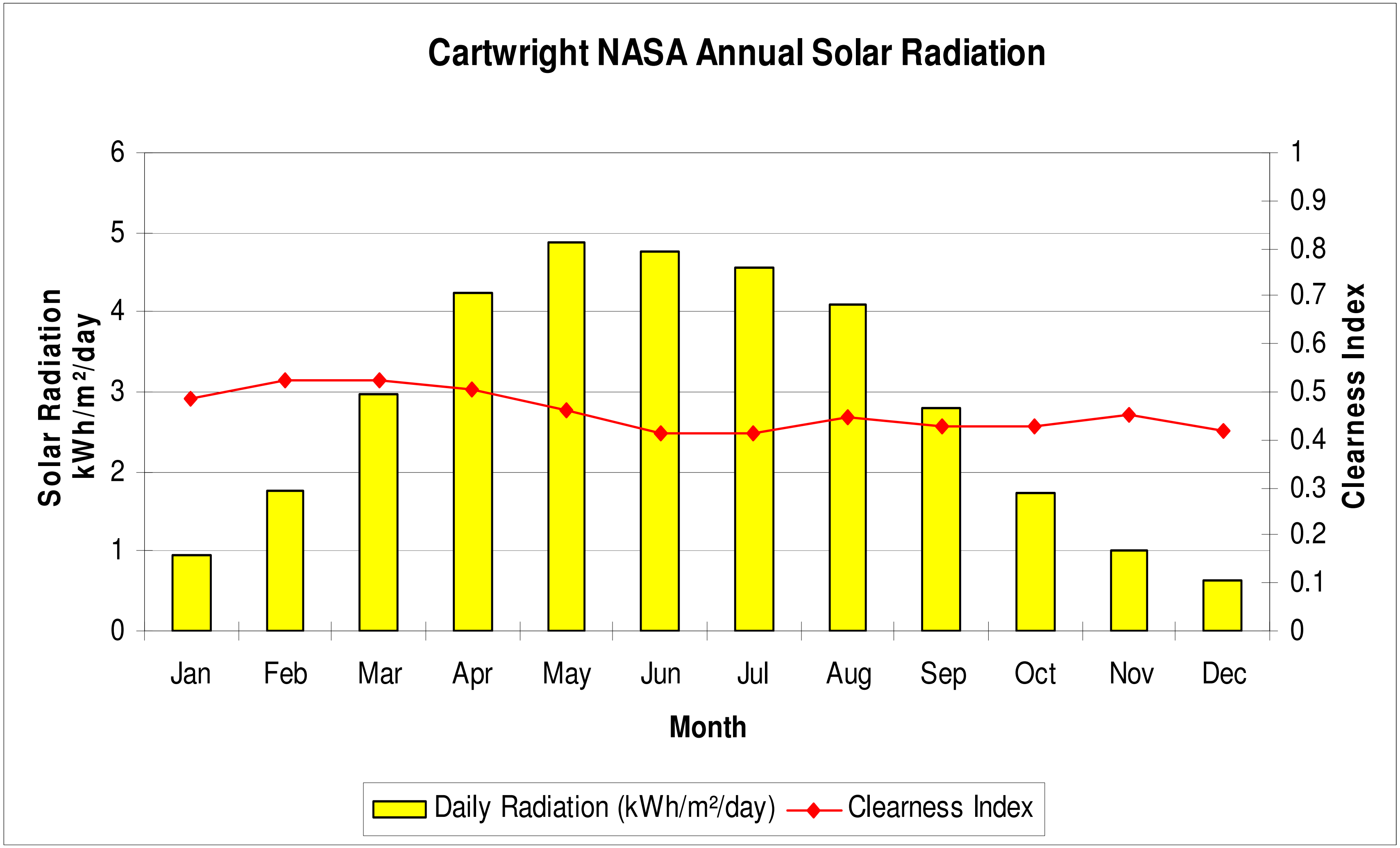
Cartwright Solar Radiation - August
Solar Radiation (W/m 2)
0
200
400
600
800
1000
1200
1400
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date

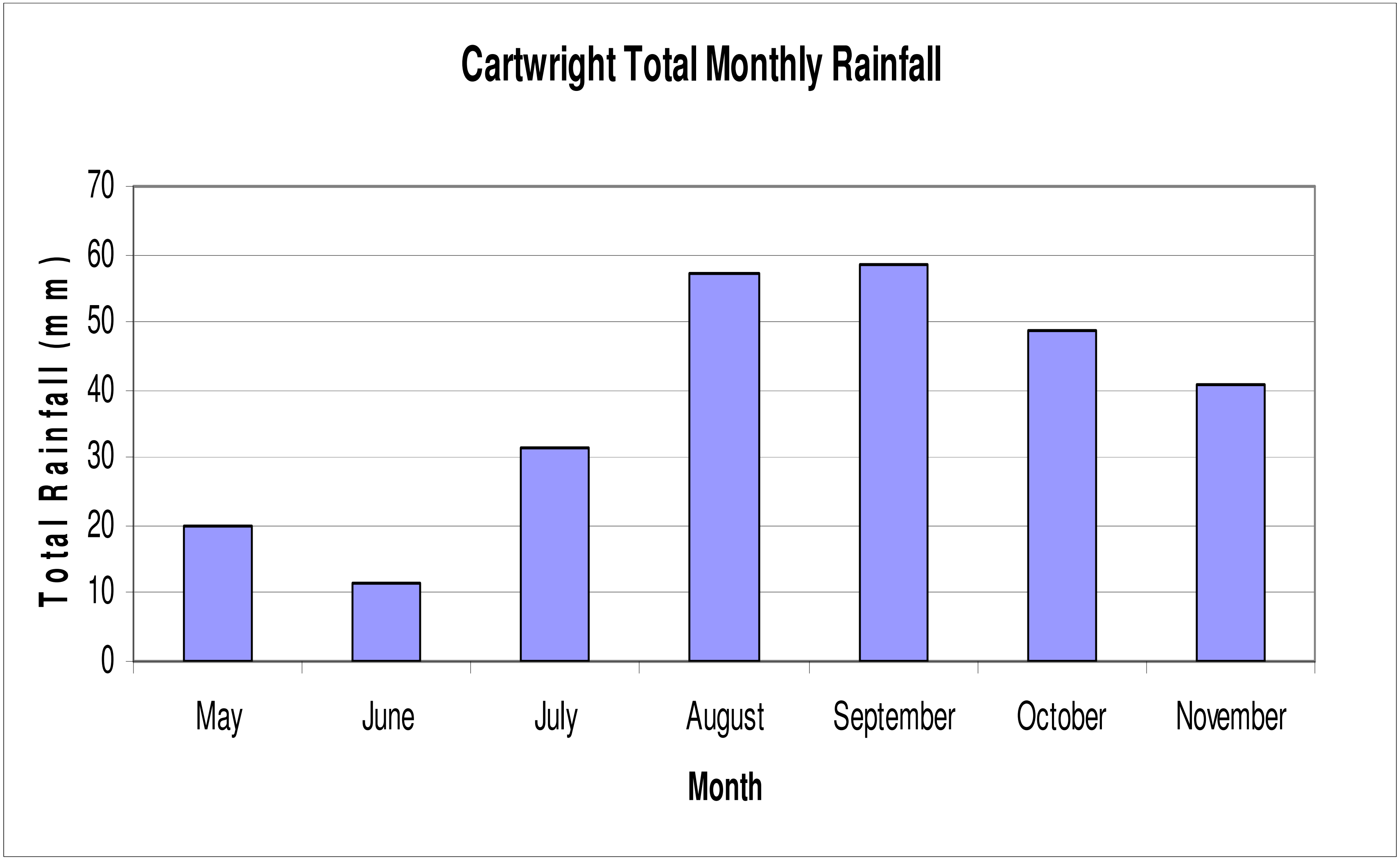


Cartwright Solar Radiation - September
Solar Radiation (W/m 2)
0
200
400
600
800
1000
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Cartwright Solar Radiation - October
Solar Radiation (W/m 2)
800
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Cartwright Solar Radiation - November
Solar Radiation (W/m 2)
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Cartwright NASA Annual Solar Radiation
Solar Radiation kWh/m²/day
6
5
4
3
2
1
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Clearness Index
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Daily Radiation (kWh/m²/day)
Clearness Index



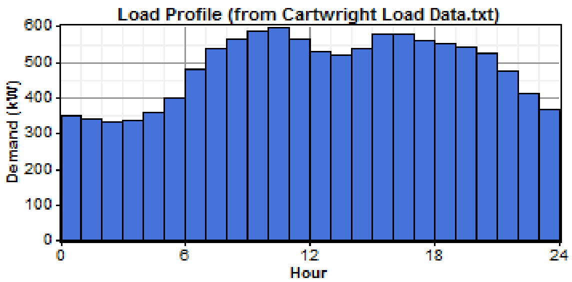
Cartwright Total Monthly Rainfall
Total Rainfall (mm)
0
10
20
30
40
50
60
70
May
June
July
August
September
October
November
Month

HOMER Input Summary

File name: Cartwright.hmr
File version: 2.67 beta
Author:

AC Load: Cartwright Net System Load

Data source:	Cartwright Load Data.txt
Daily noise:	8.89%
Hourly noise:	7.19%
Scaled annual average:	11,800, 11,995, 12,216, 12,414, 12,636 kWh/d
Scaled peak load:	978, 994, 1,013, 1,029, 1,048 kW
Load factor:	0.503



PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
50.000	400,000	400,000	10,000
100.000	750,000	750,000	15,000

Sizes to consider:	0, 50, 100 kW
Lifetime:	20 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	53.7 deg
Azimuth:	0 deg
Ground reflectance:	20%

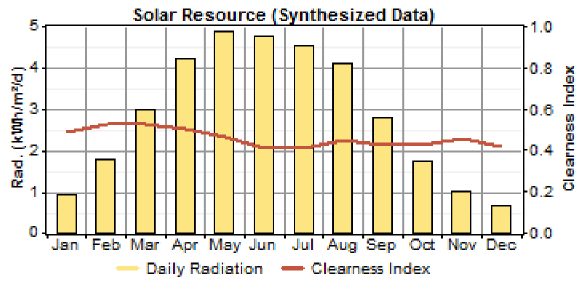
Solar Resource

Latitude: 53 degrees 42 minutes North
Longitude: 57 degrees 0 minutes West
Time zone: GMT -4:00

Data source: Synthetic

Month	Clearness Index	Average Radiation
		(kWh/m^2/day)
Jan	0.487	0.940
Feb	0.525	1.770
Mar	0.523	2.980
Apr	0.505	4.230
May	0.463	4.870
Jun	0.414	4.760
Jul	0.414	4.550
Aug	0.448	4.100
Sep	0.426	2.810
Oct	0.428	1.730
Nov	0.454	1.020
Dec	0.416	0.640

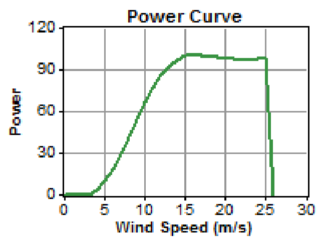
Scaled annual average: 2.86 kWh/m²/d



AC Wind Turbine: Northern Power NW100/21

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	500,000	400,000	10,000

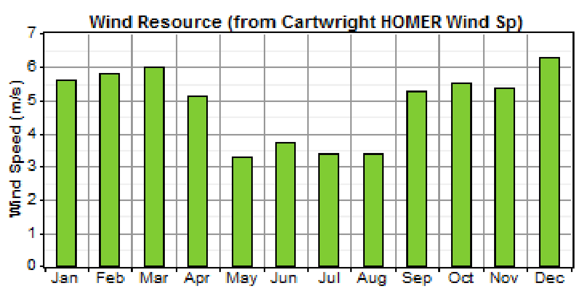
Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Lifetime: 20 yr
Hub height: 37 m



Wind Resource

Data source: Cartwright HOMER Wind Speed Data.txt

Month	Wind Speed (m/s)
Jan	5.61
Feb	5.78
Mar	5.99
Apr	5.13
May	3.30
Jun	3.69
Jul	3.40
Aug	3.36
Sep	5.25
Oct	5.48
Nov	5.35
Dec	6.28



Weibull k: 1.45
Autocorrelation factor: 0.868
Diurnal pattern strength: 0.115
Hour of peak wind speed: 13
Scaled annual average: 4.88 m/s
Anemometer height: 9 m
Altitude: 9 m

Wind shear profile: Logarithmic
Surface roughness length: 0.1 m

AC Hydro:

Capital cost:	$ 20,695,000, 2,200,000
Replacement cost:	$ 0
O&M cost:	$ 263,080, 4,990/yr
Lifetime:	60 yr
Available head:	9.1, 50.0 m
Design flow rate:	26,260, 160 L/s
Min. flow ratio:	15, 10%
Max. flow ratio:	100%
Turbine efficiency:	85%
Pipe head loss:	0%

Consider systems without hydro: Yes

Hydro Resource

Data source: Synthetic

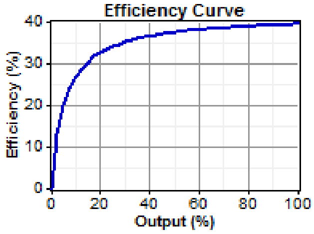
Month	Stream Flow
	(L/s)
Jan	765
Feb	494
Mar	482
Apr	882
May	1,765
Jun	1,706
Jul	1,765
Aug	1,765
Sep	1,706
Oct	1,765
Nov	1,706
Dec	1,294

Residual flow: 0 L/s
Scaled annual average: 1,346, 45 L/s

AC Generator: 567

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
600.000	0	400,000	1.684

Sizes to consider:	600 kW
Lifetime:	100,000 hrs
Min. load ratio:	30%
Heat recovery ratio:	0%
Fuel used:	#1 Diesel Arctic Grade
Fuel curve intercept:	0.0127 L/hr/kW
Fuel curve slope:	0.233 L/hr/kW

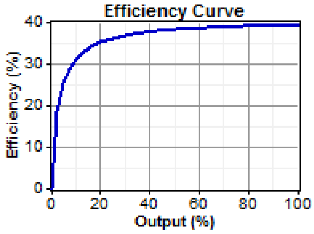


AC Generator: 2052

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)

800.000	0	600,000	2.489

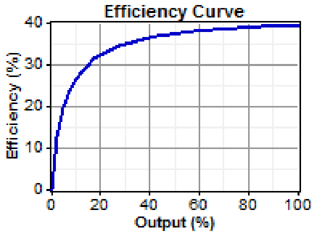
Sizes to consider: 800 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.00725 L/hr/kW
Fuel curve slope: 0.24 L/hr/kW



AC Generator: 2036

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
450.000	0	400,000	1.684

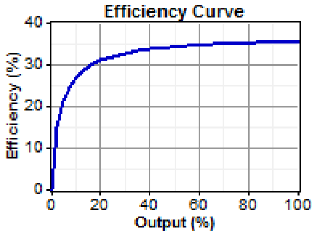
Sizes to consider: 450 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0133 L/hr/kW
Fuel curve slope: 0.233 L/hr/kW



AC Generator: 2045

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
520.000	0	400,000	1.684

Sizes to consider: 520 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.00964 L/hr/kW
Fuel curve slope: 0.264 L/hr/kW



Fuel: #1 Diesel Arctic Grade

Price: $ 0.945, 0.944, 0.963, 0.993, 0.993/L
Lower heating value: 45.8 MJ/kg
Density: 809 kg/m3

Carbon content:	88.0%
Sulfur content:	0.0500%

Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
100.000	64,000	64,000	6,400

Sizes to consider:	0, 100 kW
Lifetime:	15 yr
Inverter efficiency:	90%
Inverter can parallel with AC generator:	Yes
Rectifier relative capacity:	100%
Rectifier efficiency:	85%

Economics

Annual real interest rate:	8%
Project lifetime:	60 yr
Capacity shortage penalty:	$ 0/kWh
System fixed capital cost:	$ 0
System fixed O&M cost:	$ 0/yr

Generator control

Check load following:	Yes
Check cycle charging:	No

Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	No

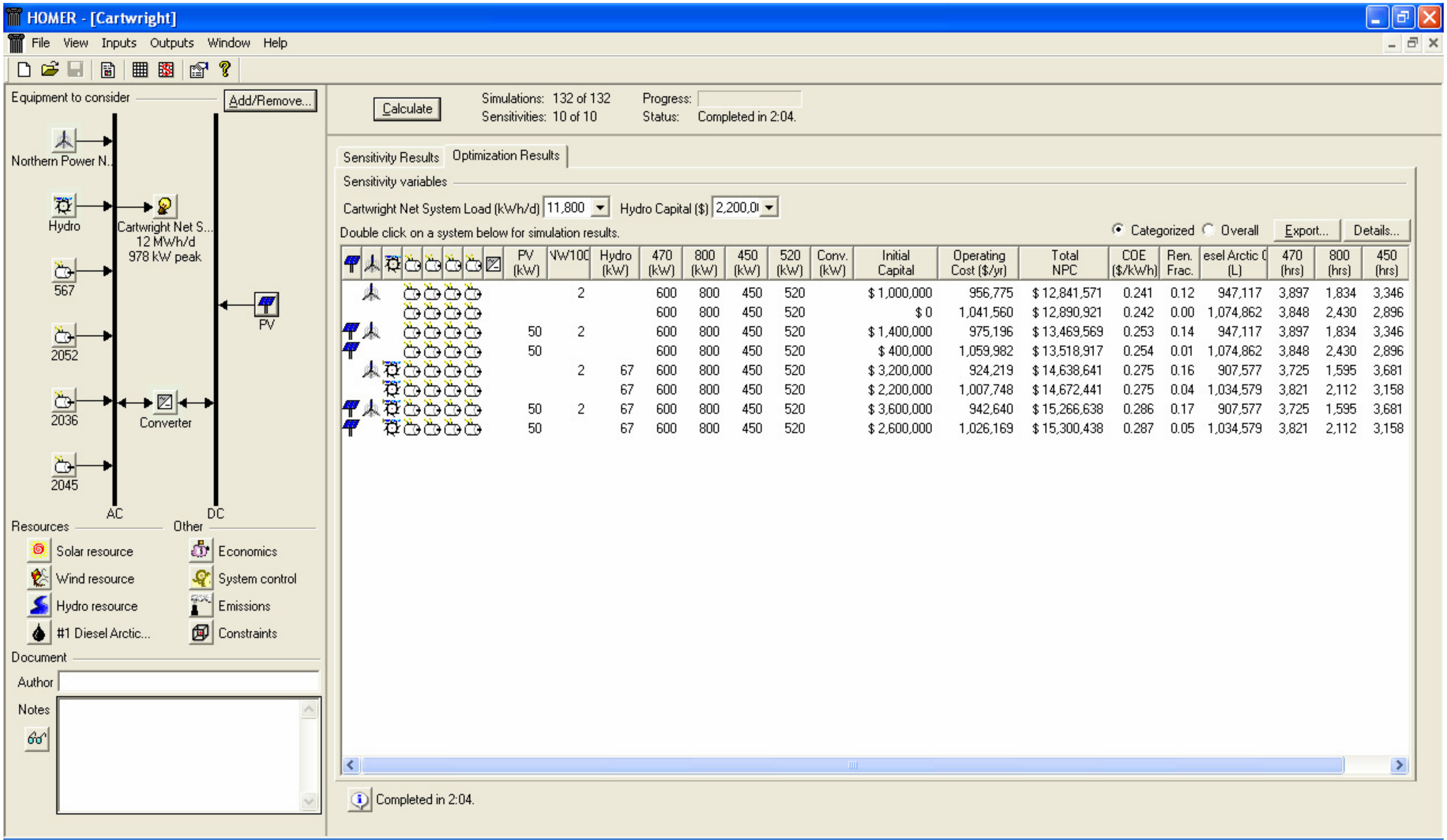
Emissions

Carbon dioxide penalty:	$ 0/t
Carbon monoxide penalty:	$ 0/t
Unburned hydrocarbons penalty:	$ 0/t
Particulate matter penalty:	$ 0/t
Sulfur dioxide penalty:	$ 0/t
Nitrogen oxides penalty:	$ 0/t

Constraints

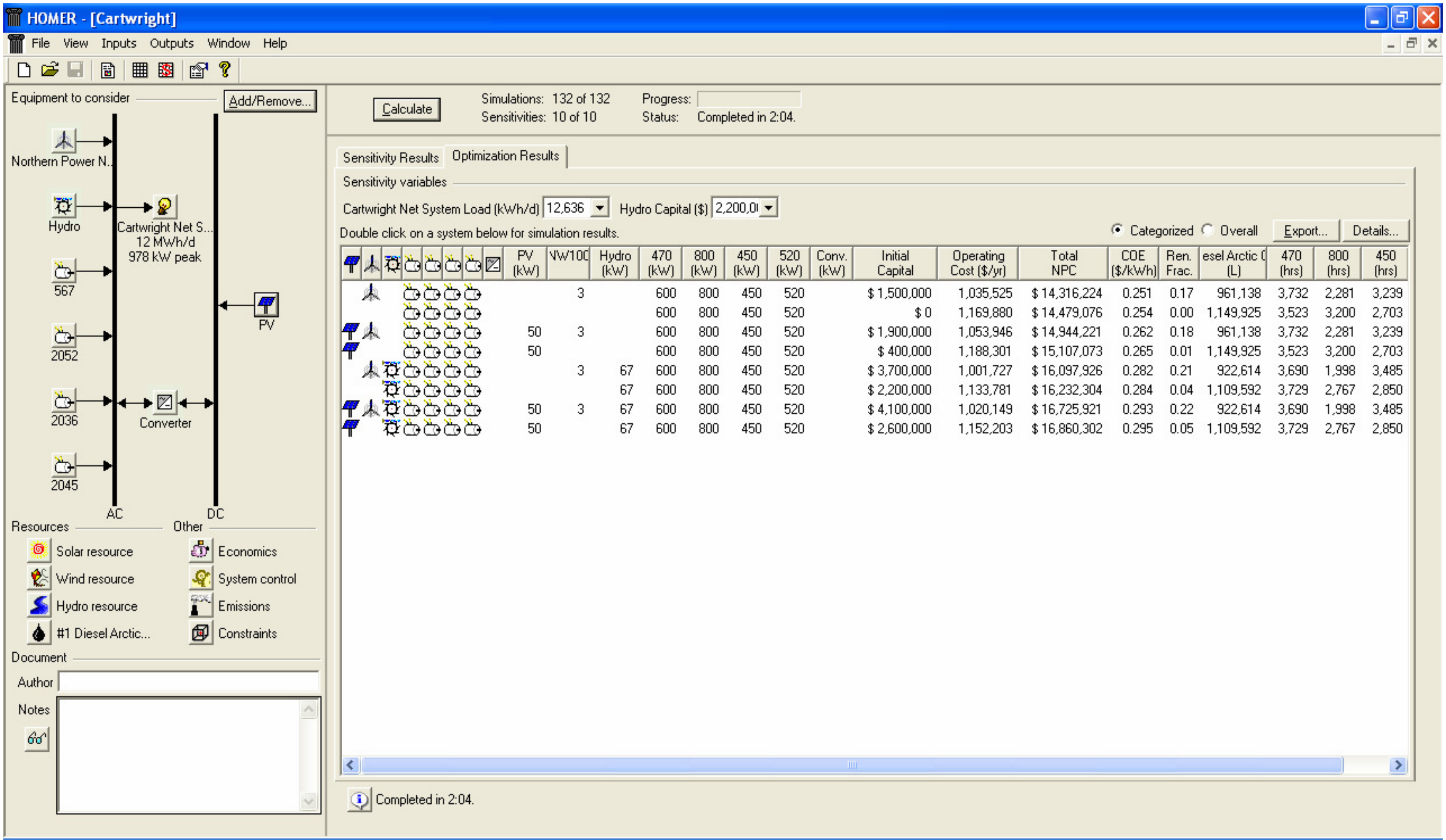
Maximum annual capacity shortage:	0%
Minimum renewable fraction:	0%

Operating reserve as percentage of hourly load:	10%
Operating reserve as percentage of peak load:	0%
Operating reserve as percentage of solar power output:	25%
Operating reserve as percentage of wind power output:	50%



PV (kW)	NW100	Hydro (kW)	470 (kW)	800 (kW)	450 (kW)	520 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic (L)	470 (hrs)	800 (hrs)	450 (hrs)
	2		600	800	450	520		$ 1,000,000	956,775	$ 12,841,571	0.241	0.12	947,117	3,897	1,834	3,346
			600	800	450	520		$ 0	1,041,560	$ 12,890,921	0.242	0.00	1,074,862	3,848	2,430	2,896
50	2		600	800	450	520		$ 1,400,000	975,196	$ 13,469,569	0.253	0.14	947,117	3,897	1,834	3,346
50			600	800	450	520		$ 400,000	1,059,982	$ 13,518,917	0.254	0.01	1,074,862	3,848	2,430	2,896
	2	67	600	800	450	520		$ 3,200,000	924,219	$ 14,638,641	0.275	0.16	907,577	3,725	1,595	3,681
		67	600	800	450	520		$ 2,200,000	1,007,748	$ 14,672,441	0.275	0.04	1,034,579	3,821	2,112	3,158
50	2	67	600	800	450	520		$ 3,600,000	942,640	$ 15,266,638	0.286	0.17	907,577	3,725	1,595	3,681
50		67	600	800	450	520		$ 2,600,000	1,026,169	$ 15,300,438	0.287	0.05	1,034,579	3,821	2,112	3,158

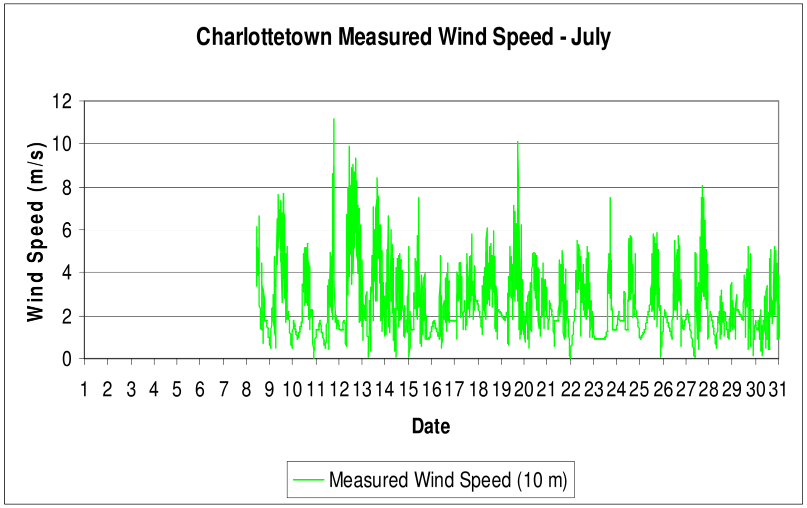
Cartwright HOMER Results – 2011 System Load

