Financial Viability of the Ontario Wind Energy Generating System

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Introduction

This report is concerned with the financial viability of the Ontario on-shore wind energy generating system (WEGS). Prior to the development of individual projects, the developers are generally optimistic in their predictions of the annual energy generation.

Many of the present operating WEGS were built under the renewable energy standard offer program (RESOP) with a 20-year contract at a price of about $100/MWh. This was supplemented by the federal eco-energy program of an additional $10/MWh. Since the introduction of the Green Energy Act, WEGS are being built under the feed-in-tariff (FIT) program with a 20-year contract at a price of $135/MWh. The eco-energy program has been cancelled by the federal government but in the short term there is residual money in the fund.

It is argued here that:

- the optimistic predictions of the wind energy developers are unlikely to be met or sustained;
- there are significant risk factors associated with wind energy in Ontario;
- despite the above-market prices offered by the Ontario Government under the RESOP and FIT programs and despite the 20-year length of the contract, investors are unlikely to see the long-term return on investment that they might expect for a development with such risk factors,

Capacity Factor of Ontario Wind Energy Generating Systems (WEGS).

Table 1 shows the capacity factor for those WEGS that have been operating for at least 2 years. The capacity factor is the power output divided by the nameplate power output. It varies as the wind speed varies, and can be averaged by day, month or year.

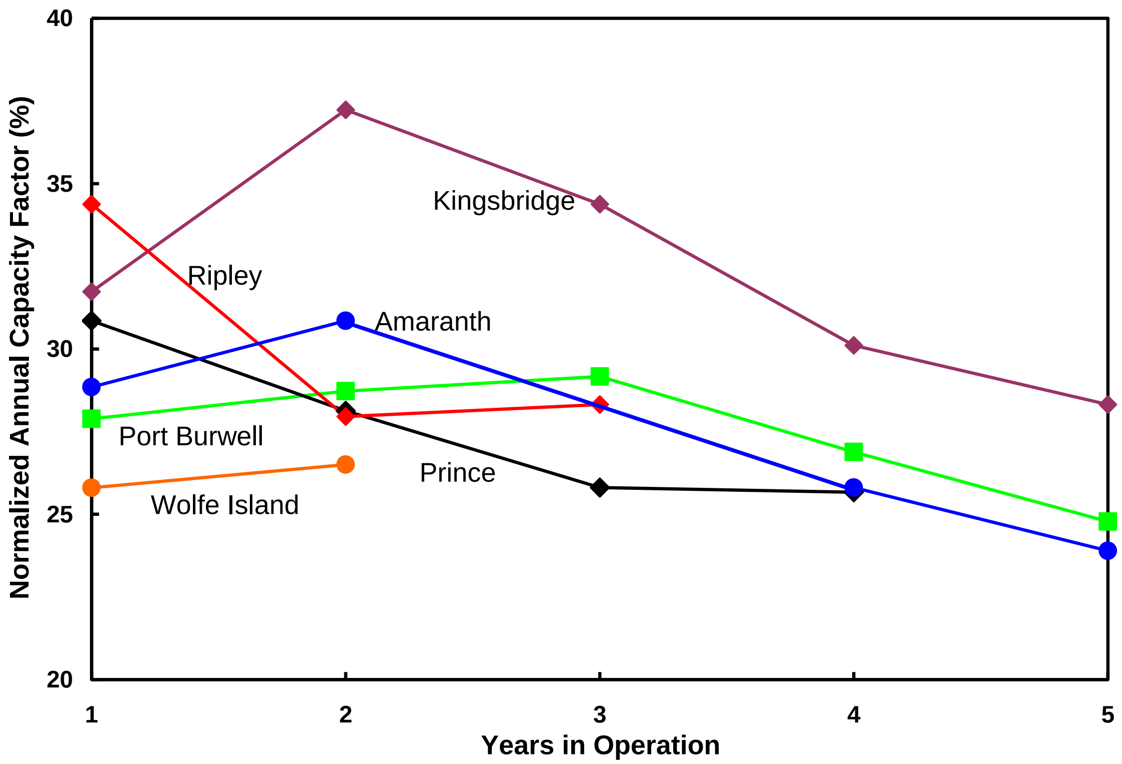
Table 1: Annual Average Capacity Factor (Efficiency) Given as a Percentage.

Year July to June	Amaranth 1	Amaranth 1 and 2	Kingsbridge	Port Alma	Port Burwell	Prince	Ripley	Underwood	Wolfe Island
2006 – 2007	30		33		29				
2007 – 2008	29		35		27	29			
2008 – 2009			33		28	27	33		
2009 - 2010		24	28	34	25	24	26	26	24
2010 - 2011		28	32	35	28	29	33	32	30

These capacity factors come from the hourly output data provided by the Independent Energy System Operator (IESO) [1]. The background for the table is given in Appendix A of this report. From Table 1 we see that the maximum annual average is 35%, the minimum is 24% and the average is 29%.

