The Potential for Wind Energy in Atlantic Canada

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Abstract

Canadians are among the highest per-capita producers of carbon dioxide in the world due to their heavy reliance on fossil fuels. This problem is exacerbated in Atlantic Canada by government policies that foster the reduction of foreign oil imports through the use of indigenous coal. Fortunately, Atlantic Canada is well situated to take advantage of many renewable sources of energy, such as solar, biomass, hydroelectric, and wind. This paper considers the environmental and economic benefits of utilizing the region's vast wind potential.

1 Introduction

Canada, in common with most other industrialized countries, relies heavily on fossil fuels in all sectors of its economy. Much of the demand for fossil fuels has been met through indigenous sources of coal, oil, and natural gas. However, through extravagant use, declining stocks, and geographical disparities, many regions of the country are now forced to rely upon foreign sources of oil to satisfy demand. One region in particular is Atlantic Canada, which consists of the country's four easternmost provinces.

Atlantic Canada has a small population (approximately 2 million people) and occupies roughly 5.4 per cent of Canada's landmass [8]. The economy of Atlantic Canada is resource-based, with the majority of the workforce involved in primary industries such as fishing, forestry, and pulp and paper. As a result, the region has a high energy intensity. With little economically recoverable oil or natural gas, the region relies heavily on imported oil and indigenous coal [3].

Projected energy usage in the region suggests that many economic and energy planners still believe that economic growth goes hand-in-hand with an increased energy demand. For example, the Canadian government's National Energy Board (NEB), which forecasts energy production and usage for Canada, consistently projects higher energy demand in Atlantic Canada [9, 10]. In the case of Atlantic Canada, carbon dioxide emissions from increased fossil fuel demand are expected to rise anywhere from 40 to 52 per cent over 1988 levels by the year 2005 [7].

On the basis of declining Canadian oil production and the corresponding rise in demand for foreign oil, as well as the inexorable link between environmental damage and fossil fuels, this paper examines the costs and potential ecological benefits of utilizing the region's vast wind resource. Through the use of a software tool that permits the modelling of wind turbines and wind farms, the paper shows that wind is a viable, renewable energy source for Atlantic Canada.

2 Data

The data used by the modelling tool comes from three sources: Environment Canada (wind data for Atlantic Canada); Test Station for Windmills (Danish wind turbine data); and Oregon State University (wind site costing).

2.1 Wind Data for Atlantic Canada

The Atmospheric Environment Service (AES) is the branch of Environment Canada that is responsible for collecting Canadian climate data, including solar radiation, temperature, precipitation, and wind. In Atlantic Canada, AES maintains some 77 stations, all of which record wind data using either type U2A wind equipment or type 45B anemometers [5]. Wind data collected by the U2A equipment is more accurate since it uses sixteen compass points as opposed to the eight employed by the type 45B. In most cases, the wind data has been collected over a period of at least twenty years. Data for each site is expressed on a monthly basis as a mean wind speed and as a percentage of the monthly total for each compass direction.

The wind data supplied by AES is also annotated, describing the site in question, anemometer information, and, in some cases, the history of the equipment used at the site. For example, the station information pertaining to Cape Race, Newfoundland, indicates that the anemometer is at a height of 9.1m and that "*the surrounding country is rolling, treeless with the Atlantic Ocean north-northeast to south-west.*"

It must be noted that not all AES data is as favourable as that described for Cape Race. In many sites (including Cape Race), the anemometer is not at the standard 10m height. Also, many sites are poorly located. For instance, the station at April Brook, Nova Scotia, was "*mounted on a standard 10m tower in a hollow that was surrounded by hills. It was poor exposure. It was in* *operation from November 1966 to January 1976.*" The authors estimate that the data from some 40 per cent of all sites in Atlantic Canada is of poor quality due to exposure and obstruction problems.

2.2 Danish Wind Turbine Data

In order to gain estimates of the electrical generation capacity of various sites throughout the region, wind turbine data was taken from the Catalog of Danish Wind Turbines [11]. The data in question consists of turbine rotor diameter, maximum power output, and the form factor based upon various wind speeds. Four models of turbine were examined: Bonus 150kw; Bonus 450kw; Vestas V20 100kw; and Windane-34 400kw. In all cases, turbine output is assumed to conform to a Rayleigh distribution [6].

2.3 Site Costing

The site costing information is based upon work performed by Oregon State University and described in [1]. The siting information consists of turbine capital, operating, siting, and removal costs, as well as financial costs. Together, this information allows the calculation of the unit energy cost (UEC) of a wind farm.

3 The Modelling Tool

The modelling tool consists of a software suite that permits a user to simulate a wind farm for a given site. The modelling tool consists of three major components.

3.1 Wind Frequency Module

The wind frequency module determines the number of hours of wind at various wind speeds for a given site based upon AES wind data using the following equation (where *freq* and *speed* are the percentage of time and the wind speed for a given direction and month, respectively):

$$\sum_{m=JAN}^{DEC} \sum_{d=North}^{NorthEast} hours(speed(d,m)) = freq(d,m) \times speed(d,m)$$

The results obtained by the module are recorded as the number of hours over the period of a year at a specified wind speed. The module works with either 8 or 16 point data. For example, the AES data for Cape Race produces the wind-speed duration curve shown in table 1.