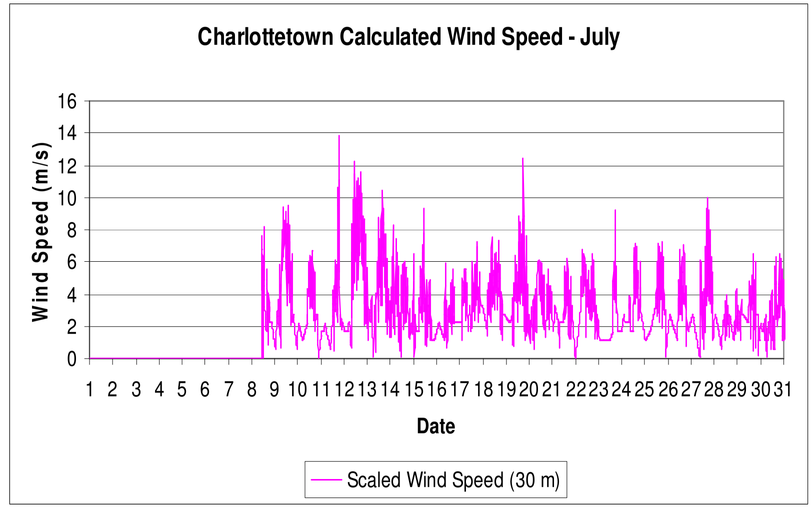


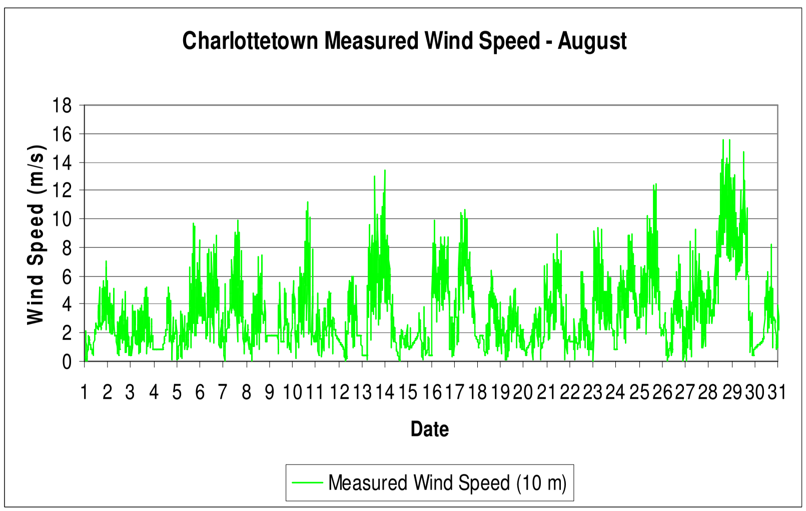
PV icon	Wind icon	Hydro icon	PV (kW)	NW100	Hydro (kW)	470 (kW)	800 (kW)	450 (kW)	520 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic (L)	470 (hrs)	800 (hrs)	450 (hrs)
	Yes			3		600	800	450	520		$ 1,500,000	1,035,525	$ 14,316,224	0.251	0.17	961,138	3,732	2,281	3,239
						600	800	450	520		$ 0	1,169,880	$ 14,479,076	0.254	0.00	1,149,925	3,523	3,200	2,703
Yes	Yes		50	3		600	800	450	520		$ 1,900,000	1,053,946	$ 14,944,221	0.262	0.18	961,138	3,732	2,281	3,239
Yes			50			600	800	450	520		$ 400,000	1,188,301	$ 15,107,073	0.265	0.01	1,149,925	3,523	3,200	2,703
	Yes	Yes		3	67	600	800	450	520		$ 3,700,000	1,001,727	$ 16,097,926	0.282	0.21	922,614	3,690	1,998	3,485
		Yes			67	600	800	450	520		$ 2,200,000	1,133,781	$ 16,232,304	0.284	0.04	1,109,592	3,729	2,767	2,850
Yes	Yes	Yes	50	3	67	600	800	450	520		$ 4,100,000	1,020,149	$ 16,725,921	0.293	0.22	922,614	3,690	1,998	3,485
Yes		Yes	50		67	600	800	450	520		$ 2,600,000	1,152,203	$ 16,860,302	0.295	0.05	1,109,592	3,729	2,767	2,850

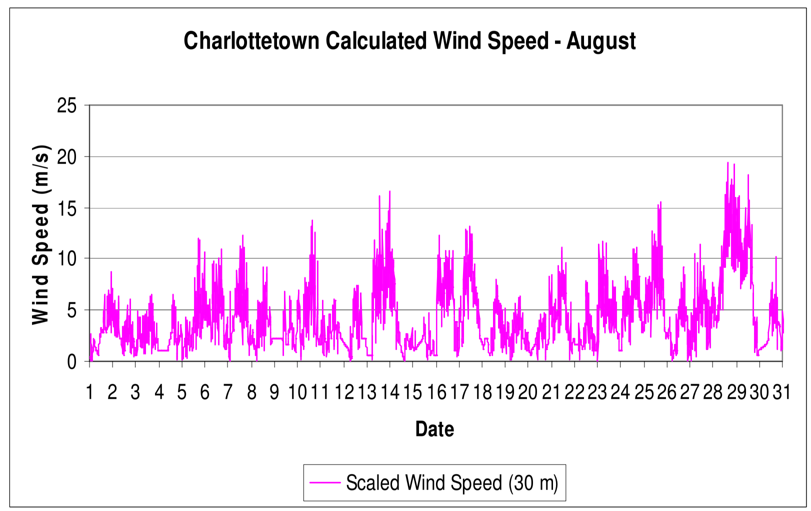
Cartwright HOMER Results – 2015 System Load

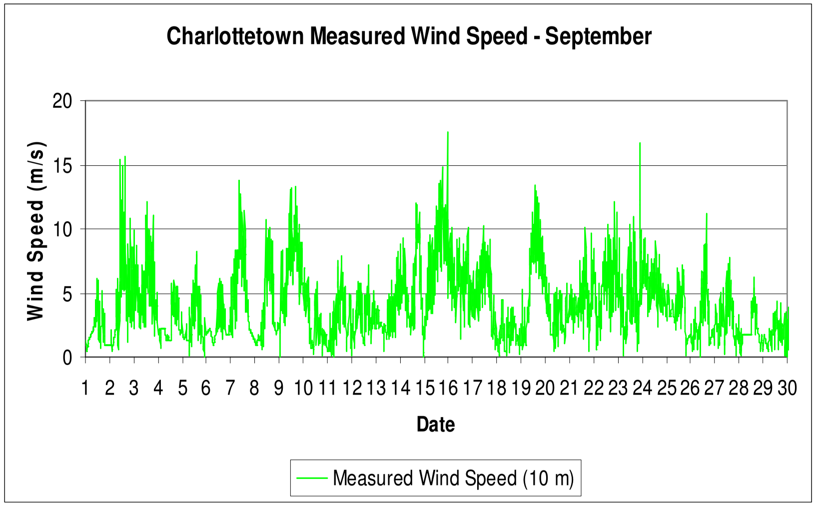
APPENDIX E - CHARLOTTETOWN

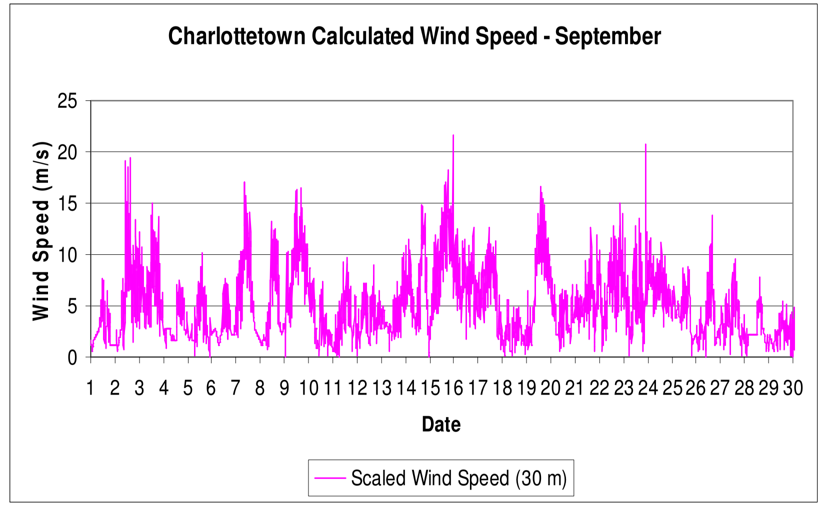

Charlottetown Measured Wind Speed - July
Wind Speed (m/s)
Date
Measured Wind Speed (10 m)

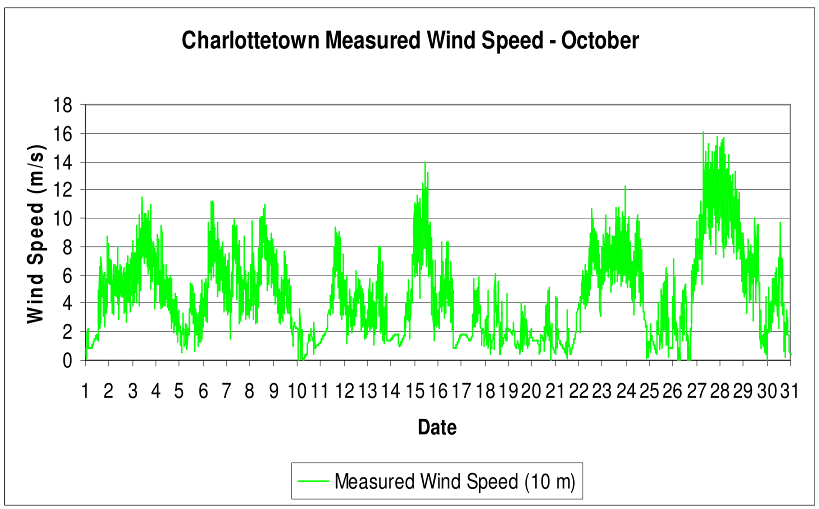

Charlottetown Calculated Wind Speed - July
Wind Speed (m/s)
Date
Scaled Wind Speed (30 m)

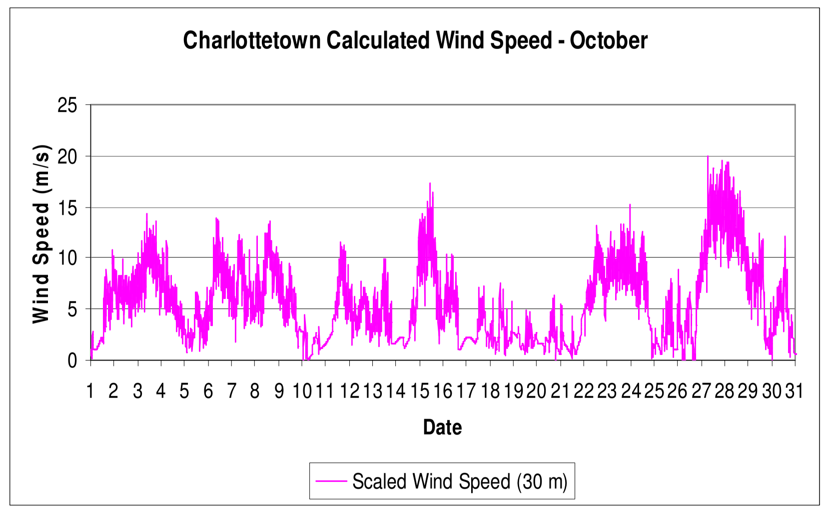

Charlottetown Measured Wind Speed - August
Wind Speed (m/s)
Date
Measured Wind Speed (10 m)

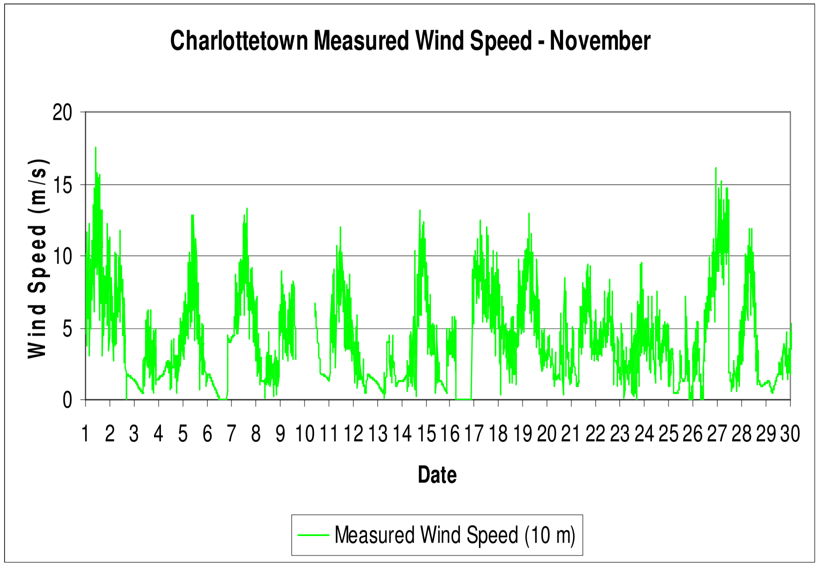

Charlottetown Calculated Wind Speed - August
Wind Speed (m/s)
Date
Scaled Wind Speed (30 m)

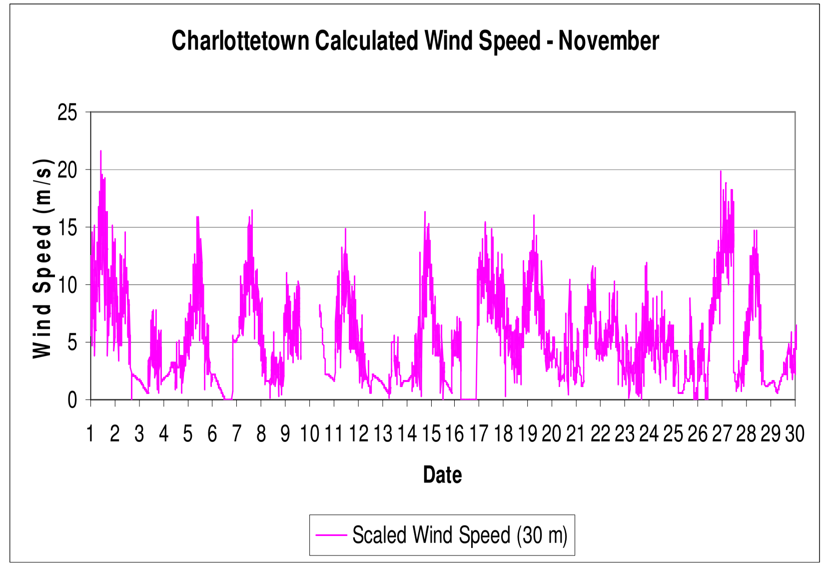

Charlottetown Measured Wind Speed - September
Wind Speed (m/s)
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (10 m)

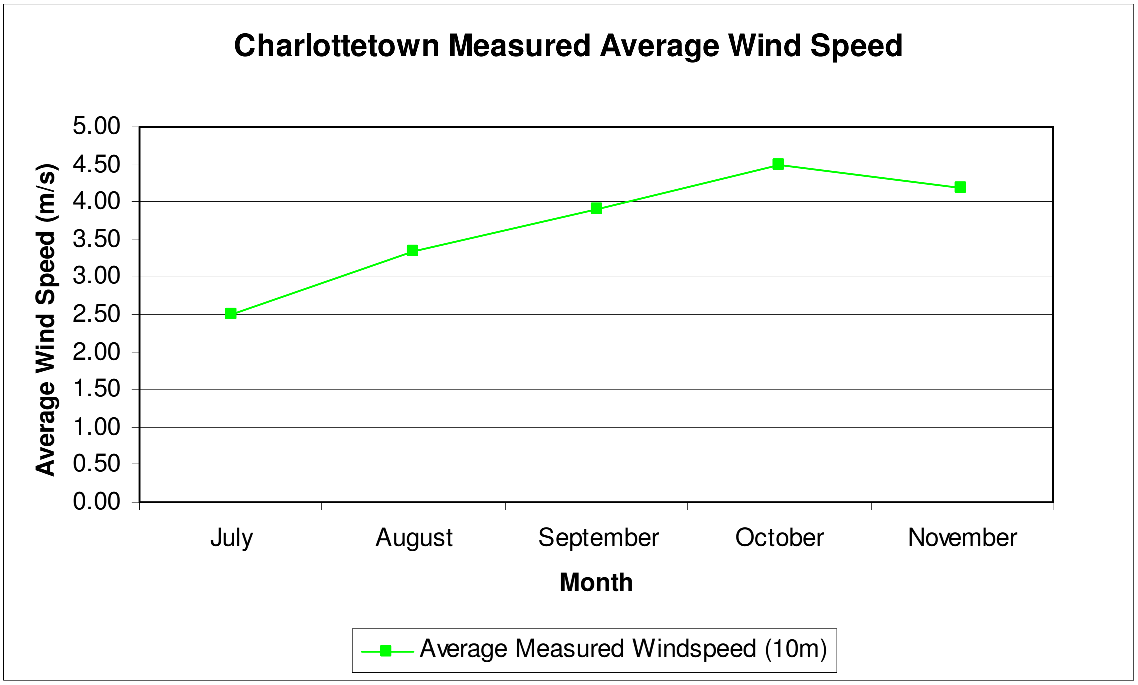

Charlottetown Calculated Wind Speed - September
Wind Speed (m/s)
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30 m)

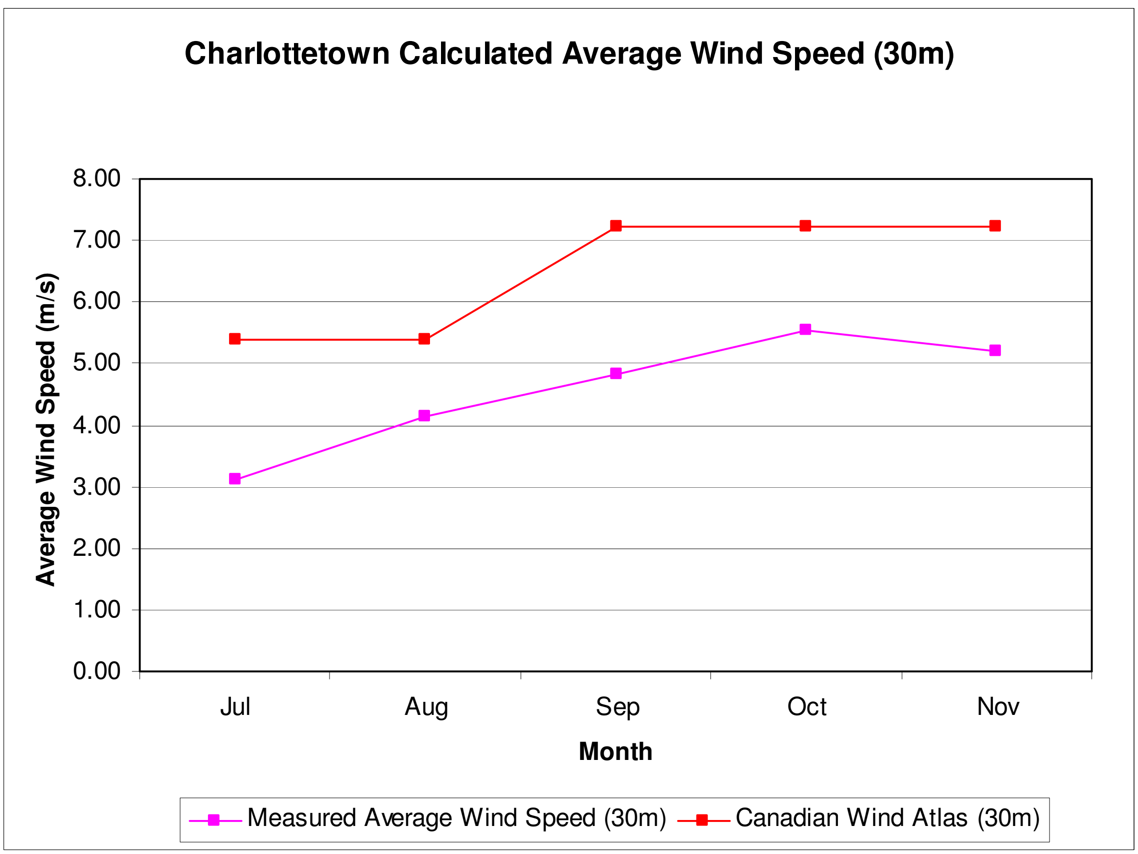

Charlottetown Measured Wind Speed - October
Wind Speed (m/s)
0
2
4
6
8
10
12
14
16
18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (10 m)

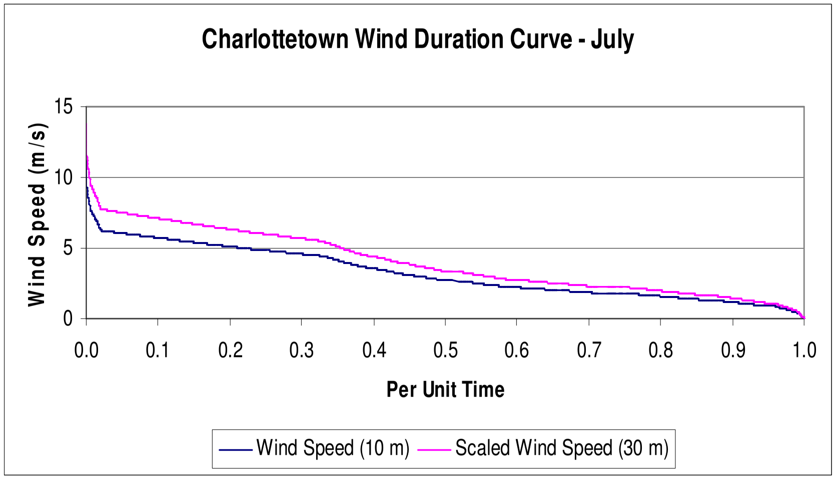

Charlottetown Calculated Wind Speed - October
Wind Speed (m/s)
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30 m)

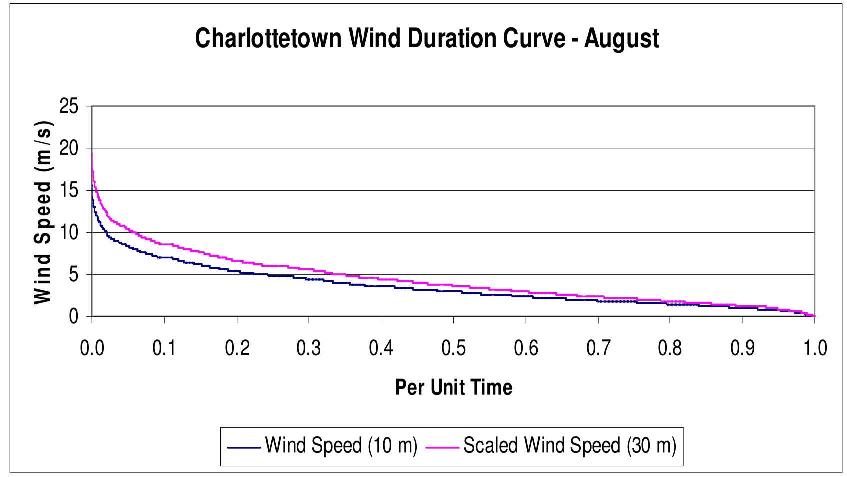

Charlottetown Measured Wind Speed - November
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (10 m)

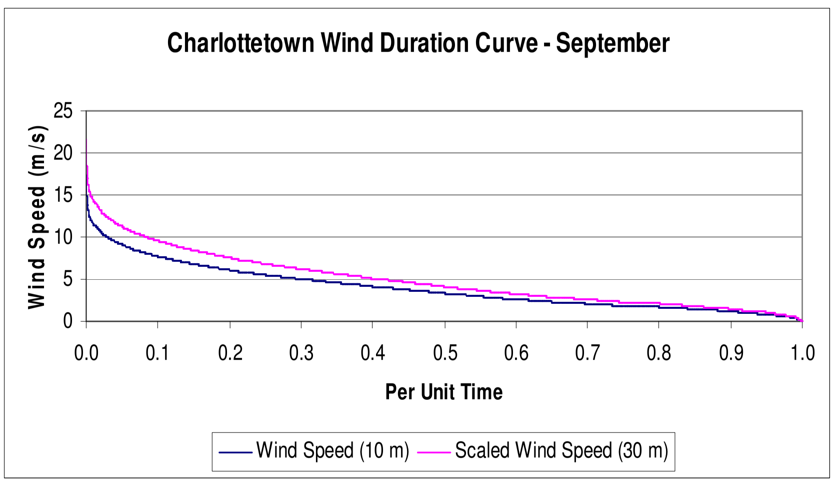

Charlottetown Calculated Wind Speed - November
Wind Speed (m/s)
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30 m)

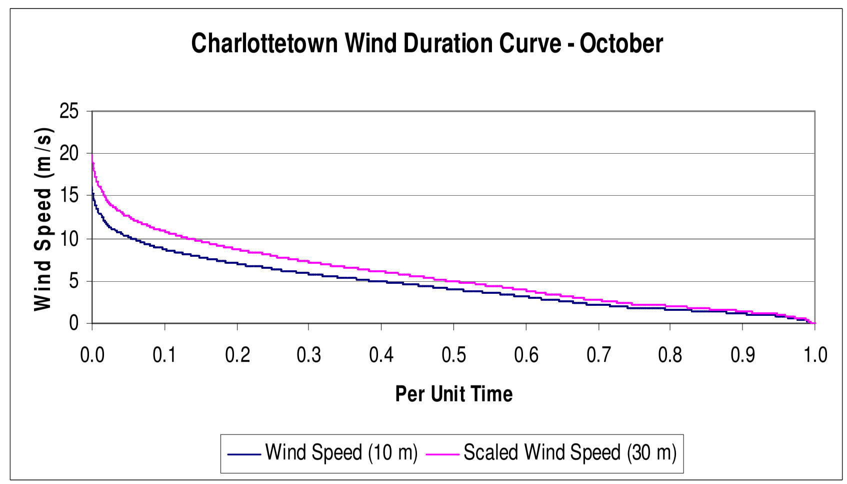

Charlottetown Measured Average Wind Speed
Average Wind Speed (m/s)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
July
August
September
October
November
Month
Average Measured Windspeed (10m)

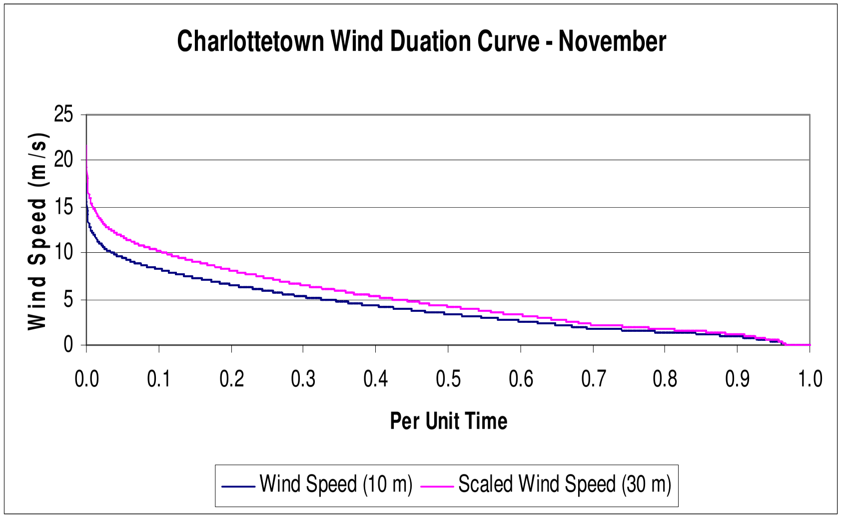

Charlottetown Calculated Average Wind Speed (30m)
Average Wind Speed (m/s)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Jul
Aug
Sep
Oct
Nov
Month
Measured Average Wind Speed (30m)
Canadian Wind Atlas (30m)

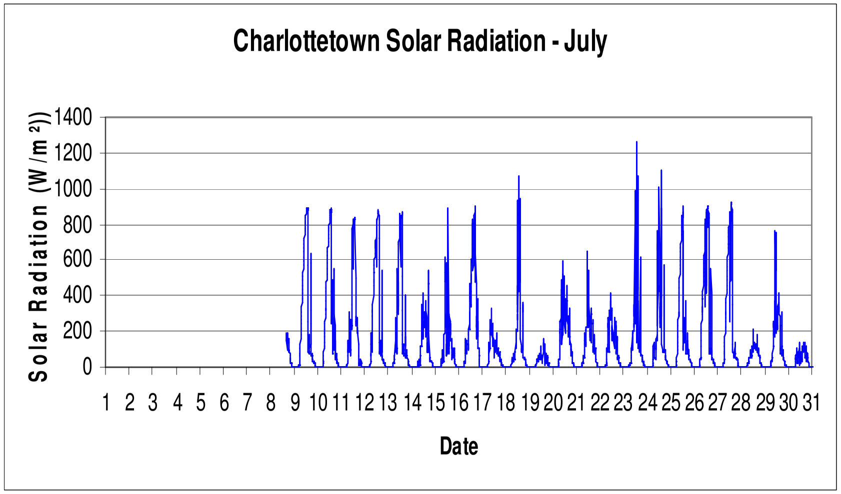

Charlottetown Wind Duration Curve - July
Wind Speed (m/s)
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (10 m)
Scaled Wind Speed (30 m)

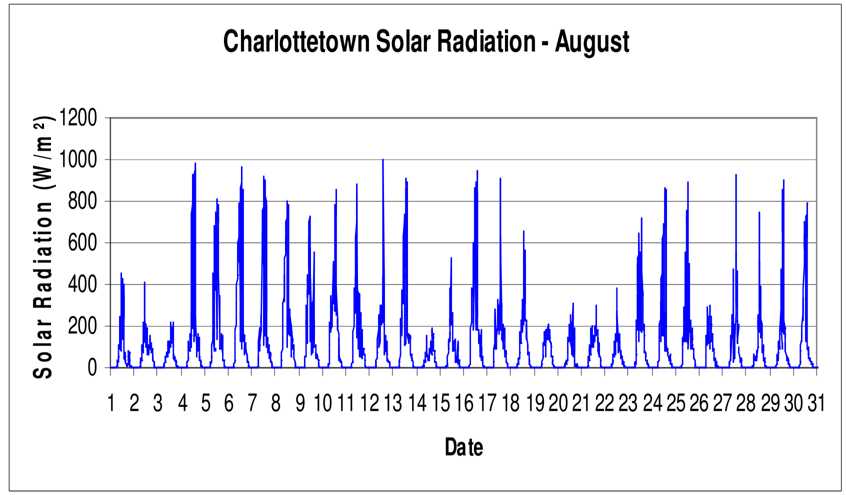

Charlottetown Wind Duration Curve - August
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (10 m)
Scaled Wind Speed (30 m)

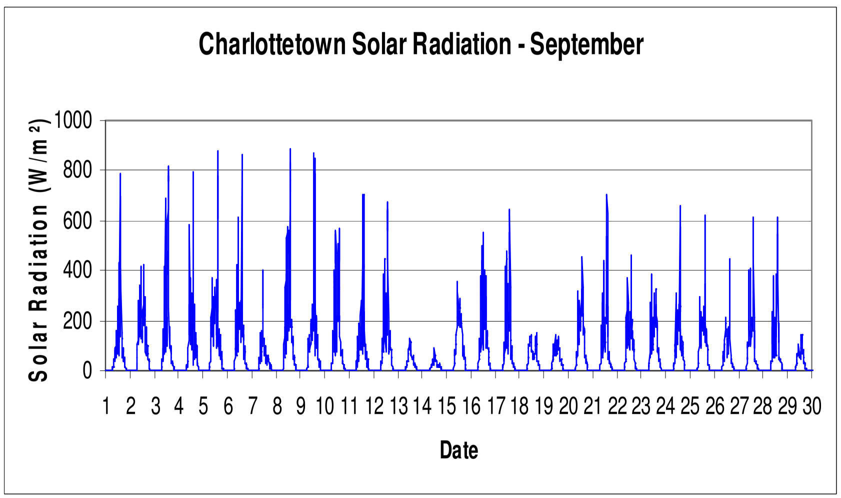

Charlottetown Wind Duration Curve - September
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (10 m)
Scaled Wind Speed (30 m)

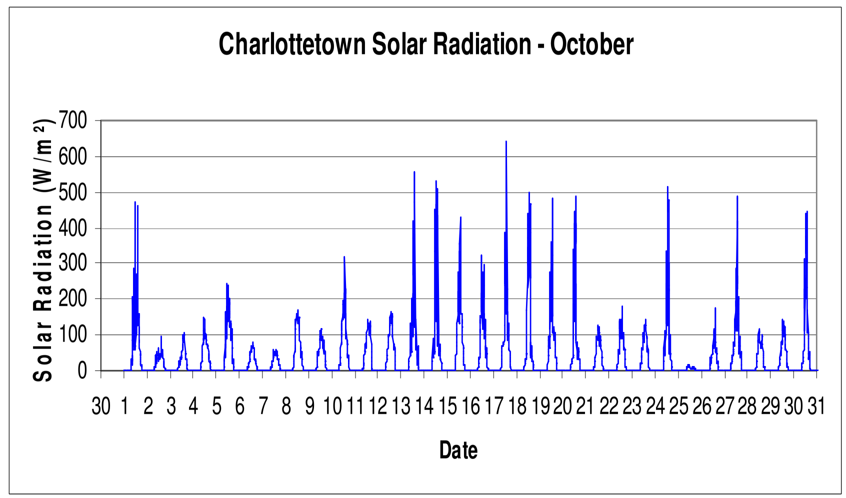

Charlottetown Wind Duration Curve - October
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (10 m)
Scaled Wind Speed (30 m)

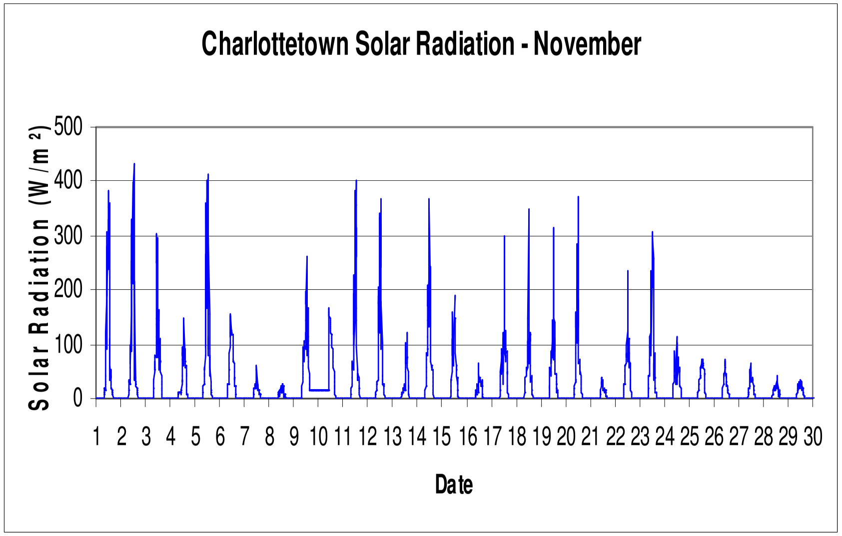

Charlottetown Wind Duation Curve - November
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Wind Speed (10 m)
Scaled Wind Speed (30 m)

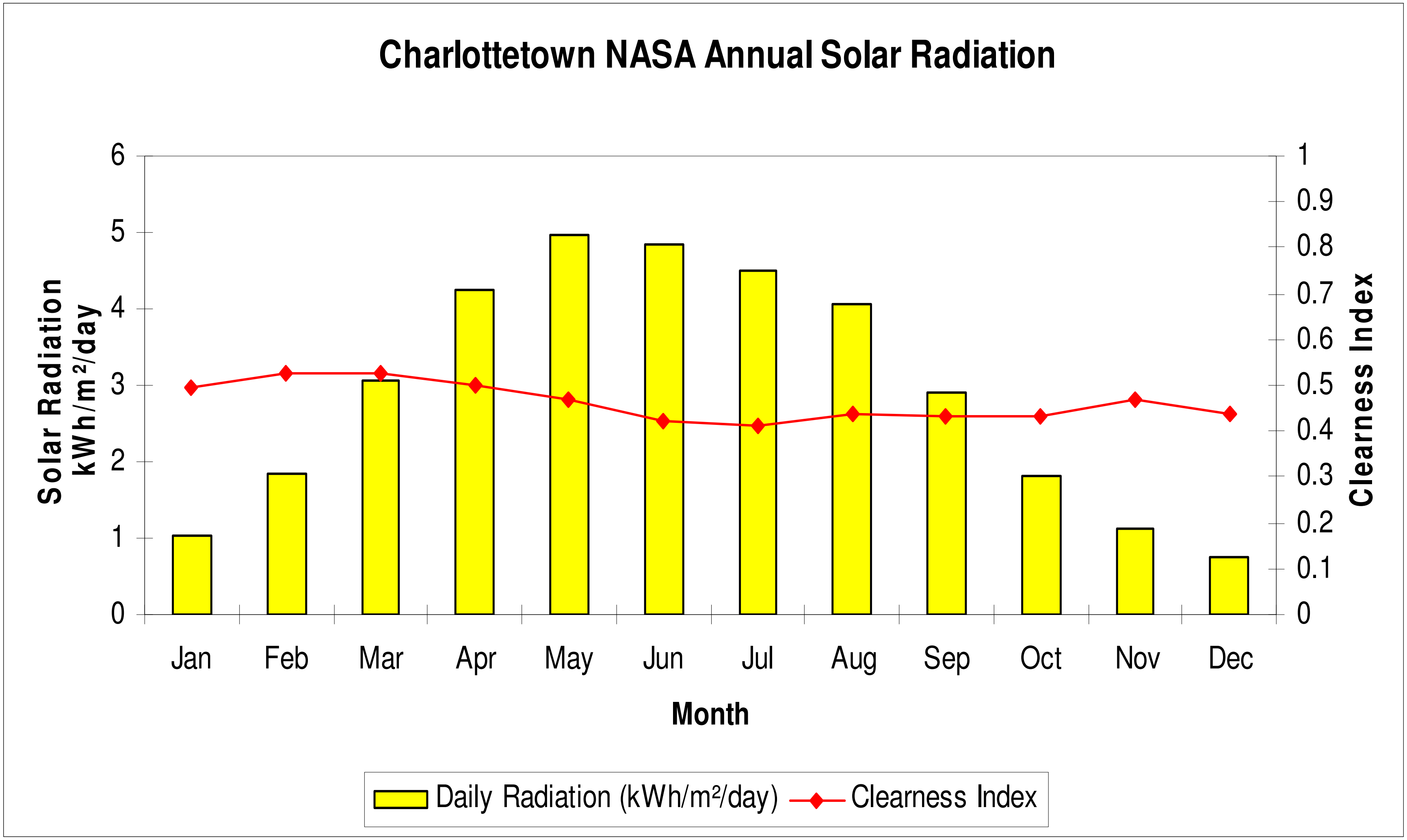

Charlottetown Solar Radiation - July
Solar Radiation (W/m 2))
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date

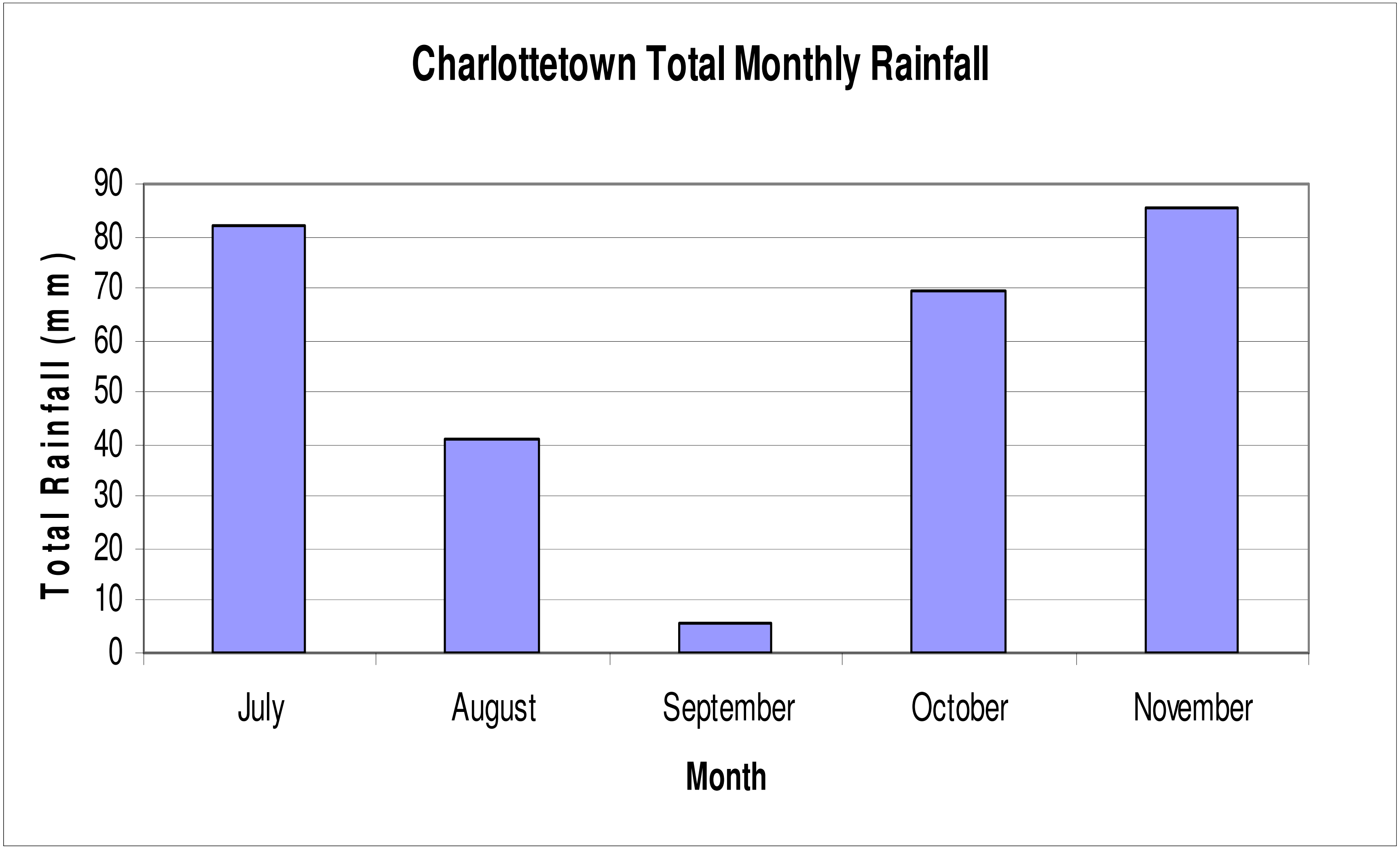

Charlottetown Solar Radiation - August
Solar Radiation (W/m 2)
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Charlottetown Solar Radiation - September
Solar Radiation (W/m 2)
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Charlottetown Solar Radiation - October
Solar Radiation (W/m 2)
700
600
500
400
300
200
100
0
30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Charlottetown Solar Radiation - November
Solar Radiation (W/m 2)
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Charlottetown NASA Annual Solar Radiation
Solar Radiation kWh/m²/day
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Clearness Index
Daily Radiation (kWh/m²/day)
Clearness Index

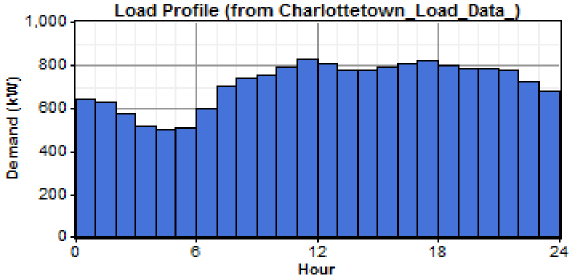

Charlottetown Total Monthly Rainfall
Total Rainfall (mm)
90
80
70
60
50
40
30
20
10
0
July
August
September
October
November
Month

HOMER Input Summary

File name: Charlottetown.hmr
File version: 2.67 beta
Author:

AC Load: Charlottetown Net System Load

Data source:	Charlottetown_Load_Data_2008.dmd
Daily noise:	8.27%
Hourly noise:	5.35%
Scaled annual average:	14,800, 14,912, 14,995, 15,104, 15,211 kWh/d
Scaled peak load:	1,185, 1,194, 1,201, 1,210, 1,218 kW
Load factor:	0.520



PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
50.000	400,000	400,000	10,000
100.000	750,000	750,000	15,000

Sizes to consider:	0, 50, 100 kW
Lifetime:	20 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	52.8 deg
Azimuth:	0 deg
Ground reflectance:	20%

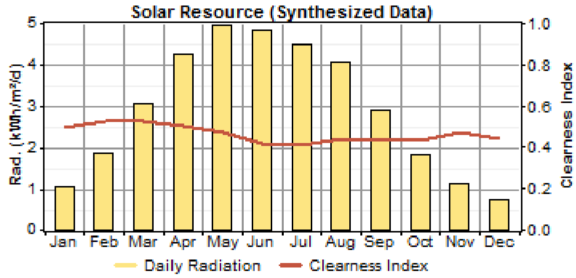
Solar Resource

Latitude: 52 degrees 46 minutes North
Longitude: 56 degrees 6 minutes West
Time zone: GMT -3:30

Data source: Synthetic

Month	Clearness Index	Average Radiation
		(kWh/m^2/day)
Jan	0.494	1.030
Feb	0.524	1.850
Mar	0.524	3.060
Apr	0.502	4.250
May	0.471	4.970
Jun	0.422	4.850
Jul	0.409	4.510
Aug	0.440	4.060
Sep	0.433	2.910
Oct	0.433	1.820
Nov	0.471	1.130
Dec	0.440	0.740

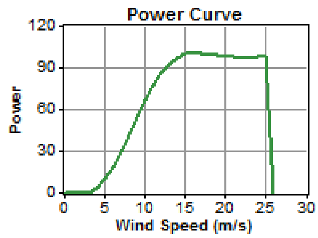
Scaled annual average: 2.92 kWh/m²/d



AC Wind Turbine: Northern Power NW100/21

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	500,000	400,000	10,000

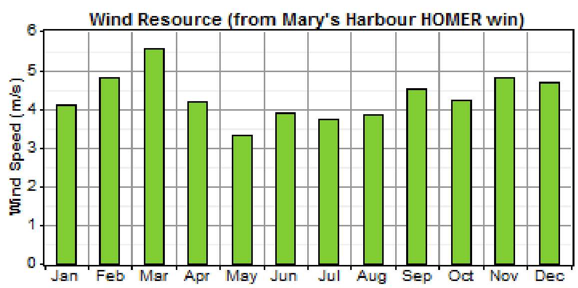
Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Lifetime: 20 yr
Hub height: 37 m



Wind Resource

Data source: Mary's Harbour HOMER wind speeds.txt

Month	Wind Speed (m/s)
Jan	4.11
Feb	4.78
Mar	5.56
Apr	4.18
May	3.30
Jun	3.89
Jul	3.71
Aug	3.83
Sep	4.51
Oct	4.22
Nov	4.80
Dec	4.69



Weibull k: 1.60
Autocorrelation factor: 0.861
Diurnal pattern strength: 0.0797
Hour of peak wind speed: 10
Scaled annual average: 4.29 m/s
Anemometer height: 10 m
Altitude: 11 m

Wind shear profile: Logarithmic
Surface roughness length: 0.01 m

AC Hydro:

Capital cost: $ 10,406,000, 40,689,000, 3,391,000, 19,175,000, 7,132,000, 4,300,000, 3,200,000
Replacement cost: $ 0
O&M cost: $ 193,260, 263,280, 10,900, 50,440, 15,890, 7,890, 5,450/yr
Lifetime: 60 yr
Available head: 30, 40, 20, 20, 35, 33, 32 m
Design flow rate: 5,840, 5,970, 870, 4,000, 720, 380, 270 L/s
Min. flow ratio: 15, 10, 20, 15, 15, 15, 15%
Max. flow ratio: 100%
Turbine efficiency: 85%
Pipe head loss: 0%

Consider systems without hydro: Yes

Hydro Resource

Data source: Synthetic

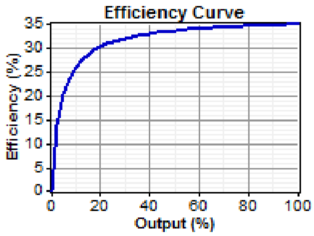
Month	Stream Flow (L/s)
Jan	824
Feb	529
Mar	588
Apr	1,671
May	1,694
Jun	1,671
Jul	1,694
Aug	1,694
Sep	1,671
Oct	1,694
Nov	1,659
Dec	1,471

Residual flow: 0 L/s
Scaled annual average: 763, 1,029, 76, 348, 109, 54, 37 L/s

AC Generator: 204

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
250.000	0	380,000	1.128

Sizes to consider: 250 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0108 L/hr/kW
Fuel curve slope: 0.268 L/hr/kW

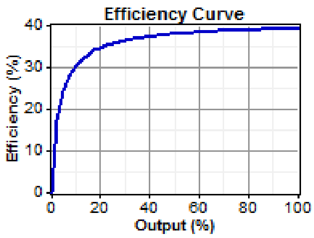


AC Generator: 2060

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)

725.000	0	600,000	1.850

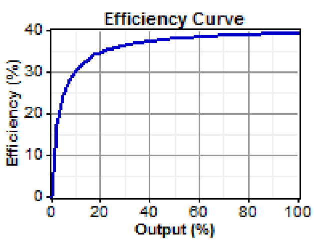
Sizes to consider: 725 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.008 L/hr/kW
Fuel curve slope: 0.24 L/hr/kW



AC Generator: 2061

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
725.000	0	600,000	1.850

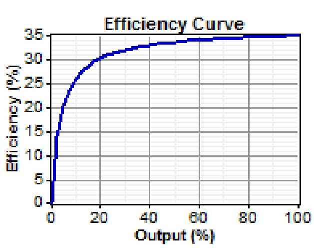
Sizes to consider: 725 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.008 L/hr/kW
Fuel curve slope: 0.24 L/hr/kW



AC Generator: 2019

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
250.000	0	380,000	1.128

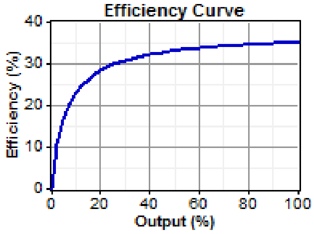
Sizes to consider: 250 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0108 L/hr/kW
Fuel curve slope: 0.268 L/hr/kW



AC Generator: 2034

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
300.000	0	400,000	1.684

Sizes to consider:	300 kW
Lifetime:	100,000 hrs
Min. load ratio:	30%
Heat recovery ratio:	0%
Fuel used:	#1 Diesel Arctic Grade
Fuel curve intercept:	0.0163 L/hr/kW
Fuel curve slope:	0.261 L/hr/kW



Fuel: #1 Diesel Arctic Grade

Price:	$ 0.928, 0.927, 0.947, 0.976, 0.976/L
Lower heating value:	45.8 MJ/kg
Density:	809 kg/m3
Carbon content:	88.0%
Sulfur content:	0.0500%

Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
100.000	64,000	64,000	6,400

Sizes to consider:	0, 100 kW
Lifetime:	15 yr
Inverter efficiency:	90%
Inverter can parallel with AC generator:	Yes
Rectifier relative capacity:	100%
Rectifier efficiency:	85%

Economics

Annual real interest rate:	8%
Project lifetime:	60 yr
Capacity shortage penalty:	$ 0/kWh
System fixed capital cost:	$ 0
System fixed O&M cost:	$ 0/yr

Generator control

Check load following:	Yes
Check cycle charging:	No

Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	No

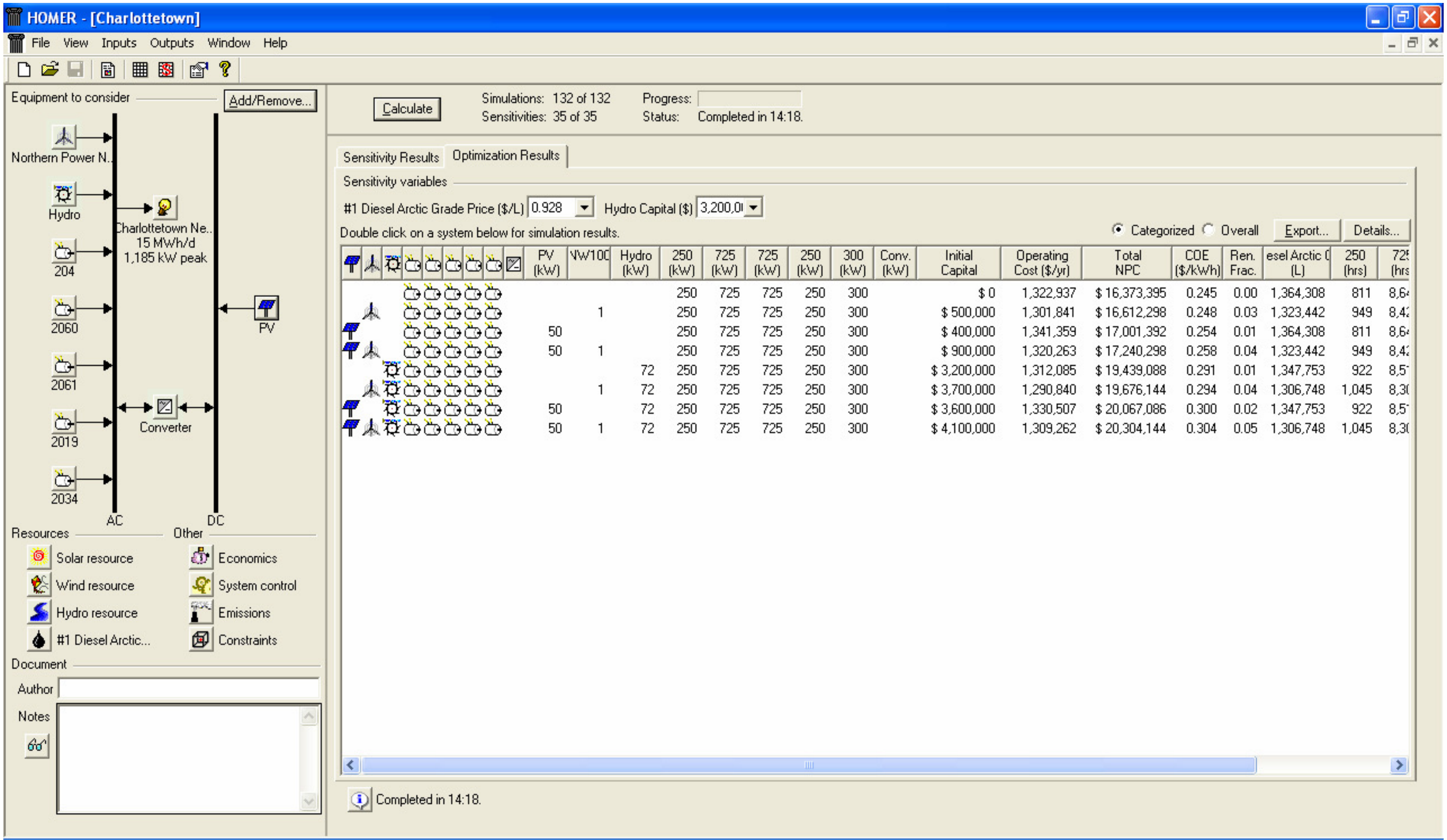
Emissions

Carbon dioxide penalty:	$ 0/t
Carbon monoxide penalty:	$ 0/t
Unburned hydrocarbons penalty:	$ 0/t
Particulate matter penalty:	$ 0/t
Sulfur dioxide penalty:	$ 0/t
Nitrogen oxides penalty:	$ 0/t