3.2 Energy Profile

The second module develops an energy profile for a given model of turbine at a given site. The output from the energy profile module consists of the expected electrical output of a turbine at each wind speed for each form factor. As an example, a Bonus 450kw wind turbine sited at Cape Race produces the energy profile shown in table 2 (assuming a Rayleigh distribution).

3.3 Wind Farm

The data generated by the aforementioned modules can be combined to show the yearly electrical output for a single turbine or group of turbines (i.e., a wind farm) at a specified site. The third module is designed to calculate the unit energy cost of a wind farm consisting of a number of given wind turbines; the costs are based upon the data supplied by the University of Oregon. Since the terrain at the site may vary, the module allows the user to specify the number of turbines at a given form factor. It is assumed that the turbines making up the wind farm are optimally spaced.

For instance, a wind farm consisting of 100 Bonus 450kw turbines at Cape Race would produce over 94,670 MWhr per year at a cost of 5.72 cents per kilowatt hour.

4 Simulation Results

The modelling tool described above is being used to determine the potential for wind energy in Atlantic Canada. Since the AES data is limited to a small fraction of possible sites in the region, the results of the modelling tool are limited to these sites. However, to give an indication of this potential, table 3 shows the simulation results from six sites across the region. Each site supports a wind farm of 100 Bonus 150kw turbines operating at 95 per cent availability. Figure 1 shows the location of each wind farm.

5 Concluding Remarks

This paper has considered the potential of wind power in Atlantic Canada. A modelling tool was described; simulation results from the tool have shown that using current wind turbine technology, electricity can be generated at rates that are competitive with existing thermal power stations.

The environmental benefits of replacing coal-fired generation with electricity from wind turbines include carbon dioxide reduction (the major greenhouse gas) and sulphur dioxide reduction (the major component in acid rain). Finally, given the present high unemployment rates in Atlantic Canada, the development of a wind industry (construction and running of wind farms) would help both the employment situation and the environment.

The authors are presently examining the following issues:

- A more comprehensive survey of Atlantic Canada's wind resource is required, culminating in the production of a regional wind atlas. At present, U.S. Windpower has two sites under examination in Nova Scotia [4].

- Due to the intermittent nature of the wind, conversion of the electricity to hydrogen may be required. Fortunately, there are large salt domes in Nova Scotia that could be used for hydrogen storage [2].

- The icing of turbine blades is an issue requiring further study, given the climatic conditions in the higher latitudes near the Atlantic Ocean.

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Table 1: Wind speed duration curve for Cape Race (AES data)

Speed (m/s):	4	5	6	7	8	9	10	11
Total Hours:	329.9	543.1	2091.1	2324.8	1358.5	1280.7	548.3	133.3

Table 2: Simulated electrical output from a Bonus 450kw at Cape Race

Speed (m/s)	4	5	6	7	8	9	10	11
MWhr produced	7.2	24.9	158.7	253.2	192.9	221.1	109.2	29.4

Table 3: Energy potential for selected wind farm sites

Map Ref.	Site	MWhr/yr	Cap. Fact. (%)	Cost (cents/kwhr)
1	Battle Harbour	38,871	29.6	4.66
2	Twillingate	35,525	27.0	5.09
3	Cape Race	40,267	30.6	4.51
4	Port aux Basques	30,578	23.3	5.90
5	Canso	22,812	17.5	7.83
6	Miscou Island	26,014	20.0	6.85

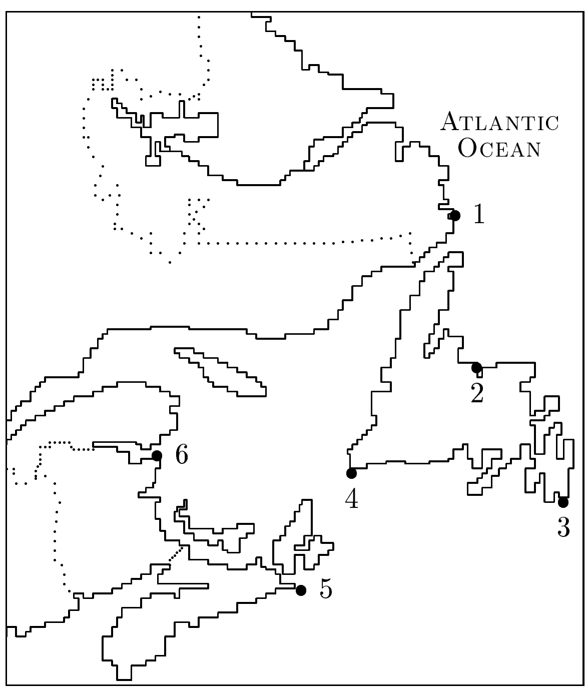

Figure 1: Sample wind farm sites