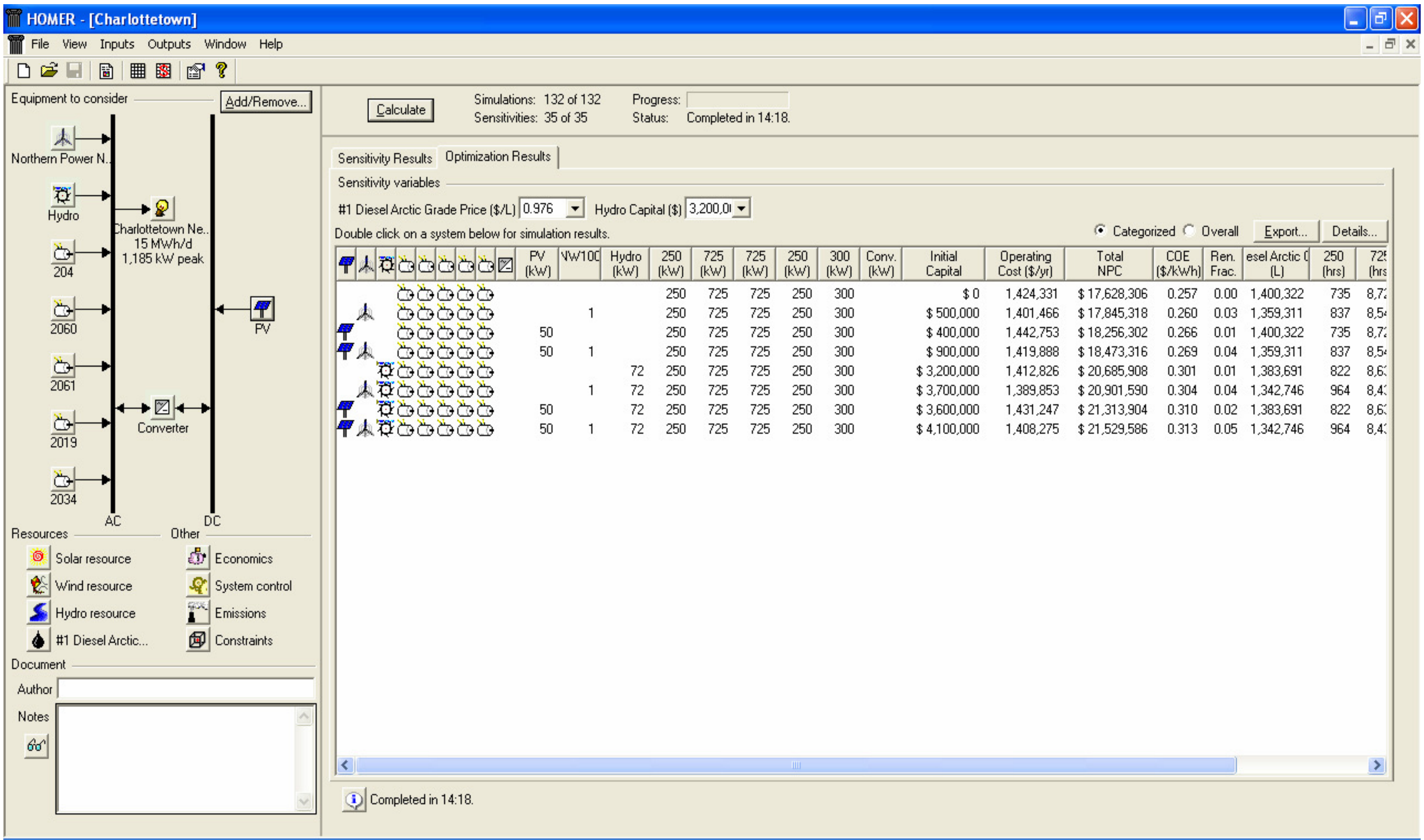
Constraints

Maximum annual capacity shortage:	0%
Minimum renewable fraction:	0%

Operating reserve as percentage of hourly load:	10%
Operating reserve as percentage of peak load:	0%
Operating reserve as percentage of solar power output:	25%
Operating reserve as percentage of wind power output:	50%



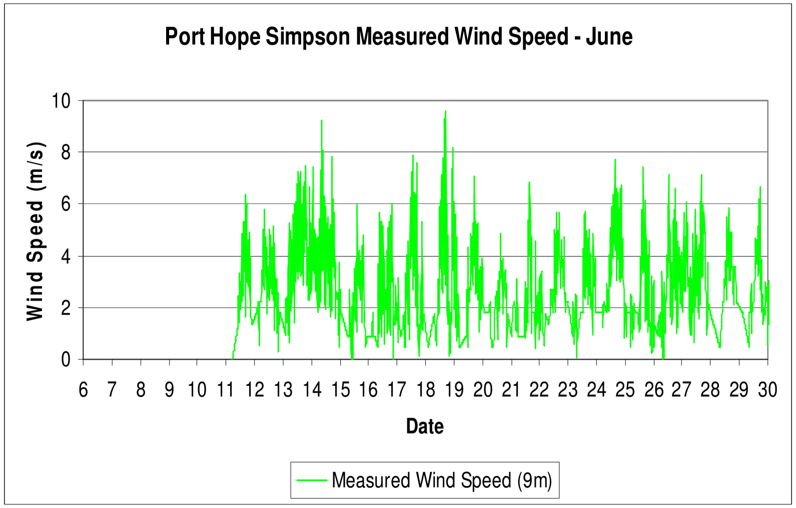
Charlottetown HOMER Results – 2011 System

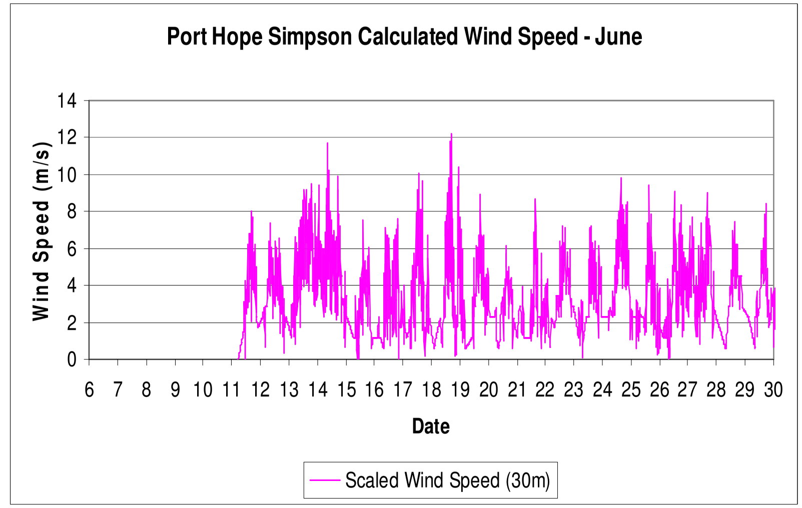


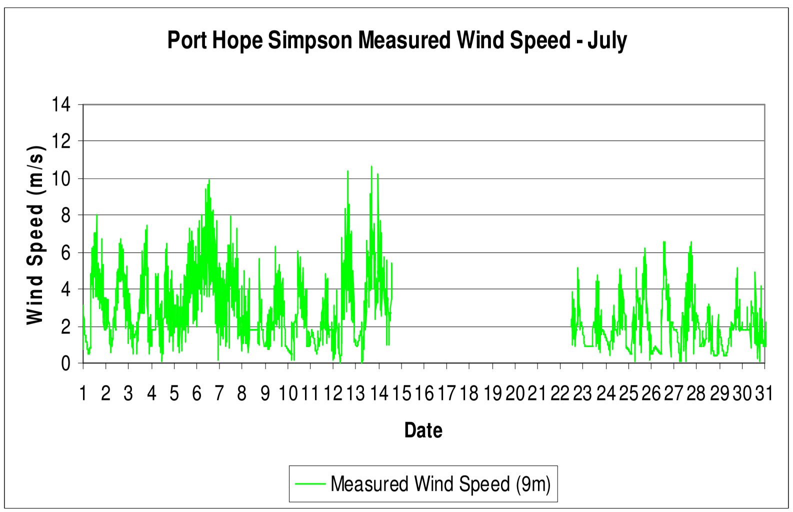
PV (kW)	NW100	Hydro (kW)	250 (kW)	725 (kW)	725 (kW)	250 (kW)	300 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic (L)	250 (hrs)	72 (hrs
			250	725	725	250	300		$ 0	1,424,331	$ 17,628,306	0.257	0.00	1,400,322	735	8,7
	1		250	725	725	250	300		$ 500,000	1,401,466	$ 17,845,318	0.260	0.03	1,359,311	837	8,5
50			250	725	725	250	300		$ 400,000	1,442,753	$ 18,256,302	0.266	0.01	1,400,322	735	8,7
50	1		250	725	725	250	300		$ 900,000	1,419,888	$ 18,473,316	0.269	0.04	1,359,311	837	8,5
		72	250	725	725	250	300		$ 3,200,000	1,412,826	$ 20,685,908	0.301	0.01	1,383,691	822	8,6
	1	72	250	725	725	250	300		$ 3,700,000	1,389,853	$ 20,901,590	0.304	0.04	1,342,746	964	8,4
50		72	250	725	725	250	300		$ 3,600,000	1,431,247	$ 21,313,904	0.310	0.02	1,383,691	822	8,6
50	1	72	250	725	725	250	300		$ 4,100,000	1,408,275	$ 21,529,586	0.313	0.05	1,342,746	964	8,4

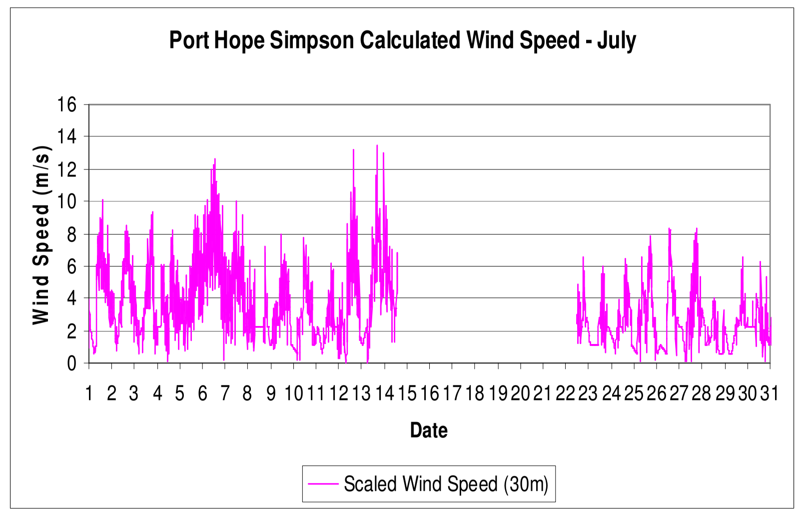
Charlottetown HOMER Results – 2015 System

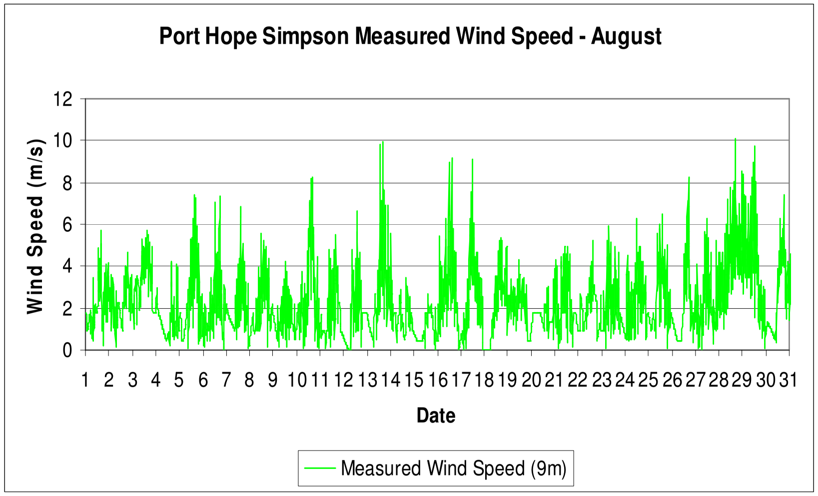
APPENDIX F – PORT HOPE SIMPSON

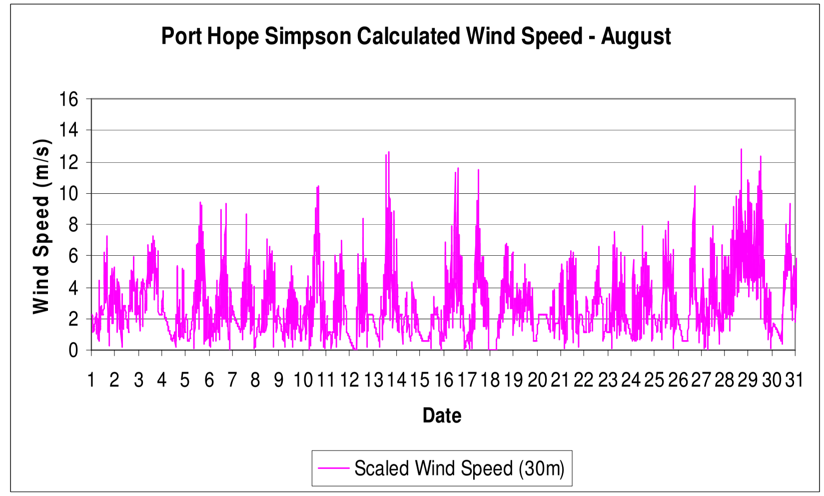

Port Hope Simpson Measured Wind Speed - June
Wind Speed (m/s)
0 2 4 6 8 10
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (9m)

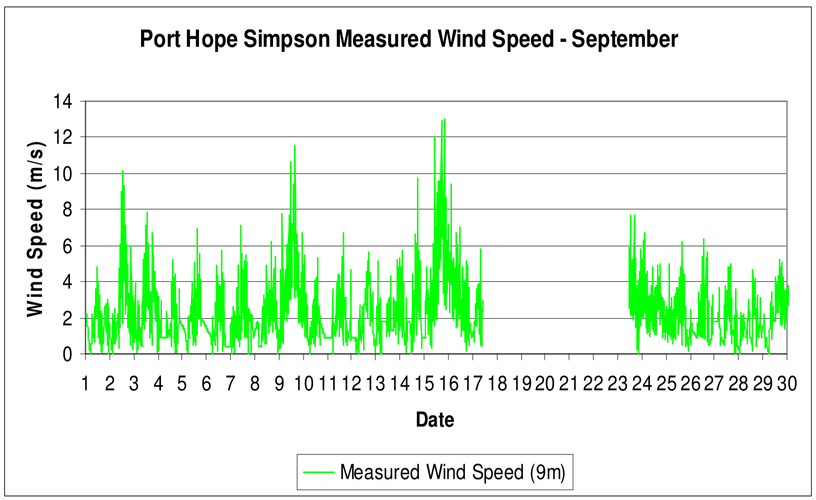

Port Hope Simpson Calculated Wind Speed - June
Wind Speed (m/s)
0 2 4 6 8 10 12 14
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)

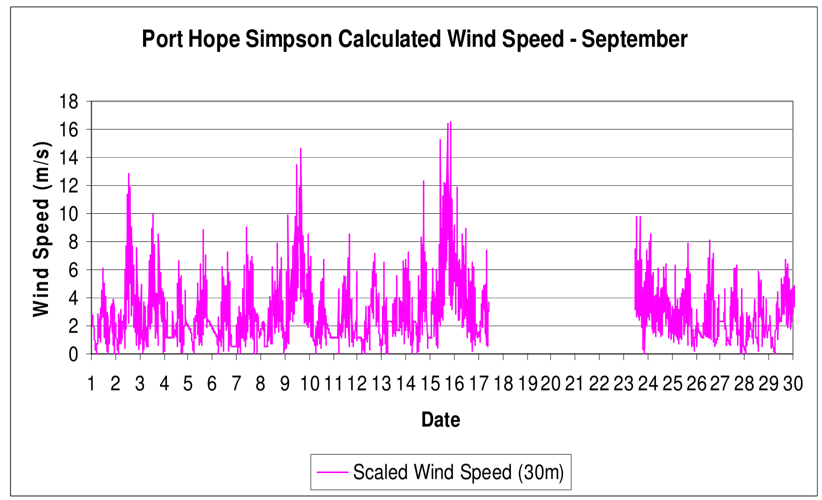

Port Hope Simpson Measured Wind Speed - July
Wind Speed (m/s)
0 2 4 6 8 10 12 14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (9m)

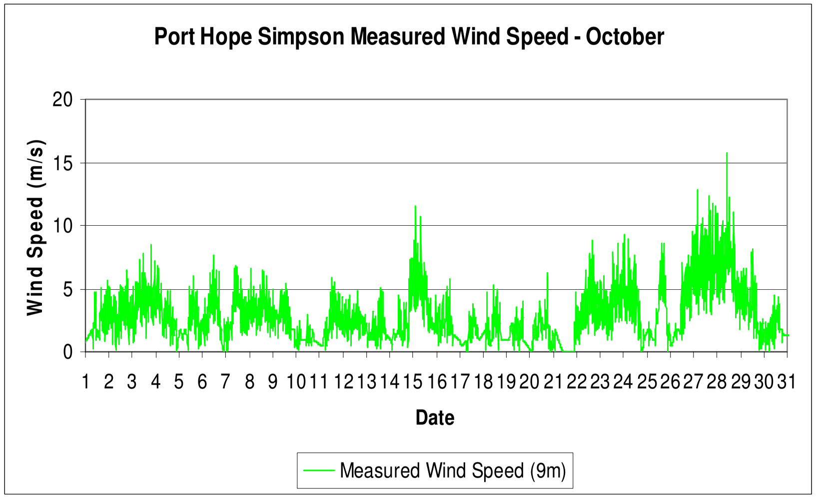

Port Hope Simpson Calculated Wind Speed - July
Wind Speed (m/s)
0 2 4 6 8 10 12 14 16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)

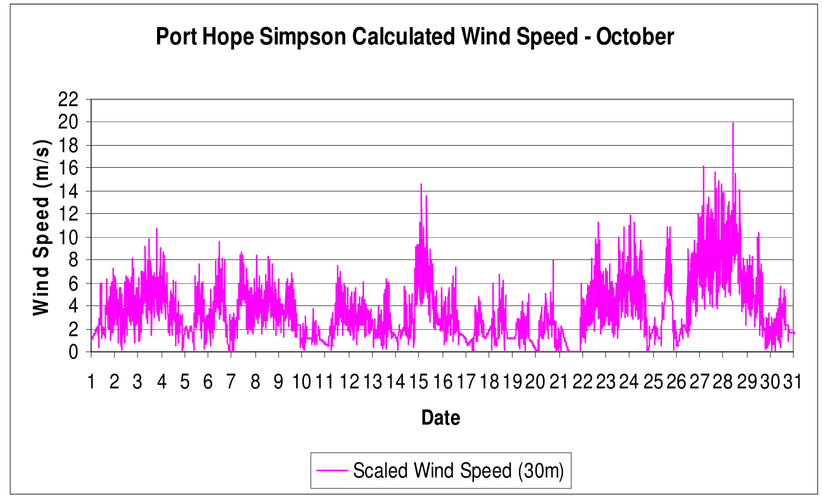

Port Hope Simpson Measured Wind Speed - August
Wind Speed (m/s)
0 2 4 6 8 10 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (9m)

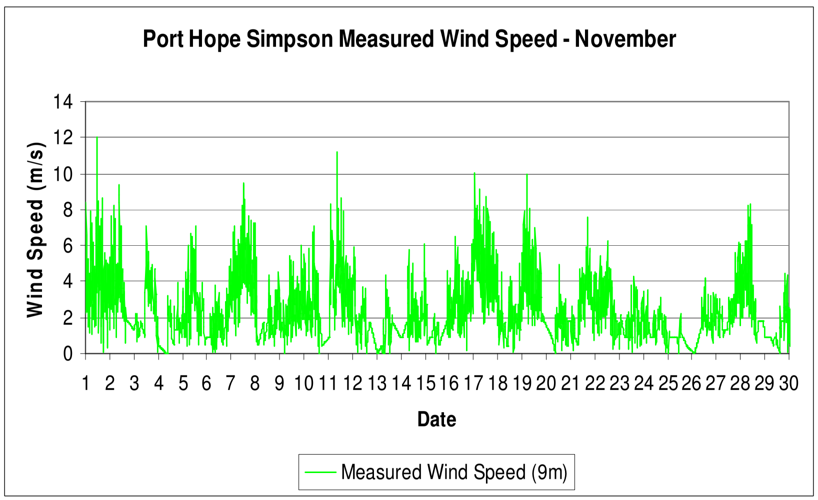

Port Hope Simpson Calculated Wind Speed - August
Wind Speed (m/s)
0 2 4 6 8 10 12 14 16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)

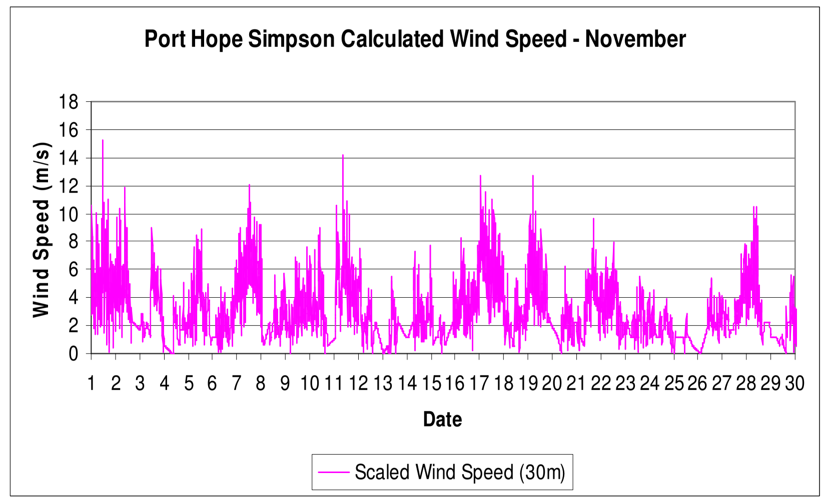

Port Hope Simpson Measured Wind Speed - September
Wind Speed (m/s)
0 2 4 6 8 10 12 14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (9m)

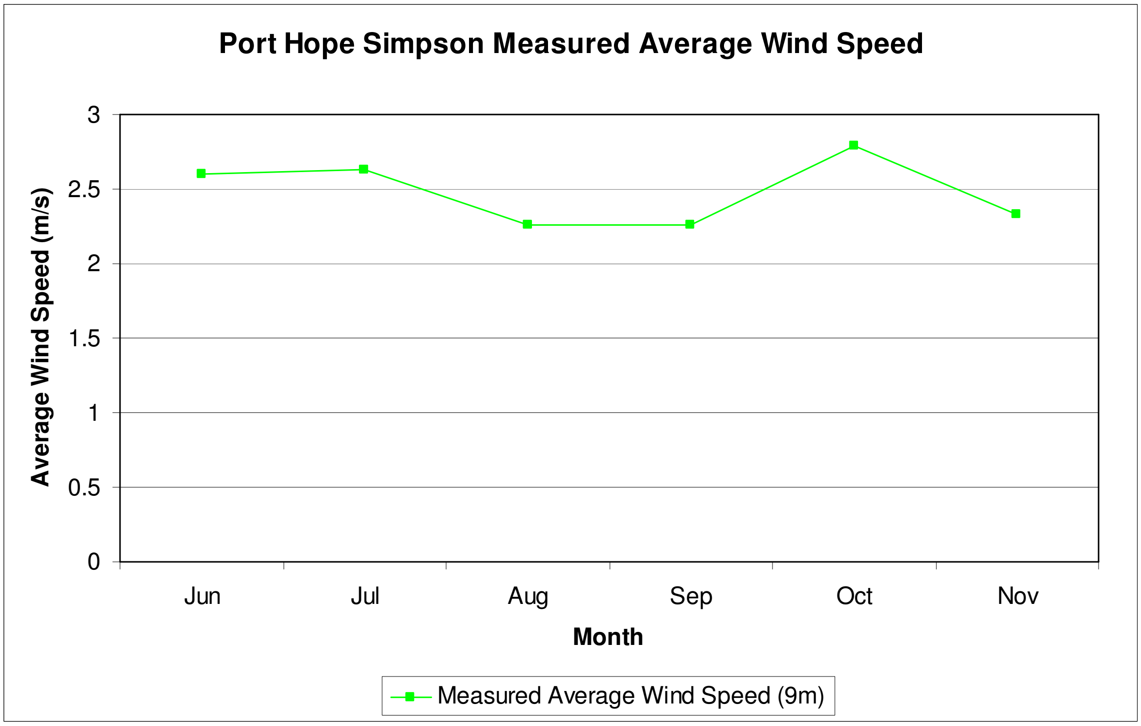

Port Hope Simpson Calculated Wind Speed - September
Wind Speed (m/s)
0 2 4 6 8 10 12 14 16 18
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)

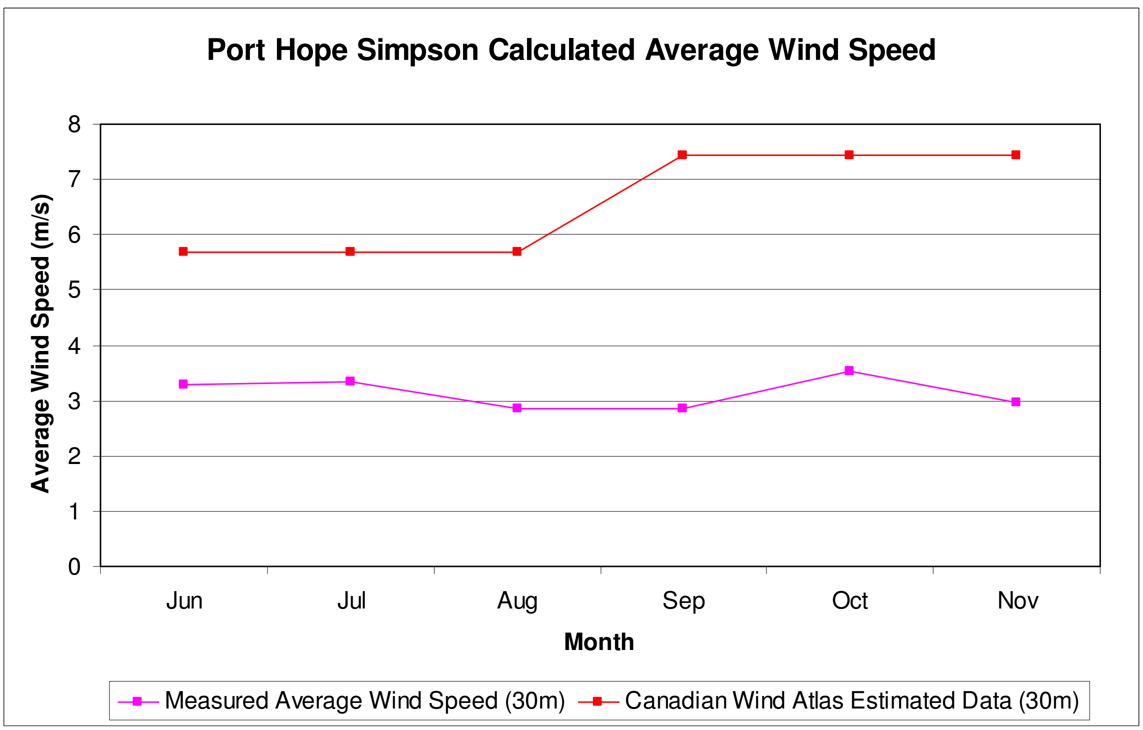

Port Hope Simpson Measured Wind Speed - October
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Measured Wind Speed (9m)

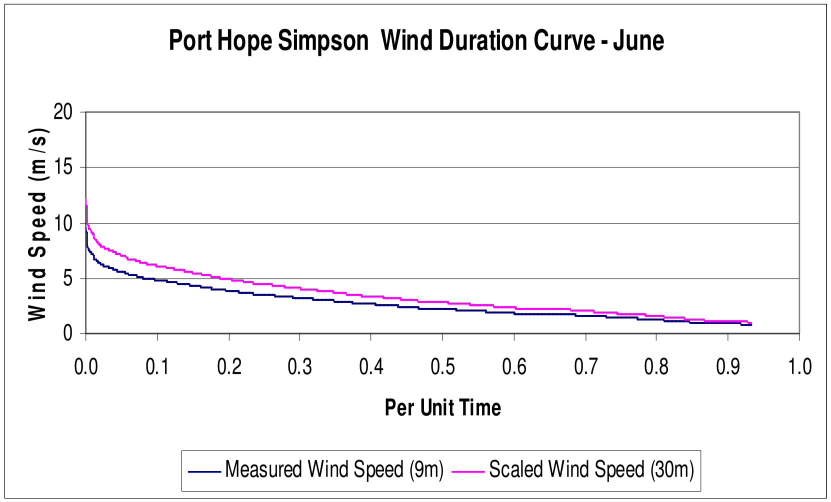

Port Hope Simpson Calculated Wind Speed - October
Wind Speed (m/s)
22
20
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)

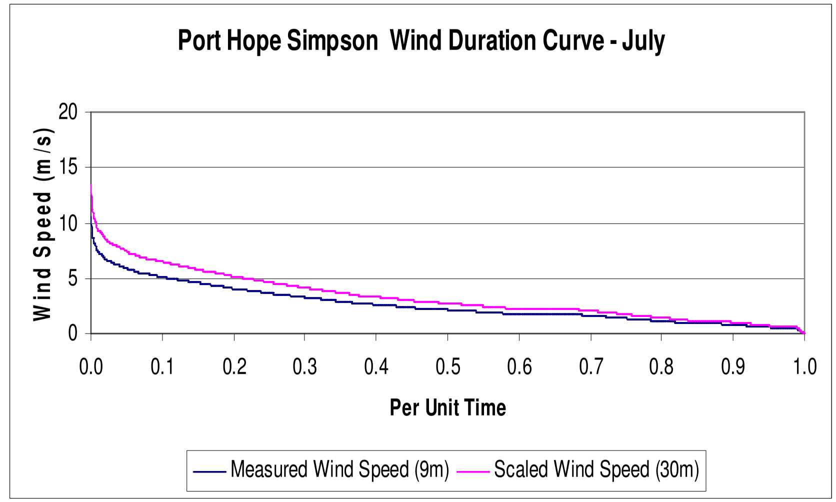

Port Hope Simpson Measured Wind Speed - November
Wind Speed (m/s)
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Measured Wind Speed (9m)

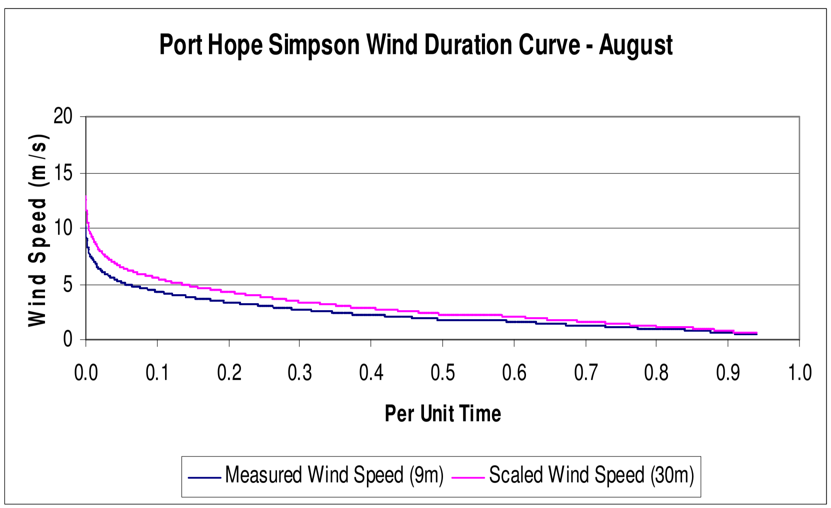

Port Hope Simpson Calculated Wind Speed - November
Wind Speed (m/s)
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)

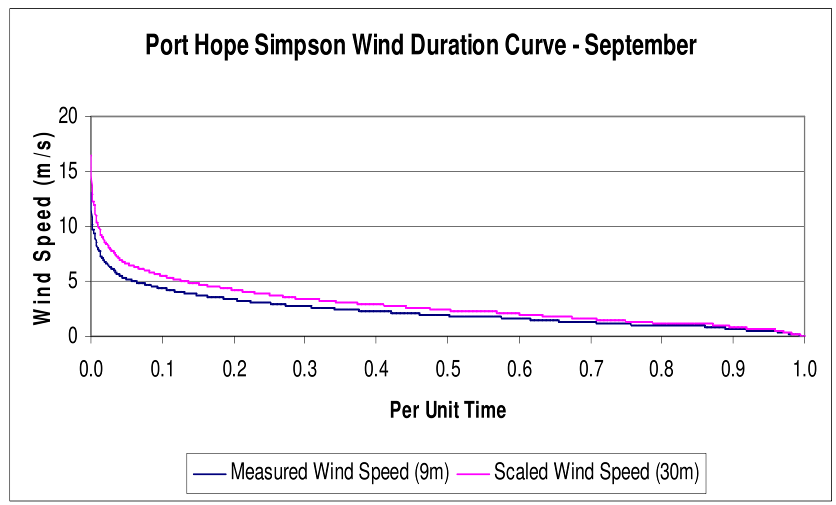

Port Hope Simpson Measured Average Wind Speed
Average Wind Speed (m/s)
3
2.5
2
1.5
1
0.5
0
Jun
Jul
Aug
Sep
Oct
Nov
Month
Measured Average Wind Speed (9m)


Port Hope Simpson Calculated Average Wind Speed
Average Wind Speed (m/s)
8
7
6
5
4
3
2
1
0
Jun
Jul
Aug
Sep
Oct
Nov
Month
Measured Average Wind Speed (30m)
Canadian Wind Atlas Estimated Data (30m)

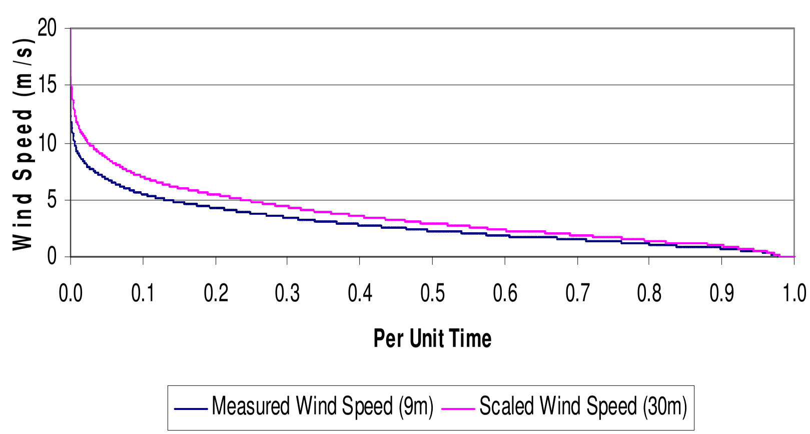

Port Hope Simpson Wind Duration Curve - June
Wind Speed (m/s)
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (9m)
Scaled Wind Speed (30m)


Port Hope Simpson Wind Duration Curve - July
Wind Speed (m/s)
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (9m)
Scaled Wind Speed (30m)

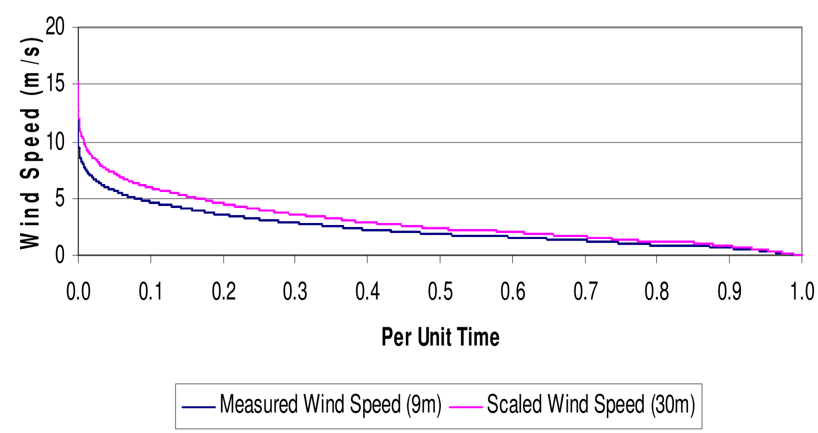

Port Hope Simpson Wind Duration Curve - August
Wind Speed (m/s)
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (9m)
Scaled Wind Speed (30m)

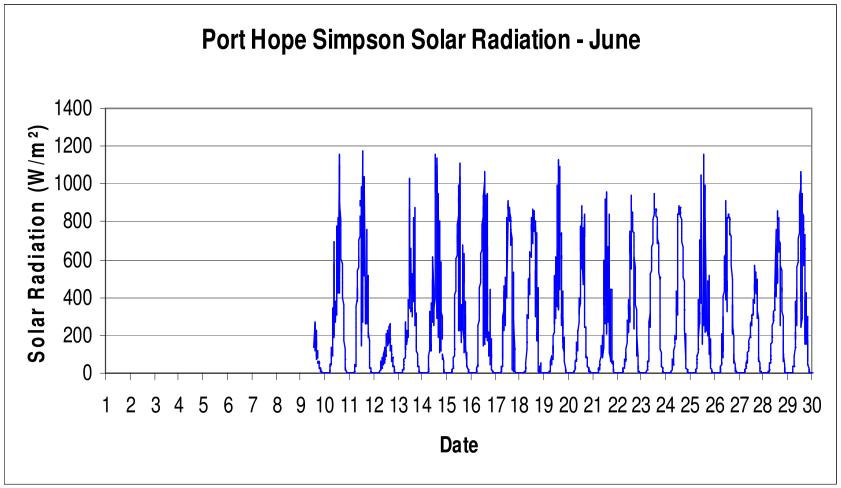

Port Hope Simpson Wind Duration Curve - September
Wind Speed (m/s)
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (9m)
Scaled Wind Speed (30m)

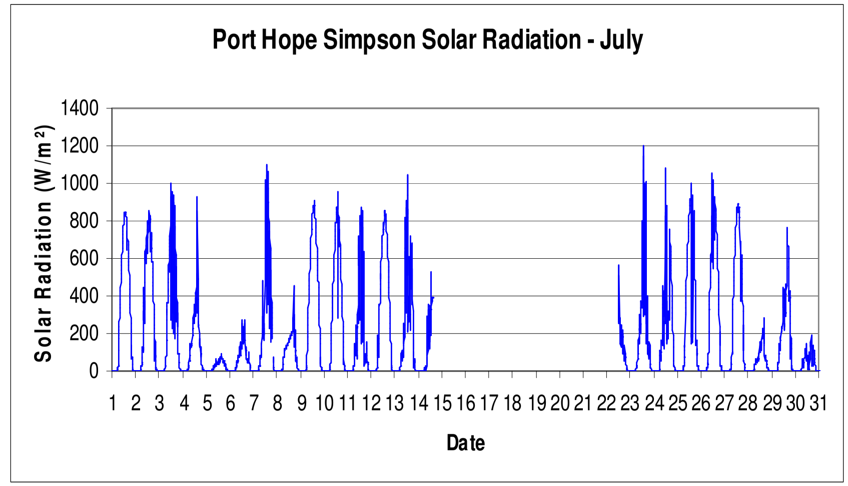
Port Hope Simpson Wind Duration Curve - October

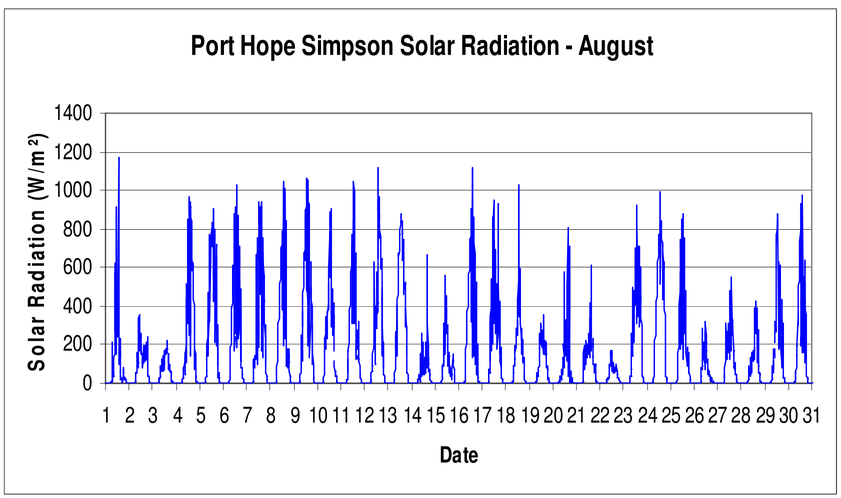


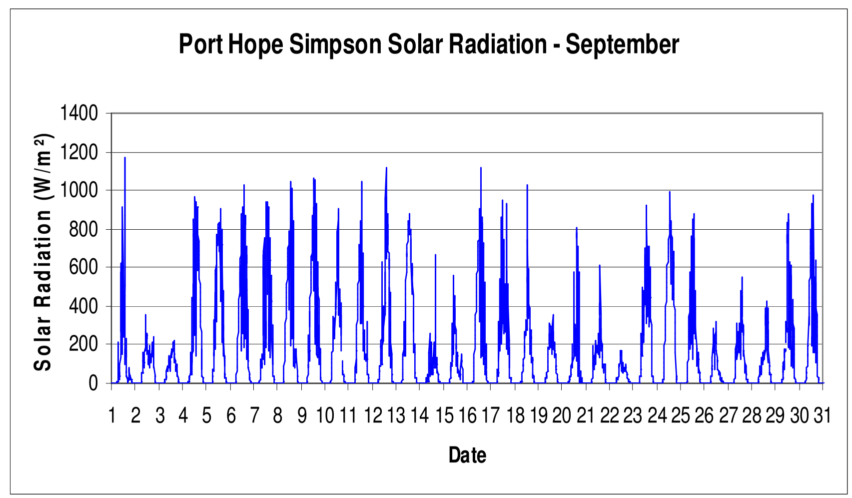
Port Hope Simpson Wind Duration Curve - November

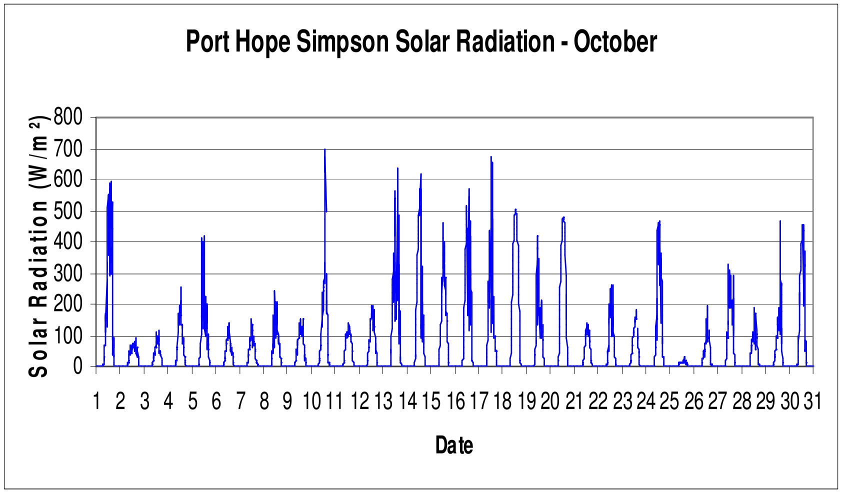


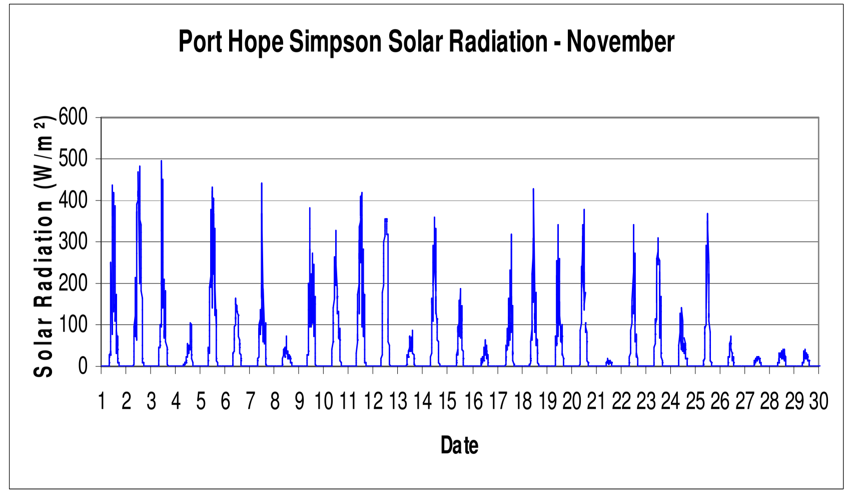

Port Hope Simpson Solar Radiation - June
Solar Radiation (W/m²)
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date

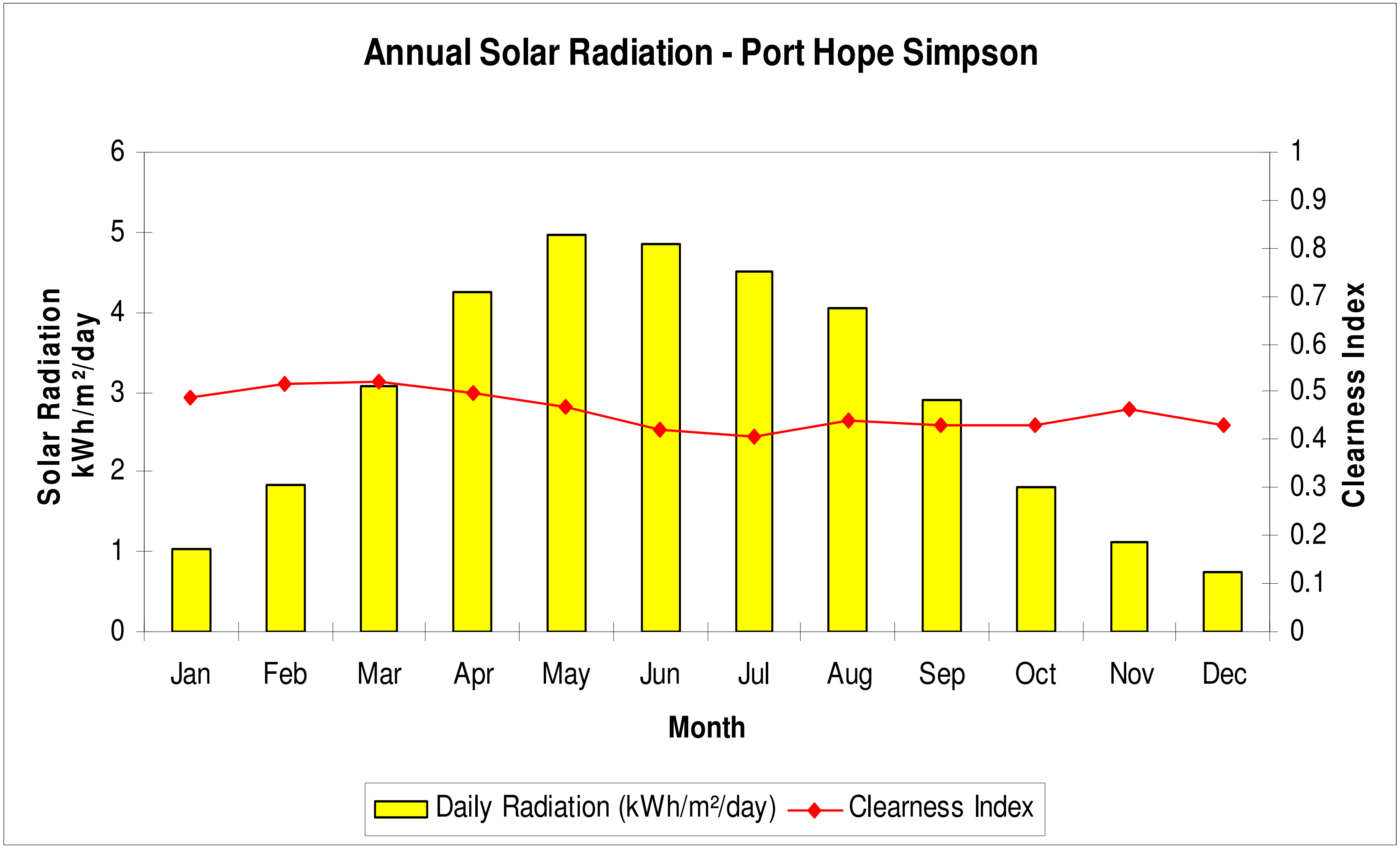

Port Hope Simpson Solar Radiation - July
Solar Radiation (W/m²)
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date

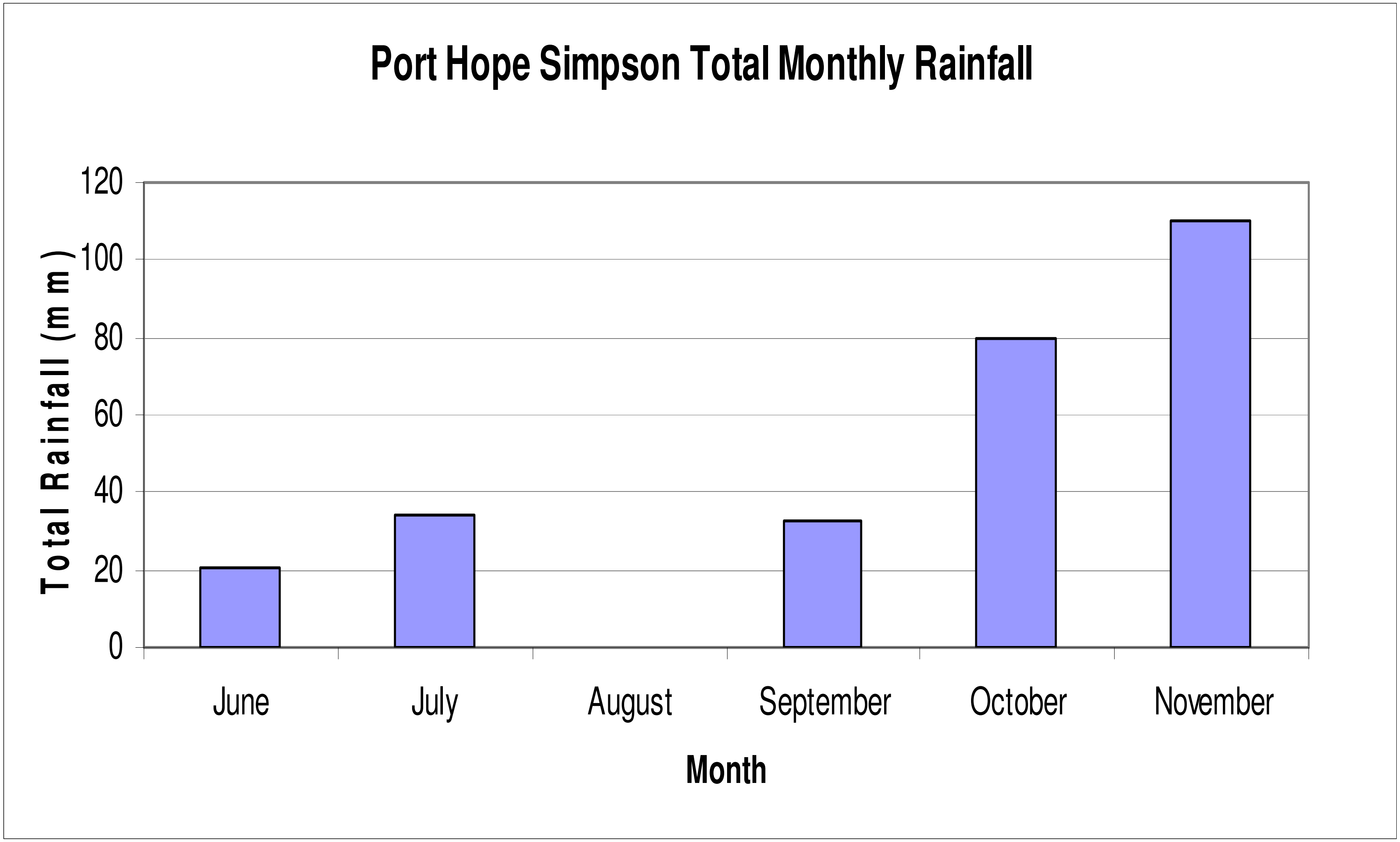

Port Hope Simpson Solar Radiation - August
Solar Radiation (W/m²)
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Port Hope Simpson Solar Radiation - September
Solar Radiation (W/m²)
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Port Hope Simpson Solar Radiation - October
Solar Radiation (W/m²)
800
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Port Hope Simpson Solar Radiation - November
Solar Radiation (W/m²)
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Annual Solar Radiation - Port Hope Simpson
Solar Radiation kWh/m²/day
6
5
4
3
2
1
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Clearness Index
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Daily Radiation (kWh/m²/day)
Clearness Index

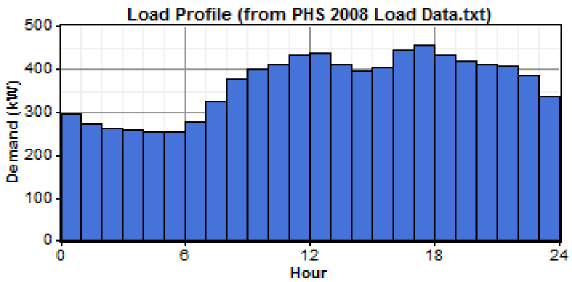

Port Hope Simpson Total Monthly Rainfall
Total Rainfall (mm)
120
100
80
60
40
20
0
June
July
August
September
October
November
Month

HOMER Input Summary

File name: PortHopeSimpson.hmr
File version: 2.68 beta
Author:
Notes:

AC Load: Port Hope Simpson Net System Load

Data source:	PHS 2008 Load Data.txt
Daily noise:	12.2%
Hourly noise:	30.2%
Scaled annual average:	9,178, 9,362, 9,518, 9,674, 9,827 kWh/d
Scaled peak load:	810, 826, 840, 854, 867 kW
Load factor:	0.472



PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
50.000	400,000	400,000	10,000
100.000	750,000	750,000	15,000

Sizes to consider:	0, 50, 100 kW
Lifetime:	20 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	52.5 deg
Azimuth:	0 deg
Ground reflectance:	20%

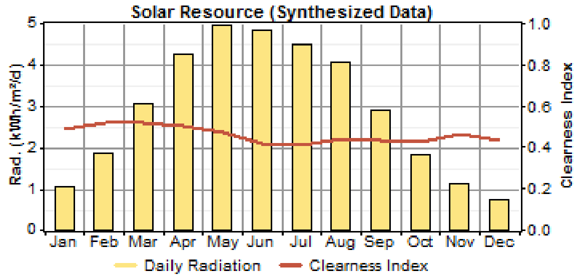
Solar Resource

Latitude:	52 degrees 33 minutes North
Longitude:	56 degrees 18 minutes West
Time zone:	GMT -3:30

Data source: Synthetic

Month	Clearness Index	Average Radiation
		(kWh/m^2/day)
Jan	0.486	1.030
Feb	0.519	1.850
Mar	0.521	3.060
Apr	0.500	4.250
May	0.470	4.970
Jun	0.422	4.850
Jul	0.409	4.510
Aug	0.439	4.060
Sep	0.431	2.910
Oct	0.430	1.820
Nov	0.464	1.130
Dec	0.431	0.740

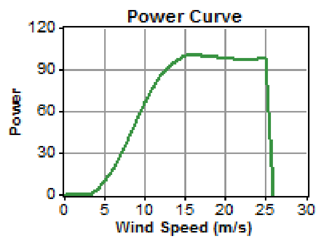
Scaled annual average: 2.92 kWh/m²/d



AC Wind Turbine: Northern Power NW100/21

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	500,000	400,000	10,000

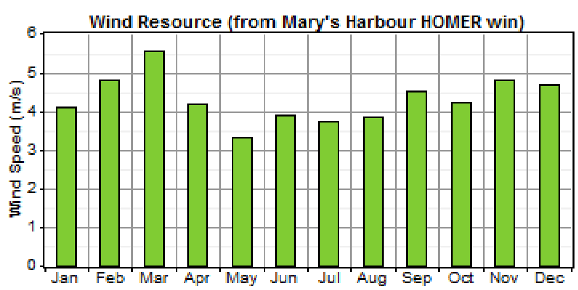
Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Lifetime: 20 yr
Hub height: 37 m



Wind Resource

Data source: Mary's Harbour HOMER wind speeds.txt

Month	Wind Speed (m/s)
Jan	4.11
Feb	4.78
Mar	5.56
Apr	4.18
May	3.30
Jun	3.89
Jul	3.71
Aug	3.83
Sep	4.51
Oct	4.22
Nov	4.80
Dec	4.69



Weibull k: 1.60
Autocorrelation factor: 0.861
Diurnal pattern strength: 0.0797
Hour of peak wind speed: 10
Scaled annual average: 4.29 m/s
Anemometer height: 9 m
Altitude: 5 m

Wind shear profile: Logarithmic
Surface roughness length: 0.01 m

AC Hydro:

Capital cost: $ 32,387,000, 58,695,000, 15,434,000, 1,700,000, 4,092,000, 3,741,000, 1,700,000, 3,400,000, 2,600,000
Replacement cost: $ 0
O&M cost: $ 283,170, 409,810, 147,320, 6,960, 12,640, 11,020, 4,170, 7,190, 3,710/yr
Lifetime: 60 yr
Available head: 28, 40, 60, 11, 40, 8, 95, 5, 7 m
Design flow rate: 23,030, 23,340, 2,230, 1,010, 500, 2,180, 70, 2,260, 830 L/s
Min. flow ratio: 15, 10, 10, 15, 10, 15, 5, 15, 15%
Max. flow ratio: 100%
Turbine efficiency: 85%
Pipe head loss: 0%

Consider systems without hydro: Yes

Hydro Resource

Data source: Synthetic

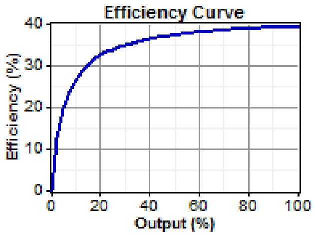
Month	Stream Flow (L/s)
Jan	2,294
Feb	1,471
Mar	1,647
Apr	4,588
May	4,706
Jun	4,588
Jul	4,706
Aug	4,706
Sep	4,588
Oct	4,706
Nov	4,588
Dec	3,824

Residual flow: 0 L/s
Scaled annual average: 3,879, 5,631, 795, 67, 120, 104, 40, 68, 54 L/s

AC Generator: 2073

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
455.000	0	400,000	1.684

Sizes to consider: 455 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0132 L/hr/kW
Fuel curve slope: 0.233 L/hr/kW

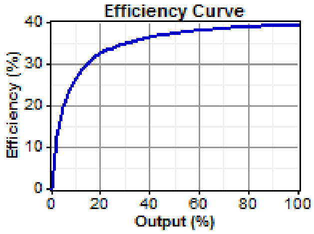


AC Generator: 2042

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)

455.000	0	400,000	1.684

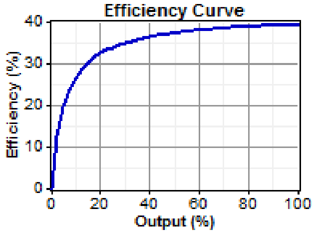
Sizes to consider:	455 kW
Lifetime:	100,000 hrs
Min. load ratio:	30%
Heat recovery ratio:	0%
Fuel used:	#1 Diesel Arctic Grade
Fuel curve intercept:	0.0132 L/hr/kW
Fuel curve slope:	0.233 L/hr/kW



AC Generator: 2043

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
455.000	0	400,000	1.684

Sizes to consider:	455 kW
Lifetime:	100,000 hrs
Min. load ratio:	30%
Heat recovery ratio:	0%
Fuel used:	#1 Diesel Arctic Grade
Fuel curve intercept:	0.0132 L/hr/kW
Fuel curve slope:	0.233 L/hr/kW



Fuel: #1 Diesel Arctic Grade

Price:	$ 0.945, 0.944, 0.963, 0.993, 0.993/L
Lower heating value:	45.8 MJ/kg
Density:	809 kg/m3
Carbon content:	88.0%
Sulfur content:	0.0500%

Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
100.000	64,000	64,000	6,400

Sizes to consider:	0, 100 kW
Lifetime:	15 yr
Inverter efficiency:	90%
Inverter can parallel with AC generator:	Yes
Rectifier relative capacity:	100%
Rectifier efficiency:	85%

Economics

Annual real interest rate:	8%
Project lifetime:	60 yr
Capacity shortage penalty:	$ 0/kWh
System fixed capital cost:	$ 0

System fixed O&M cost:	$ 0/yr

Generator control

Check load following:	Yes
Check cycle charging:	No

Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	No

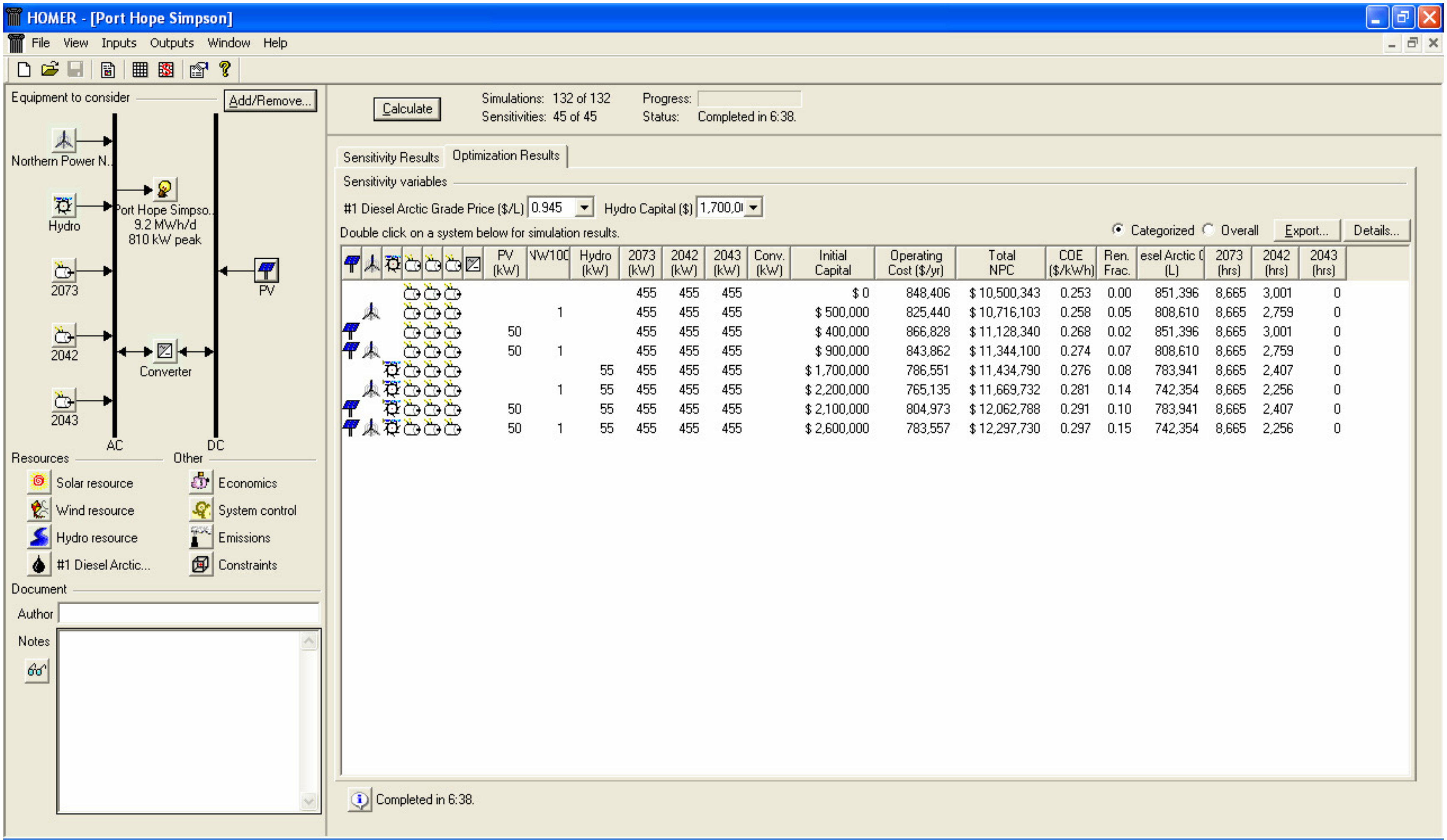
Emissions

Carbon dioxide penalty:	$ 0/t
Carbon monoxide penalty:	$ 0/t
Unburned hydrocarbons penalty:	$ 0/t
Particulate matter penalty:	$ 0/t
Sulfur dioxide penalty:	$ 0/t
Nitrogen oxides penalty:	$ 0/t

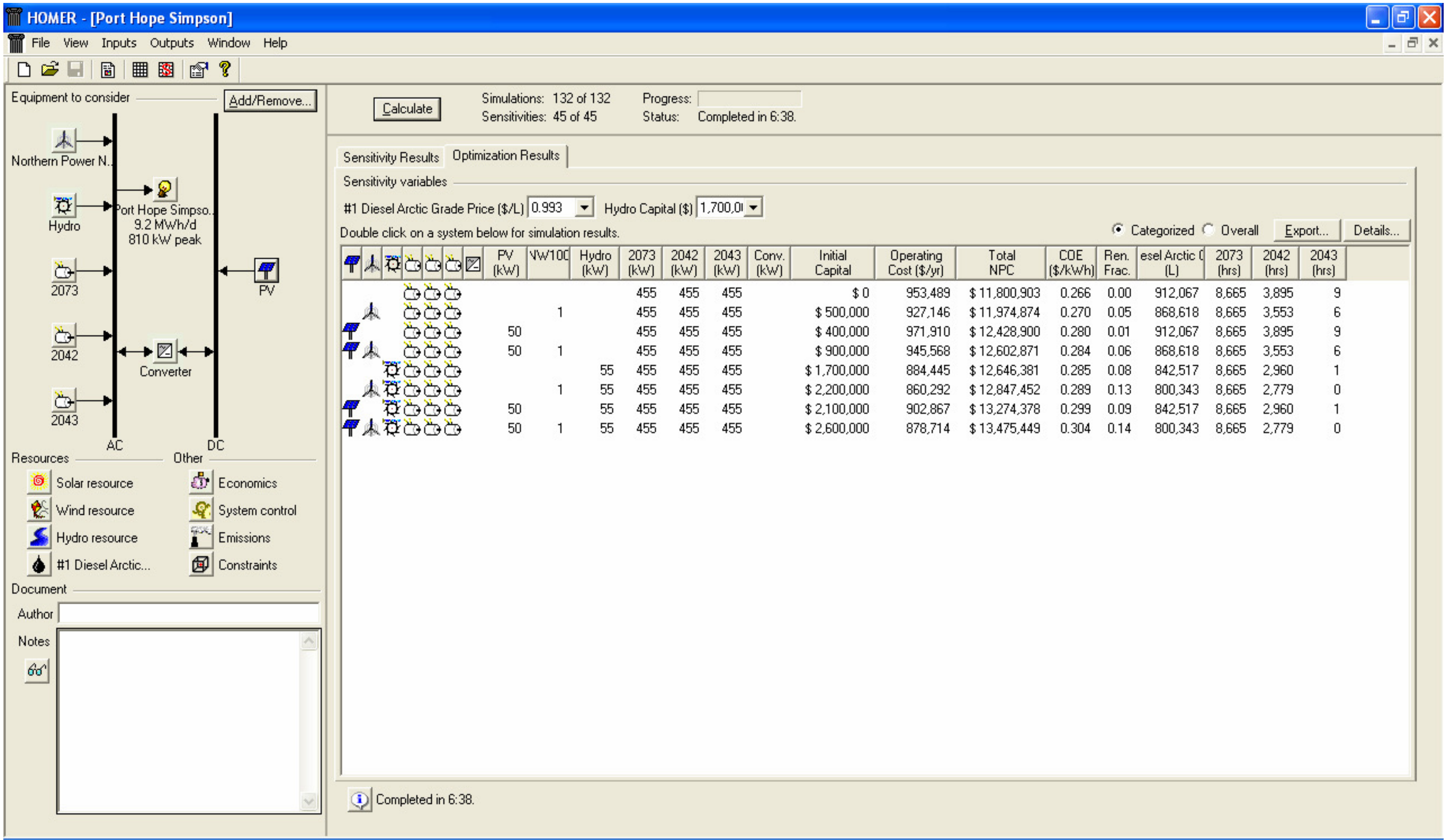
Constraints

Maximum annual capacity shortage:	0%
Minimum renewable fraction:	0%

Operating reserve as percentage of hourly load:	10%
Operating reserve as percentage of peak load:	0%
Operating reserve as percentage of solar power output:	25%
Operating reserve as percentage of wind power output:	50%



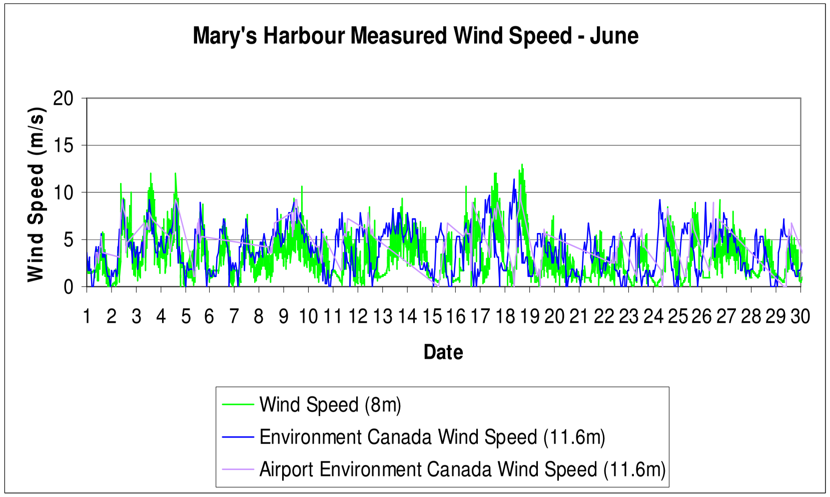
Port Hope Simspon HOMER Results – 2011 System Load

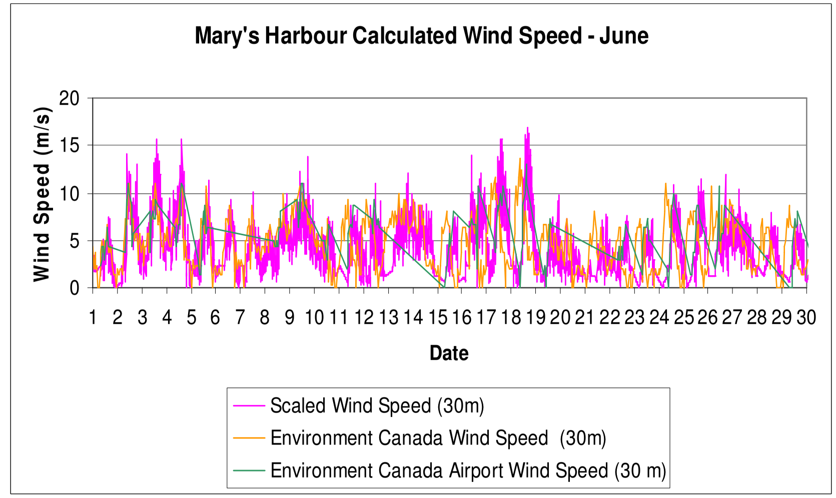


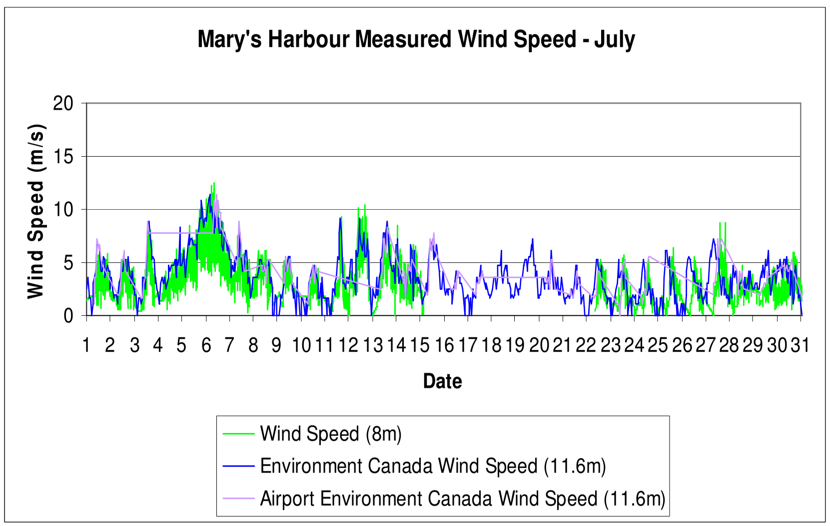
PV (kW)	NW100	Hydro (kW)	2073 (kW)	2042 (kW)	2043 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic ((L)	2073 (hrs)	2042 (hrs)	2043 (hrs)
			455	455	455		$ 0	953,489	$ 11,800,903	0.266	0.00	912,067	8,665	3,895	9
	1		455	455	455		$ 500,000	927,146	$ 11,974,874	0.270	0.05	868,618	8,665	3,553	6
50			455	455	455		$ 400,000	971,910	$ 12,428,900	0.280	0.01	912,067	8,665	3,895	9
50	1		455	455	455		$ 900,000	945,568	$ 12,602,871	0.284	0.06	868,618	8,665	3,553	6
		55	455	455	455		$ 1,700,000	884,445	$ 12,646,381	0.285	0.08	842,517	8,665	2,960	1
	1	55	455	455	455		$ 2,200,000	860,292	$ 12,847,452	0.289	0.13	800,343	8,665	2,779	0
50		55	455	455	455		$ 2,100,000	902,867	$ 13,274,378	0.299	0.09	842,517	8,665	2,960	1
50	1	55	455	455	455		$ 2,600,000	878,714	$ 13,475,449	0.304	0.14	800,343	8,665	2,779	0

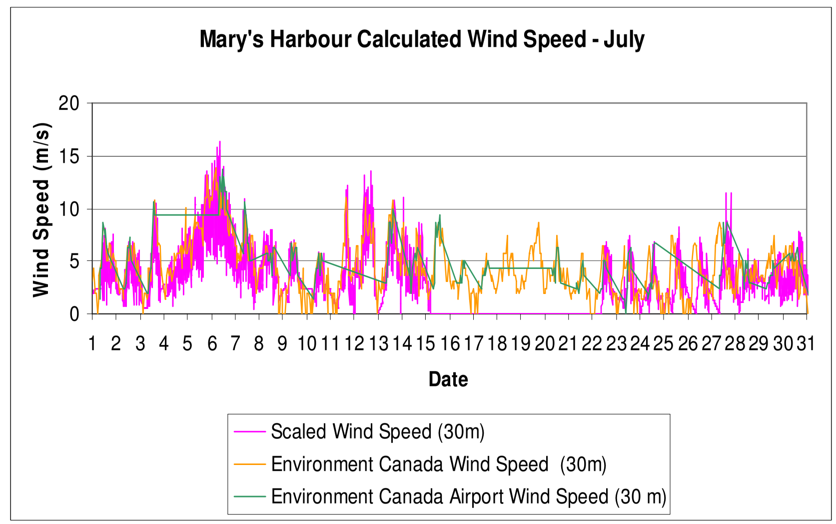
Port Hope Simpson HOMER Results – 2015 System Load

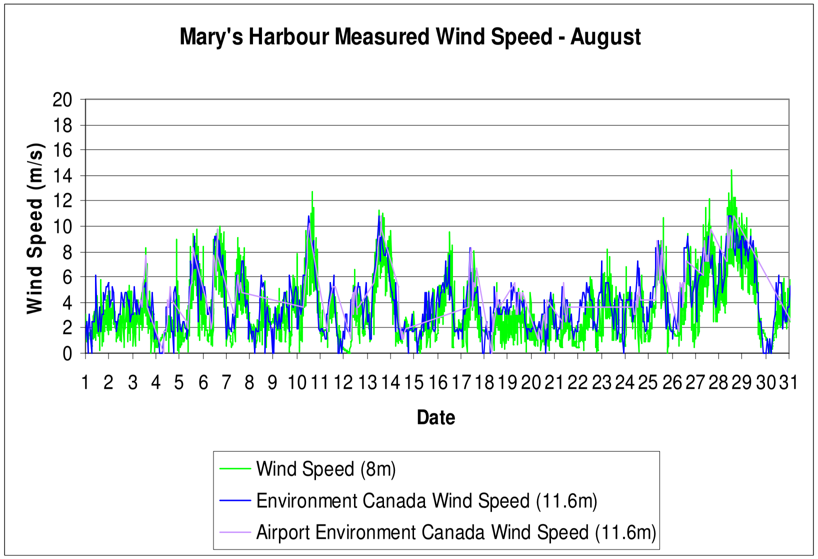
APPENDIX G – MARY'S HARBOUR

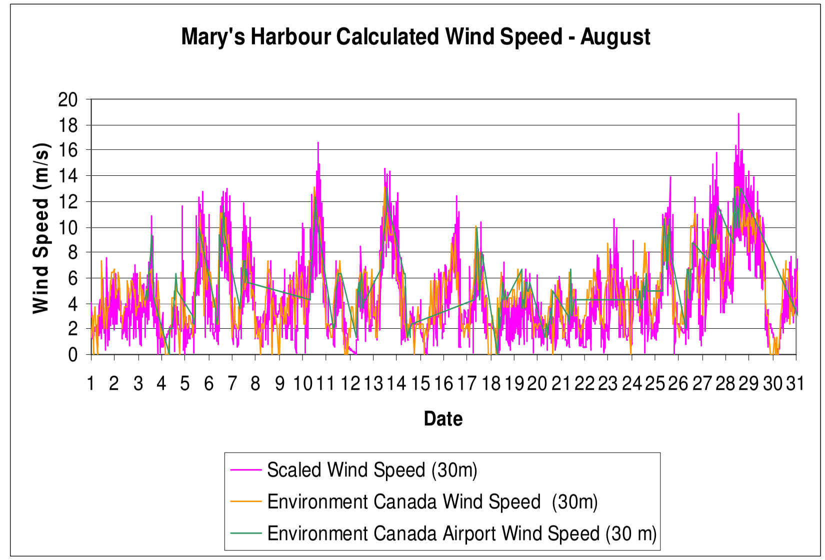

Mary's Harbour Measured Wind Speed - June
Wind Speed (m/s)
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Wind Speed (8m)
Environment Canada Wind Speed (11.6m)
Airport Environment Canada Wind Speed (11.6m)

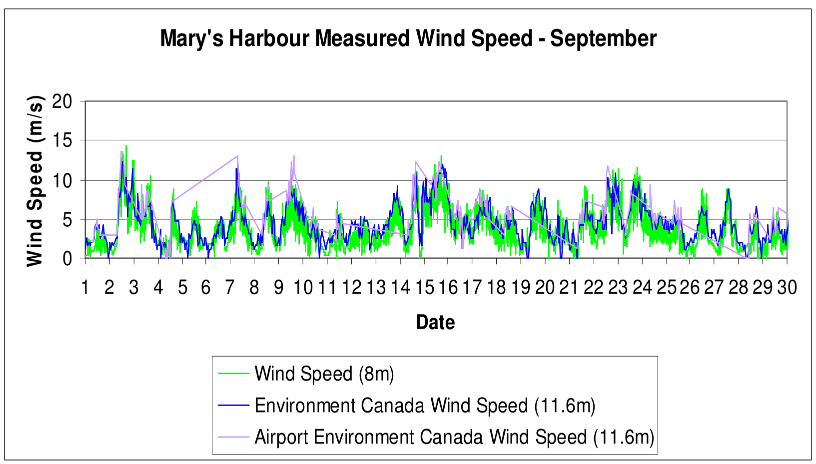

Mary's Harbour Calculated Wind Speed - June
Wind Speed (m/s)
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30 m)

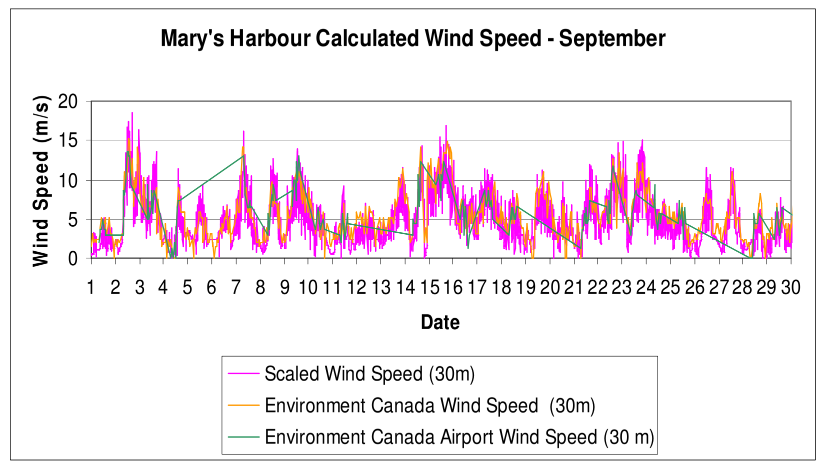

Mary's Harbour Measured Wind Speed - July
Wind Speed (m/s)
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Wind Speed (8m)
Environment Canada Wind Speed (11.6m)
Airport Environment Canada Wind Speed (11.6m)

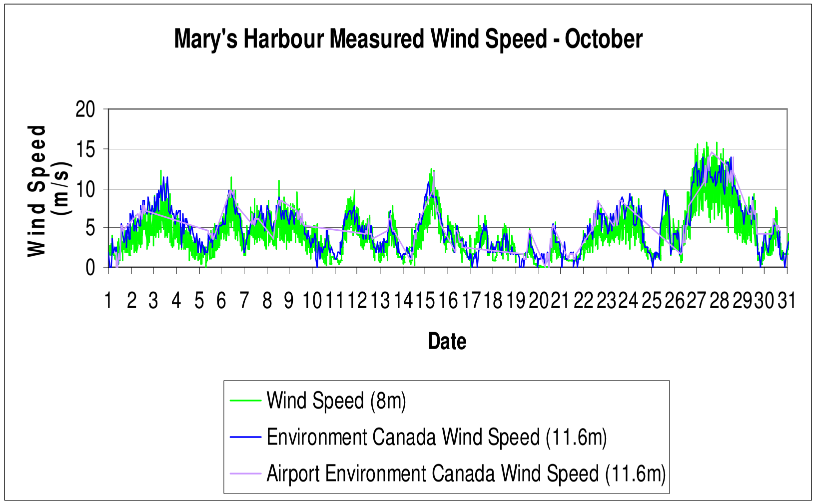

Mary's Harbour Calculated Wind Speed - July
Wind Speed (m/s)
0
5
10
15
20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30 m)

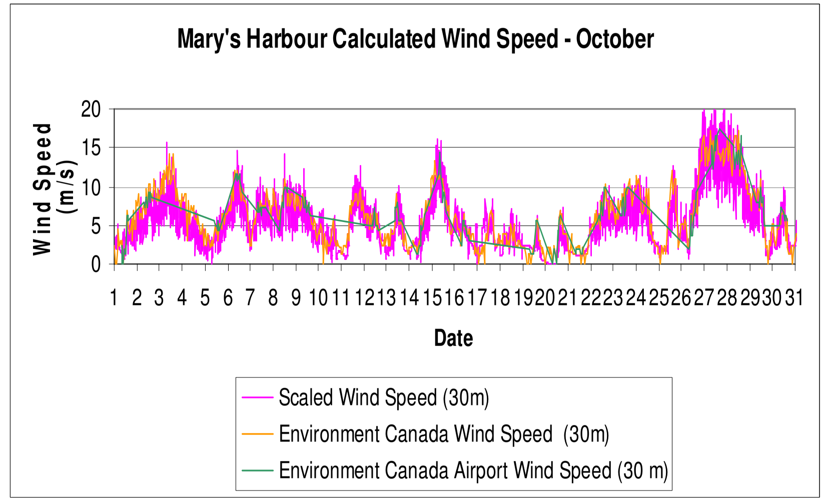

Mary's Harbour Measured Wind Speed - August
Wind Speed (m/s)
20
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Wind Speed (8m)
Environment Canada Wind Speed (11.6m)
Airport Environment Canada Wind Speed (11.6m)

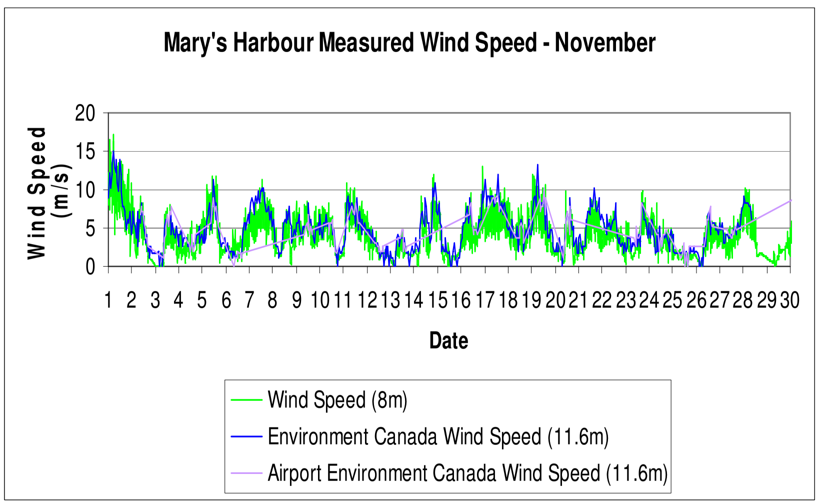

Mary's Harbour Calculated Wind Speed - August
Wind Speed (m/s)
20
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30 m)

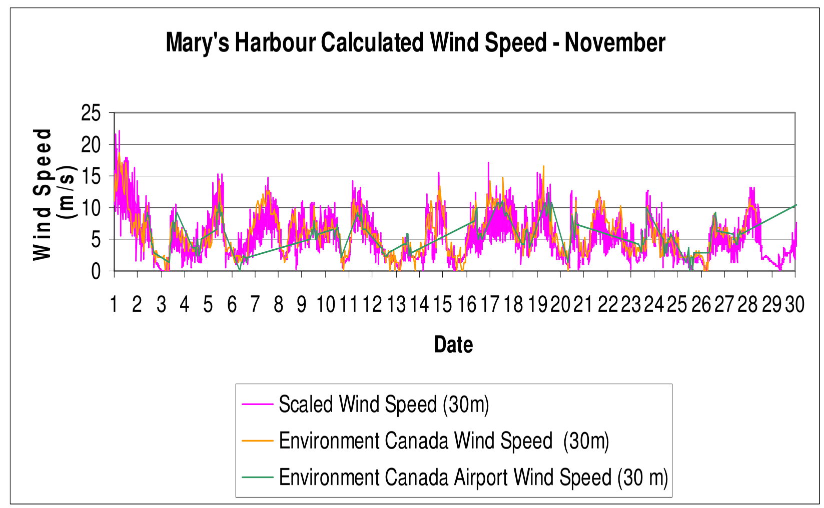

Mary's Harbour Measured Wind Speed - September
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Wind Speed (8m)
Environment Canada Wind Speed (11.6m)
Airport Environment Canada Wind Speed (11.6m)

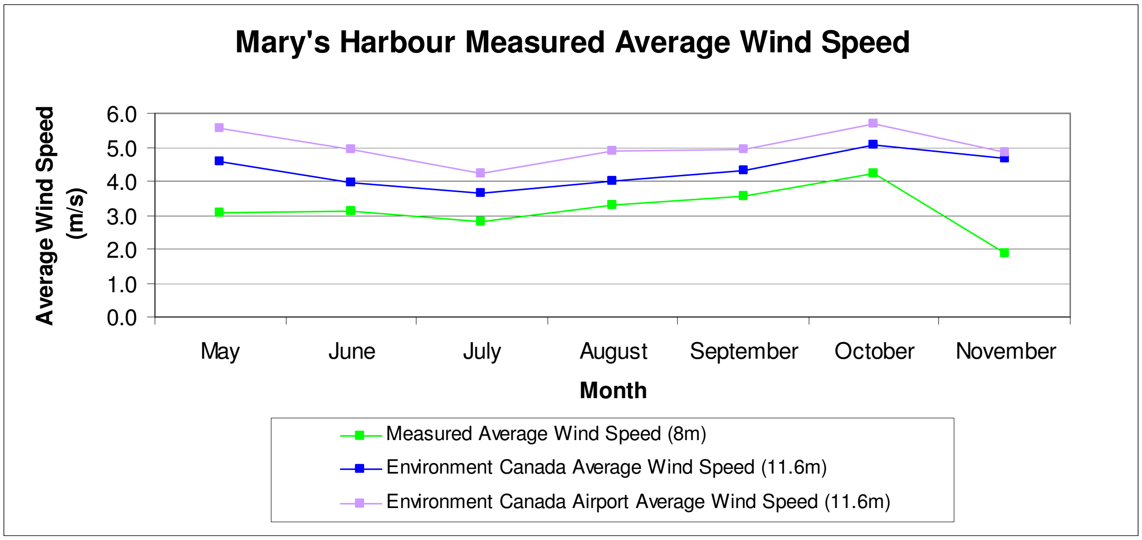

Mary's Harbour Calculated Wind Speed - September
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30 m)

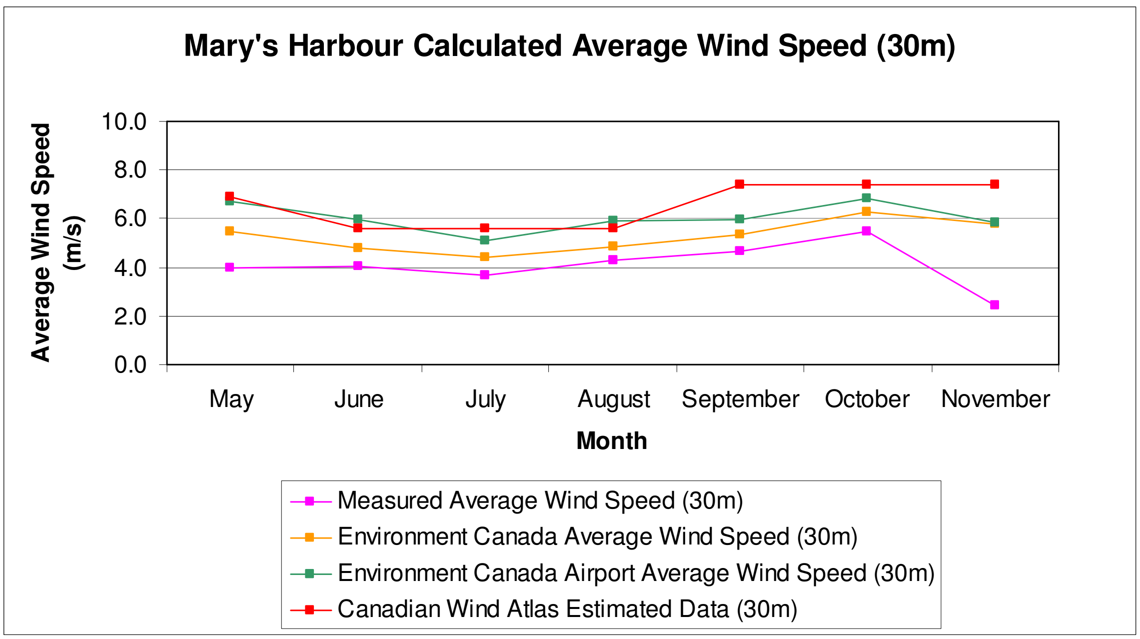

Mary's Harbour Measured Wind Speed - October
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Wind Speed (8m)
Environment Canada Wind Speed (11.6m)
Airport Environment Canada Wind Speed (11.6m)

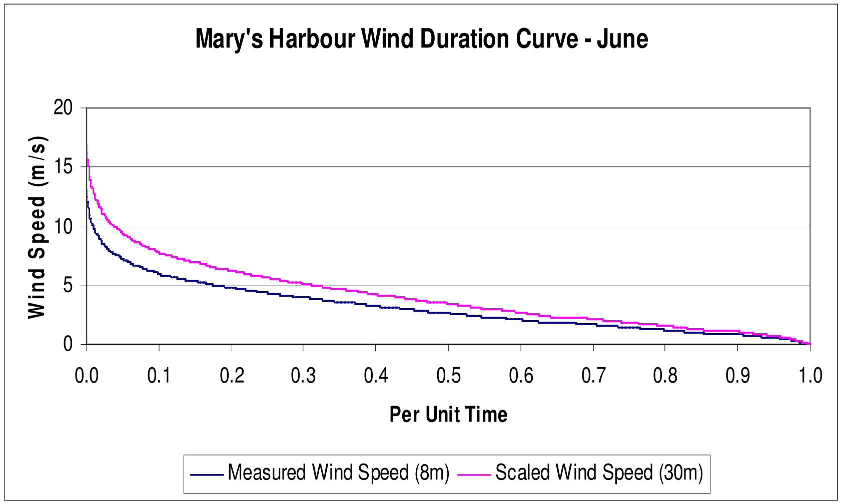

Mary's Harbour Calculated Wind Speed - October
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30 m)

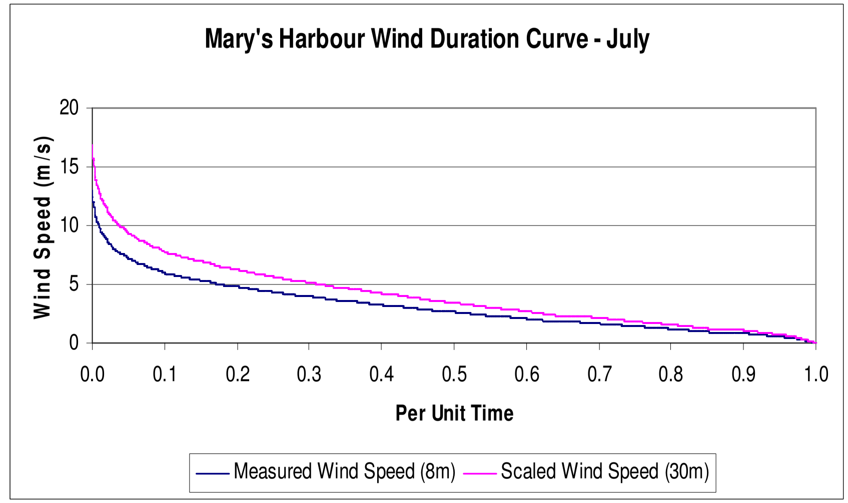

Mary's Harbour Measured Wind Speed - November
Wind Speed (m/s)
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Wind Speed (8m)
Environment Canada Wind Speed (11.6m)
Airport Environment Canada Wind Speed (11.6m)

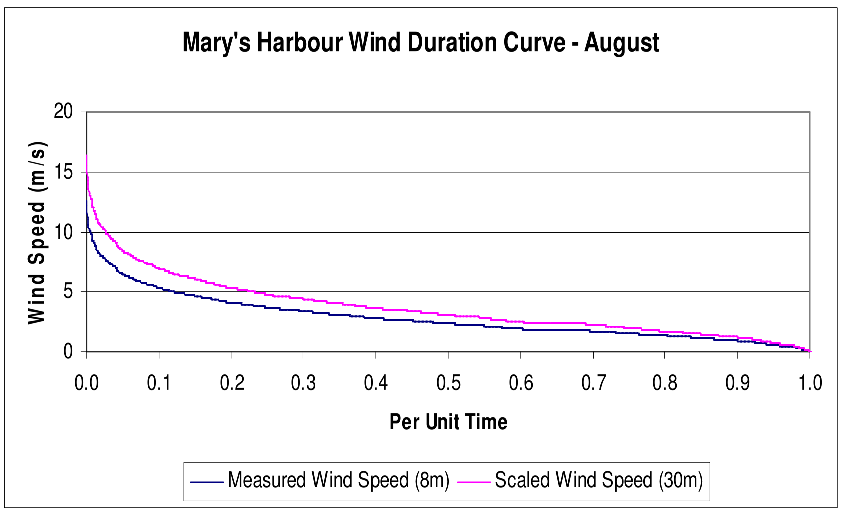

Mary's Harbour Calculated Wind Speed - November
Wind Speed (m/s)
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date
Scaled Wind Speed (30m)
Environment Canada Wind Speed (30m)
Environment Canada Airport Wind Speed (30 m)

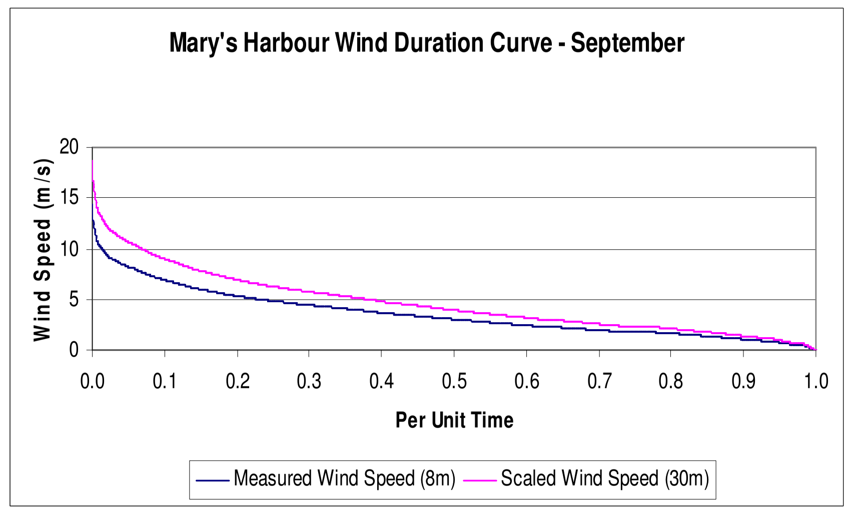

Mary's Harbour Measured Average Wind Speed
Average Wind Speed (m/s)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
May
June
July
August
September
October
November
Month
Measured Average Wind Speed (8m)
Environment Canada Average Wind Speed (11.6m)
Environment Canada Airport Average Wind Speed (11.6m)

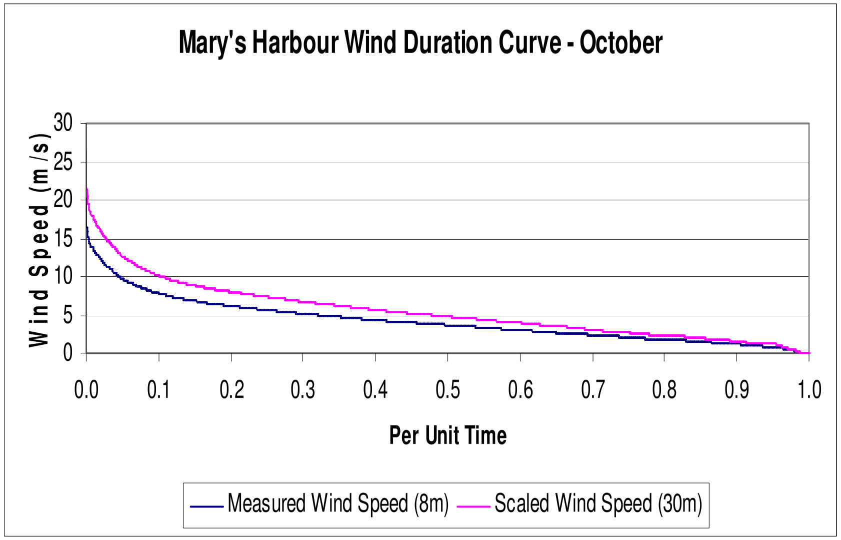

Mary's Harbour Calculated Average Wind Speed (30m)
Average Wind Speed (m/s)
10.0
8.0
6.0
4.0
2.0
0.0
May
June
July
August
September
October
November
Month
Measured Average Wind Speed (30m)
Environment Canada Average Wind Speed (30m)
Environment Canada Airport Average Wind Speed (30m)
Canadian Wind Atlas Estimated Data (30m)

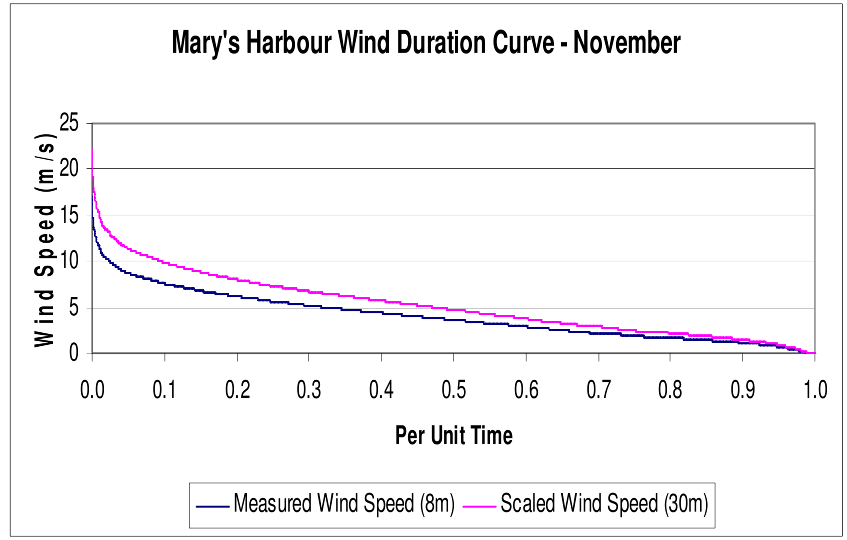

Mary's Harbour Wind Duration Curve - June
Wind Speed (m/s)
20
15
10
5
0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Per Unit Time
Measured Wind Speed (8m)
Scaled Wind Speed (30m)

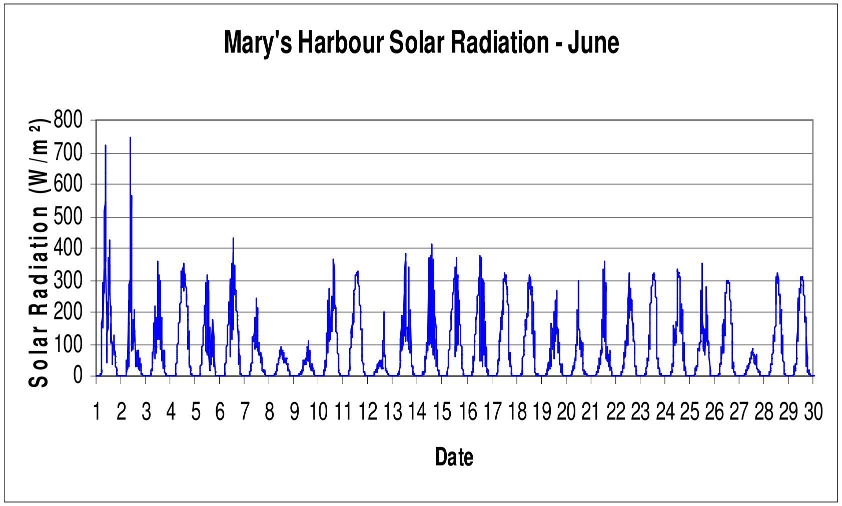

Mary's Harbour Wind Duration Curve - July
Wind Speed (m/s)
20
15
10
5
0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Per Unit Time
Measured Wind Speed (8m)
Scaled Wind Speed (30m)

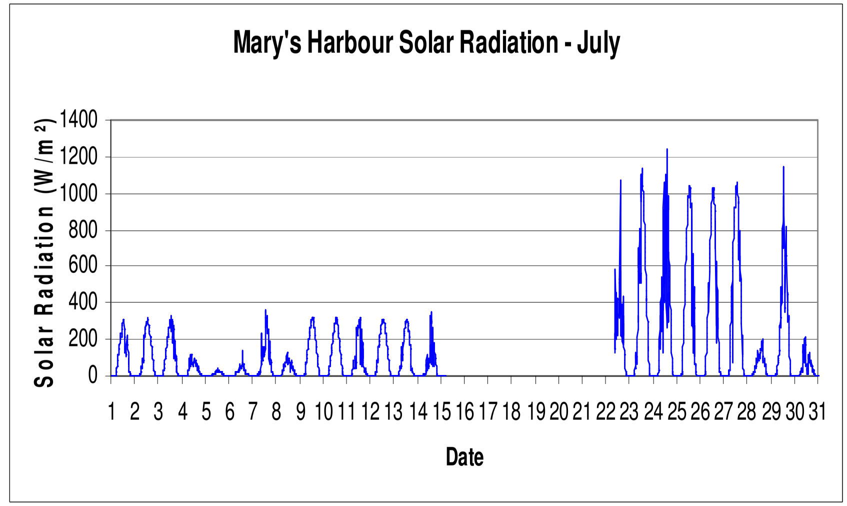

Mary's Harbour Wind Duration Curve - August
Wind Speed (m/s)
20
15
10
5
0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Per Unit Time
Measured Wind Speed (8m)
Scaled Wind Speed (30m)

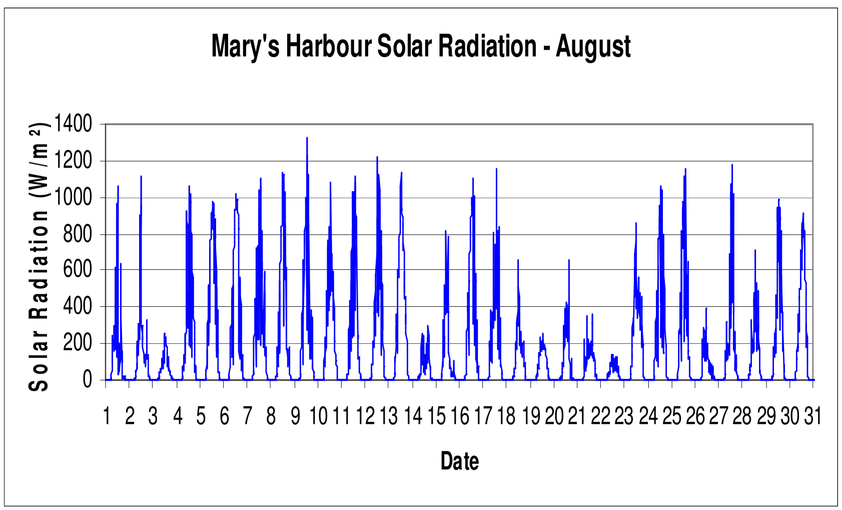

Mary's Harbour Wind Duration Curve - September
Wind Speed (m/s)
20
15
10
5
0
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Per Unit Time
Measured Wind Speed (8m)
Scaled Wind Speed (30m)

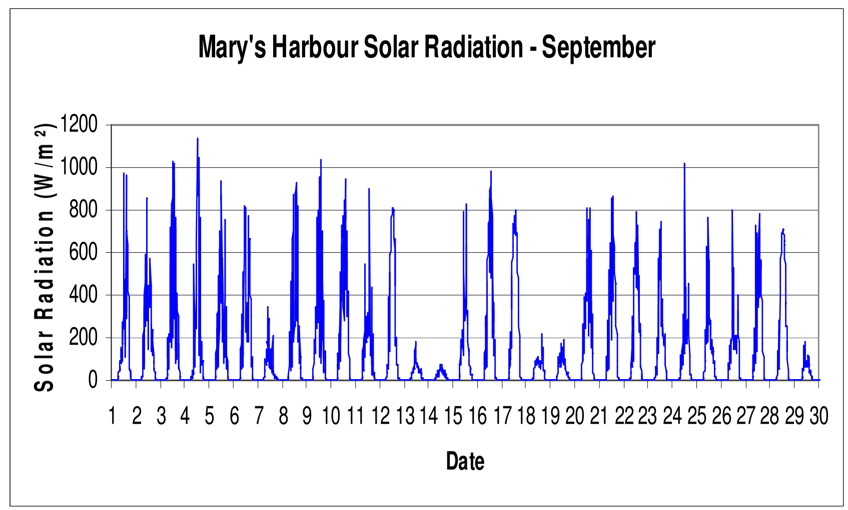

Mary's Harbour Wind Duration Curve - October
Wind Speed (m/s)
30
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (8m)
Scaled Wind Speed (30m)

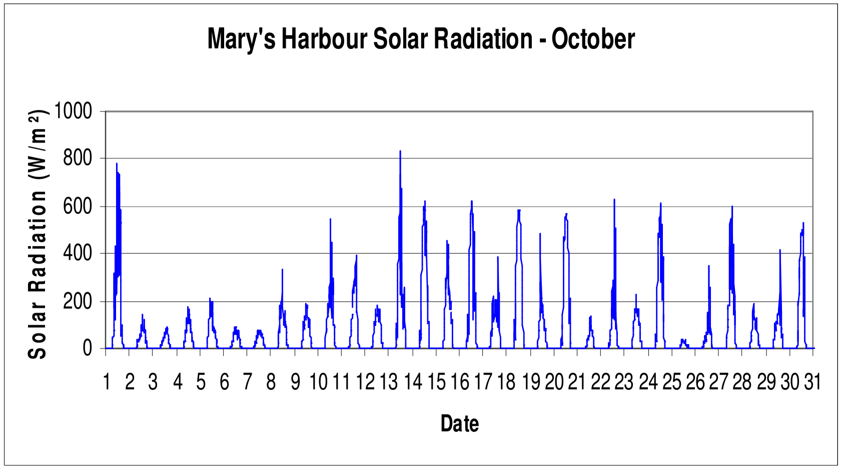

Mary's Harbour Wind Duration Curve - November
Wind Speed (m/s)
25
20
15
10
5
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Per Unit Time
Measured Wind Speed (8m)
Scaled Wind Speed (30m)

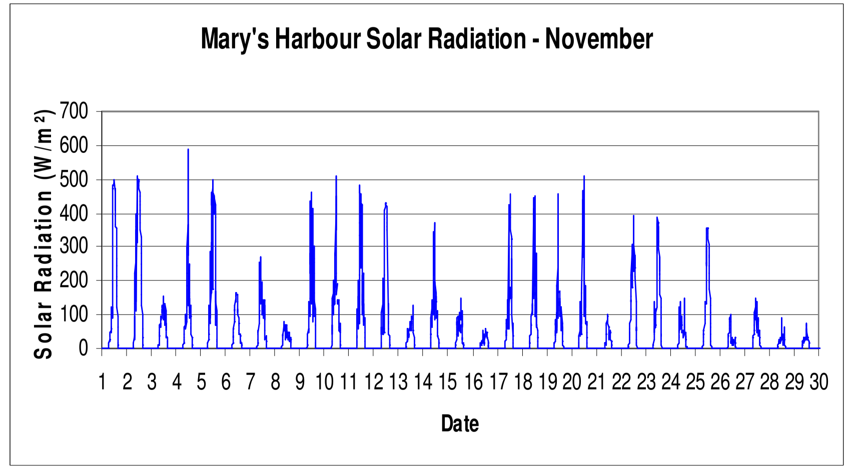

Mary's Harbour Solar Radiation - June
Solar Radiation (W/m²)
Date

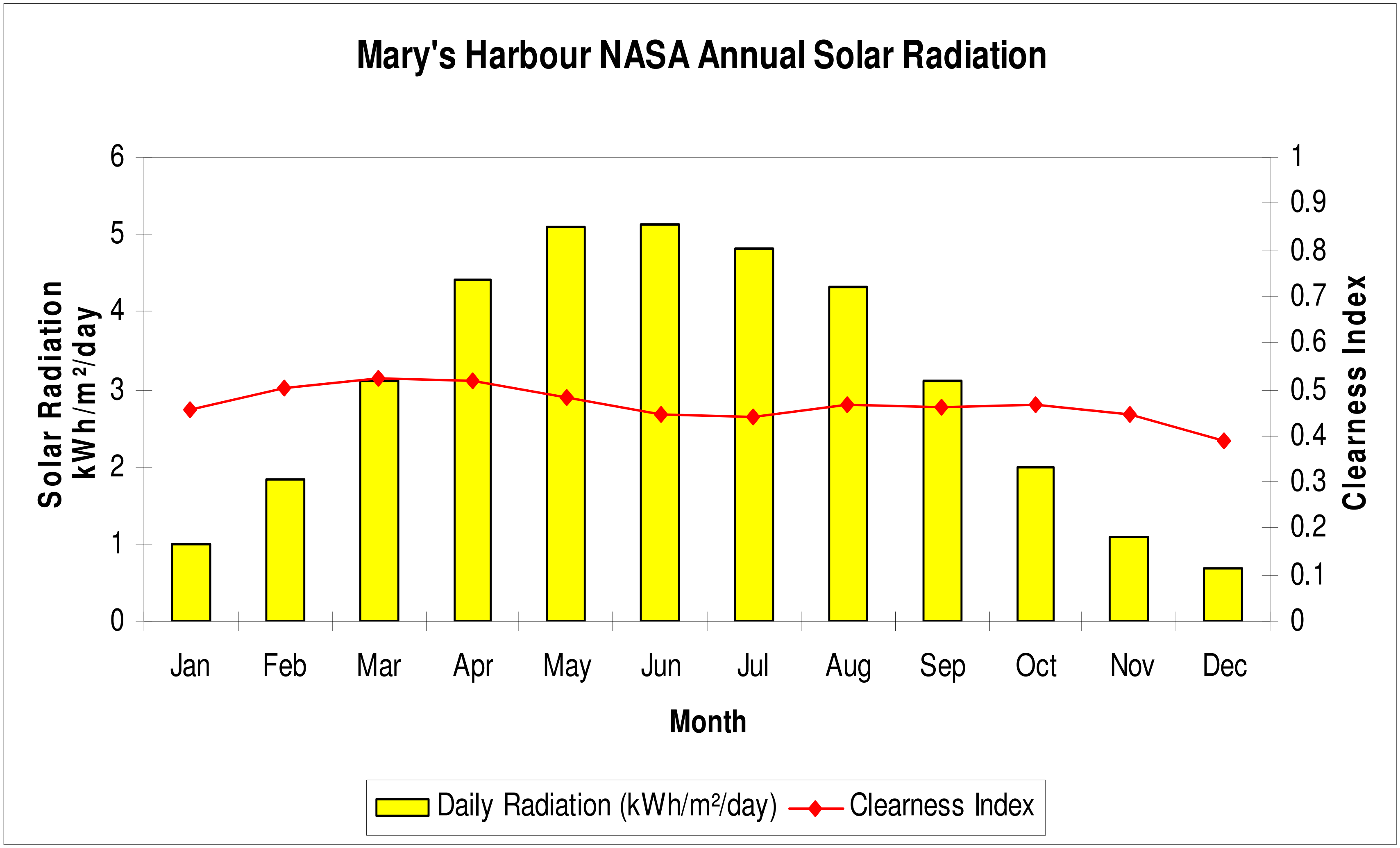

Mary's Harbour Solar Radiation - July
Solar Radiation (W/m²)
Date

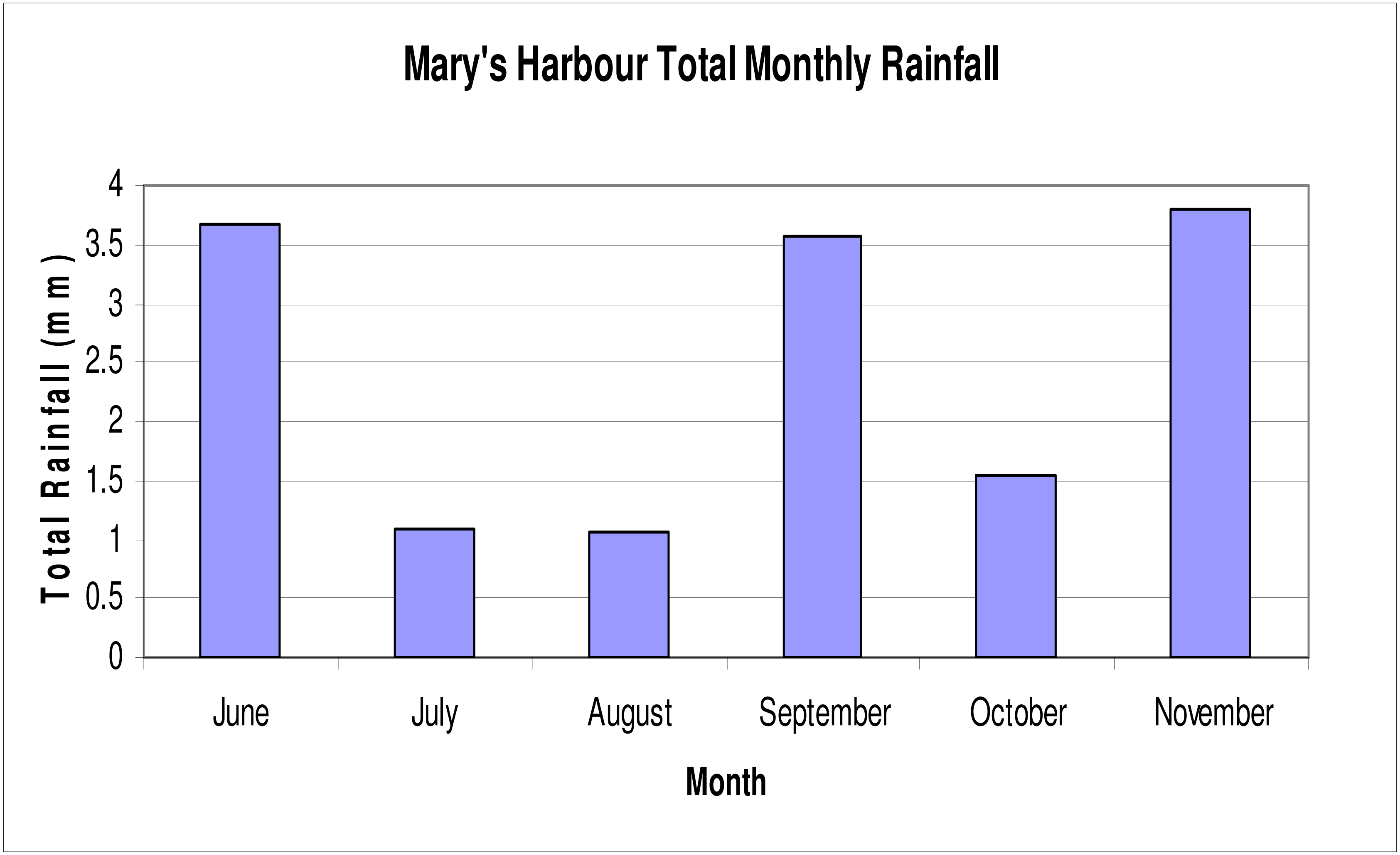

Mary's Harbour Solar Radiation - August
Solar Radiation (W/m²)
Date


Mary's Harbour Solar Radiation - September
Solar Radiation (W/m²)
Date


Mary's Harbour Solar Radiation - October
Solar Radiation (W/m²)
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date


Mary's Harbour Solar Radiation - November
Solar Radiation (W/m²)
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Date


Mary's Harbour NASA Annual Solar Radiation
Solar Radiation kWh/m²/day
0
1
2
3
4
5
6
Clearness Index
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Daily Radiation (kWh/m²/day)
Clearness Index

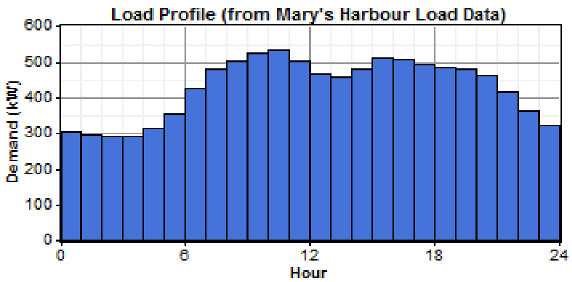

Mary's Harbour Total Monthly Rainfall
Total Rainfall (mm)
4
3.5
3
2.5
2
1.5
1
0.5
0
June
July
August
September
October
November
Month

HOMER Input Summary

File name: MSH.hmr
File version: 2.68 beta
Author:

AC Load: Mary's Harbour Net System Load

Data source:	Mary's Harbour Load Data.txt
Daily noise:	8.32%
Hourly noise:	6.61%
Scaled annual average:	10,367, 10,471, 10,573, 10,666, 10,756 kWh/d
Scaled peak load:	839, 847, 856, 863, 870 kW
Load factor:	0.515



PV

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
50.000	400,000	400,000	10,000
100.000	750,000	750,000	15,000

Sizes to consider:	0, 50, 100 kW
Lifetime:	20 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	52.3 deg
Azimuth:	0 deg
Ground reflectance:	20%

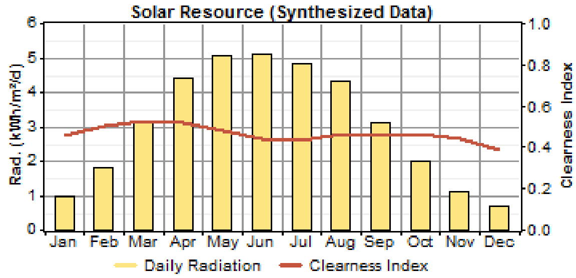
Solar Resource

Latitude: 52 degrees 18 minutes North
Longitude: 55 degrees 50 minutes West
Time zone: GMT -3:30

Data source: Synthetic

Month	Clearness Index	Average Radiation
		(kWh/m^2/day)
Jan	0.454	0.980
Feb	0.505	1.820
Mar	0.525	3.100
Apr	0.518	4.410
May	0.481	5.090
Jun	0.445	5.120
Jul	0.438	4.830
Aug	0.466	4.320
Sep	0.460	3.120
Oct	0.465	1.990
Nov	0.444	1.100
Dec	0.387	0.680

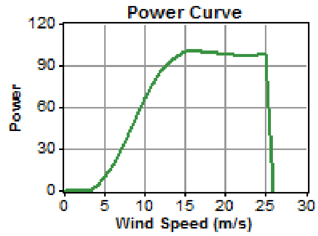
Scaled annual average: 3.04 kWh/m²/d



AC Wind Turbine: Northern Power NW100/21

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	500,000	400,000	10,000

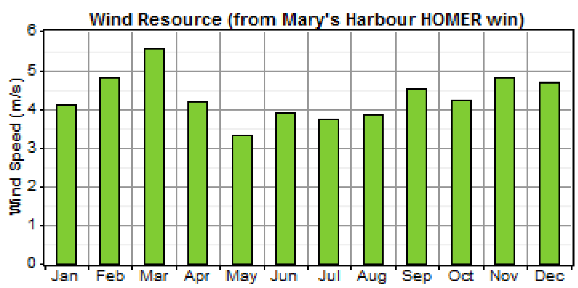
Quantities to consider: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Lifetime: 20 yr
Hub height: 37 m



Wind Resource

Data source: Mary's Harbour HOMER wind speeds.txt

Month	Wind Speed (m/s)
Jan	4.11
Feb	4.78
Mar	5.56
Apr	4.18
May	3.30
Jun	3.89
Jul	3.71
Aug	3.83
Sep	4.51
Oct	4.22
Nov	4.80
Dec	4.69



Weibull k: 1.60
Autocorrelation factor: 0.861
Diurnal pattern strength: 0.0797
Hour of peak wind speed: 10
Scaled annual average: 4.29 m/s
Anemometer height: 8 m
Altitude: 8 m

Wind shear profile: Logarithmic
Surface roughness length: 0.01 m

AC Hydro:

Capital cost: $ 3,040,000, 9,354,000, 8,769,000, 4,677,000, 5,495,000, 5,000,000, 6,900,000, 1,700,000, 3,700,000
Replacement cost: $ 0
O&M cost: $ 33,860, 44,070, 40,700, 18,550, 12,290, 7,190, 6,260, 700, 700/yr
Lifetime: 60 yr
Available head: 12, 16, 73, 12, 16, 14, 12, 5, 31 m
Design flow rate: 4,460, 4,360, 880, 2,450, 1,220, 820, 830, 210, 40 L/s
Min. flow ratio: 15, 15, 10, 15, 15, 15, 15, 15, 15%
Max. flow ratio: 100%
Turbine efficiency: 85%
Pipe head loss: 0%

Consider systems without hydro: Yes

Hydro Resource

Data source: Synthetic

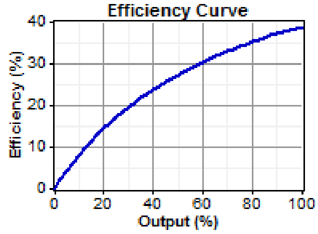
Month	Stream Flow (L/s)
Jan	188
Feb	124
Mar	141
Apr	382
May	394
Jun	382
Jul	394
Aug	394
Sep	382
Oct	394
Nov	382
Dec	318

Residual flow: 0 L/s
Scaled annual average: 321, 411, 384, 175, 117, 68, 60, 7, 7 L/s

AC Generator: 2037

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
600.000	0	600,000	1.850

Sizes to consider: 600 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.105 L/hr/kW
Fuel curve slope: 0.144 L/hr/kW

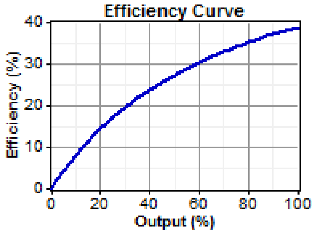


AC Generator: 2038

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)

600.000	0	600,000	1.850

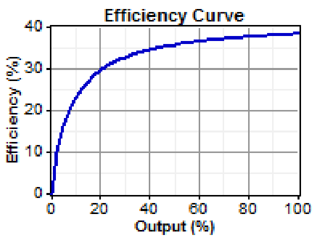
Sizes to consider: 600 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.105 L/hr/kW
Fuel curve slope: 0.144 L/hr/kW



AC Generator: 2048

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
810.000	0	600,000	2.489

Sizes to consider: 810 kW
Lifetime: 100,000 hrs
Min. load ratio: 30%
Heat recovery ratio: 0%
Fuel used: #1 Diesel Arctic Grade
Fuel curve intercept: 0.0186 L/hr/kW
Fuel curve slope: 0.235 L/hr/kW



Fuel: #1 Diesel Arctic Grade

Price: $ 0.922, 0.921, 0.941, 0.970, 0.970/L
Lower heating value: 45.8 MJ/kg
Density: 809 kg/m3
Carbon content: 88.0%
Sulfur content: 0.0500%

Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
100.000	64,000	64,000	6,400

Sizes to consider: 0, 100 kW
Lifetime: 15 yr
Inverter efficiency: 90%
Inverter can parallel with AC generator: Yes
Rectifier relative capacity: 100%
Rectifier efficiency: 85%

Economics

Annual real interest rate: 8%
Project lifetime: 60 yr
Capacity shortage penalty: $ 0/kWh
System fixed capital cost: $ 0

System fixed O&M cost:	$ 0/yr

Generator control

Check load following:	Yes
Check cycle charging:	No

Allow systems with multiple generators:	Yes
Allow multiple generators to operate simultaneously:	Yes
Allow systems with generator capacity less than peak load:	No

Emissions

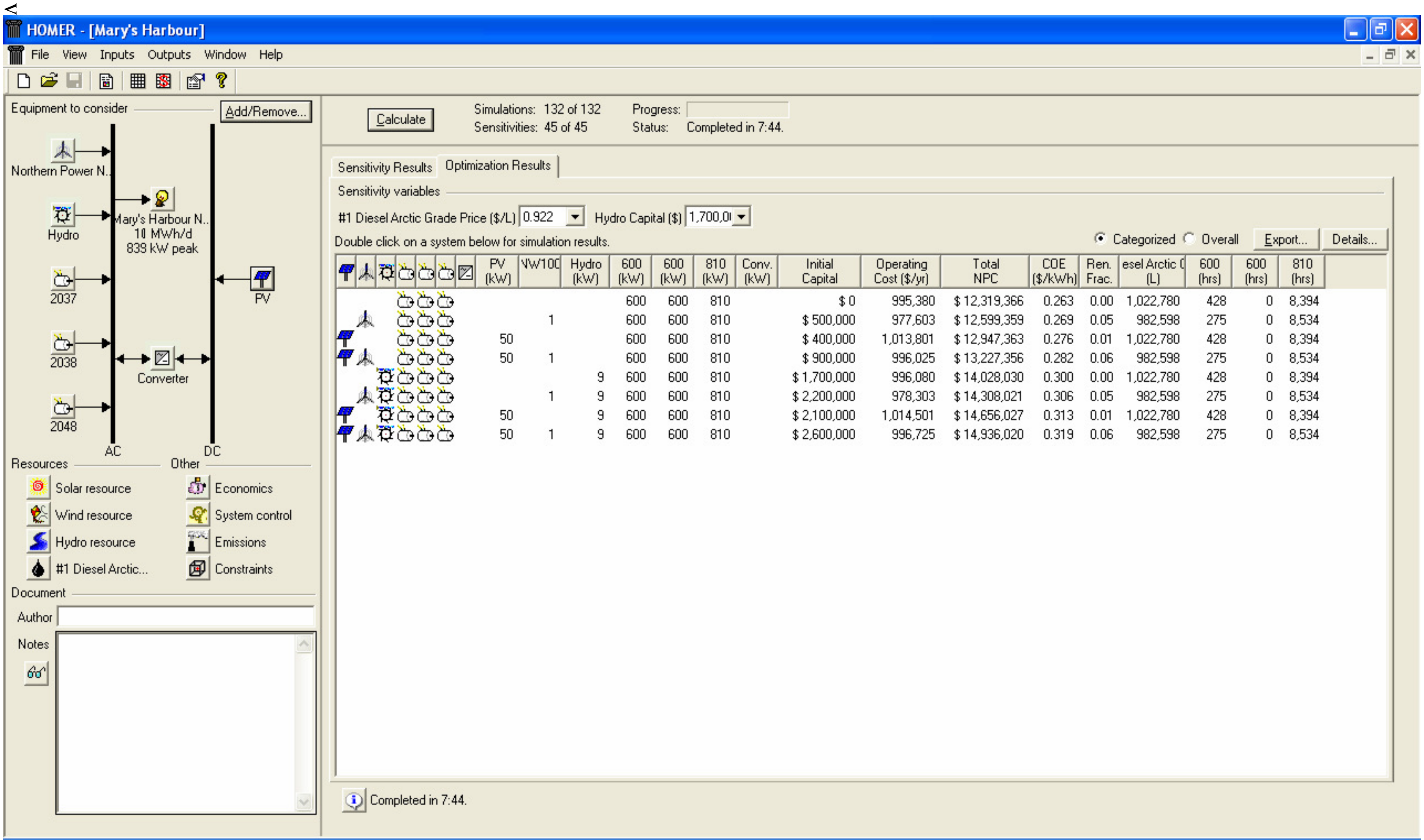
Carbon dioxide penalty:	$ 0/t
Carbon monoxide penalty:	$ 0/t
Unburned hydrocarbons penalty:	$ 0/t
Particulate matter penalty:	$ 0/t
Sulfur dioxide penalty:	$ 0/t
Nitrogen oxides penalty:	$ 0/t

Constraints

Maximum annual capacity shortage:	0%
Minimum renewable fraction:	0%

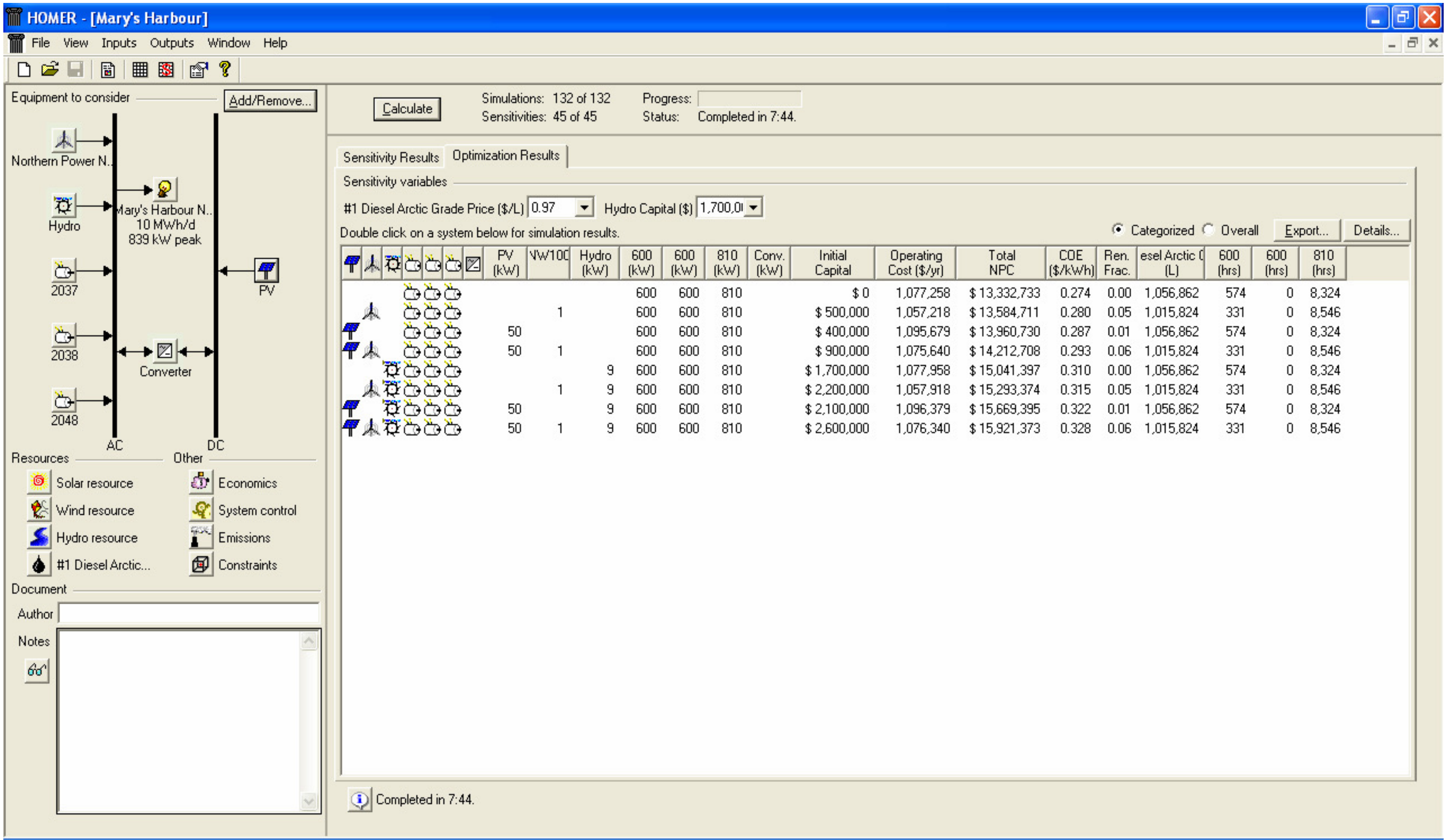
Operating reserve as percentage of hourly load:	10%
Operating reserve as percentage of peak load:	0%
Operating reserve as percentage of solar power output:	25%
Operating reserve as percentage of wind power output:	50%

v



PV (kW)	NW100	Hydro (kW)	600 (kW)	600 (kW)	810 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic ((L)	600 (hrs)	600 (hrs)	810 (hrs)
			600	600	810		$ 0	995,380	$ 12,319,366	0.263	0.00	1,022,780	428	0	8,394
	1		600	600	810		$ 500,000	977,603	$ 12,599,359	0.269	0.05	982,598	275	0	8,534
50			600	600	810		$ 400,000	1,013,801	$ 12,947,363	0.276	0.01	1,022,780	428	0	8,394
50	1		600	600	810		$ 900,000	996,025	$ 13,227,356	0.282	0.06	982,598	275	0	8,534
		9	600	600	810		$ 1,700,000	996,080	$ 14,028,030	0.300	0.00	1,022,780	428	0	8,394
	1	9	600	600	810		$ 2,200,000	978,303	$ 14,308,021	0.306	0.05	982,598	275	0	8,534
50		9	600	600	810		$ 2,100,000	1,014,501	$ 14,656,027	0.313	0.01	1,022,780	428	0	8,394
50	1	9	600	600	810		$ 2,600,000	996,725	$ 14,936,020	0.319	0.06	982,598	275	0	8,534

Mary's Harbour HOMER Results – 2011 System



PV (kW)	NW100	Hydro (kW)	600 (kW)	600 (kW)	810 (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	esel Arctic ((L)	600 (hrs)	600 (hrs)	810 (hrs)
			600	600	810		$ 0	1,077,258	$ 13,332,733	0.274	0.00	1,056,862	574	0	8,324
	1		600	600	810		$ 500,000	1,057,218	$ 13,584,711	0.280	0.05	1,015,824	331	0	8,546
50			600	600	810		$ 400,000	1,095,679	$ 13,960,730	0.287	0.01	1,056,862	574	0	8,324
50	1		600	600	810		$ 900,000	1,075,640	$ 14,212,708	0.293	0.06	1,015,824	331	0	8,546
		9	600	600	810		$ 1,700,000	1,077,958	$ 15,041,397	0.310	0.00	1,056,862	574	0	8,324
	1	9	600	600	810		$ 2,200,000	1,057,918	$ 15,293,374	0.315	0.05	1,015,824	331	0	8,546
50		9	600	600	810		$ 2,100,000	1,096,379	$ 15,669,395	0.322	0.01	1,056,862	574	0	8,324
50	1	9	600	600	810		$ 2,600,000	1,076,340	$ 15,921,373	0.328	0.06	1,015,824	331	0	8,546

Mary's Harbour HOMER Results – 2015 System