There are variations from year to year. This is largely because the annual-average wind speed varies from year to year. In turn, the output of wind turbines magnifies this variation; see Appendix B. The capacity factors can be normalized to remove this variation, as outlined in Appendix B. Figure 1 shows the normalized capacity factor for those Ontario WEGS that have been in operation for 3 years or more. Wolfe Island has been added because of its local significance to a proposed development on Amherst Island.

Figure 1: Normalized Capacity Factor for Ontario WEGS as a Function of Years of Service



Typically, the individual Ontario WEGS start within the first year or two at a capacity factor of about 30% (Kingsbridge, on the shore of Lake Huron, is an exception) which then declines. This decline is about 2% per year. This of course augurs very badly for a generating system designed for a 20 year life and with capital funding based upon a 20 year life. All of the analysis is based upon public WEGS power output data provided by IESO and wind speed data from Environment Canada. It involves only averaging, multiplying and dividing numbers in a spreadsheet.

Of course Ontario is not the only place with disappointing output from its WEGS.

- The Muir report from the UK shows a 24% capacity factor for the UK system over the period November 2008 to December 2010 [2].
- The New York State WEGS shows capacity factors of 19% for 2009 and 23% for 2010 [2].
- An analysis of the European WEGS shows that over the years 2003 to 2007 the capacity factor of the EU15 56 GW system was 21% [3].

It turns out that the Ontario system is not the only one to show a systematic decrease in capacity factor with time. Over a 5-year period the Danish WEGS showed an average 1.5%/annum decline in normalized annual average capacity factor (see Appendix B).

One obvious problem with many WEGS in Ontario is the high density of the turbines. In the words of Rolf Miller, Director of Wind Assessment at Chicago-based Acciona Windpower, turbines are being “shoe-horned in” in Ontario [4]. The latest research from John Hopkins University recommends a separation of turbines of 15 blade diameters to avoid wake loss [5] and hence loss of capacity factor. For a modern 2.3 MW turbine this recommendation corresponds to a density of about 0.5 turbine/km^2. The Wolfe Island project, as an example, corresponds to 1 turbine/ km^2, a high density which goes part way to explaining its poor performance. The effect of the high density is quite apparent: in modest wind speeds the down-wind turbines rotate more slowly than the up-wind turbines! However, this is only one possible cause of poor performance and does not explain the decrease in normalized capacity factor with time.

Financial Viability

A. Development Costs and Financial Carrying Costs

It is estimated that the cost of a WEGS development is at least $2.5 million/MW. We can expect investment banks to lend up to 80% of the capital cost at an interest rate of 6% to 8% (current rates) over a 10-year term. The carrying cost of the bank loan is $272,000 - $298,000/MW per annum. The model assumes that the annual payments will be equal over the 10-year term. Analyses will be presented for capacity factors of 20%, 25% and 30%. Judging from the data presented in Fig. 1 the latter two look optimistic over a 10-year period.

B. Operations and Maintenance Costs

Estimating the cost of operations and maintenance (O & M) is difficult: there is virtually no experience of operating industrial wind turbines beyond 10 years. As a result, robust operational data remain relatively scarce. The International Energy Agency puts O & M costs in the range $10 to $30/MWh [6]. A recent major report, the Wind Energy Operations and Maintenance Report, puts the cost of operation and maintenance at US$27/MWh [7], at the top end of the IEA estimate. In addition, major maintenance has been found to be very expensive.

Gearboxes expected to fail after 20 years are failing after 7 or 8 years [6]; rebuilds cost US$0.1M and crane costs are US$0.25M per in and out [8].

There is the additional cost of benefit to landowners ($5,000/MW per annum).

C. Anticipated Revenues

Based on the FIT tariff of $135/MWh various revenue projections can be made depending on the capacity factor. There is a possibility of some extra revenue from the Federal Eco-Energy subsidy (about $10/MWh), and some carbon credits may also be possible. However, on July 28th 2011, the Hon. Joe Oliver, Minister of Natural Resources, announced that the Federal Government will not commit to additional funding of the Eco-Energy subsidy [9].

D. Return on Investment

A sensitivity analysis was conducted to determine the range of outcomes from different cost and revenue possibilities based on assumptions concerning the

Table 2. Annual Return on Investment

Three Capacity Factor (CF) Scenarios Using Different Cost Assumptions; First 10 Years Only.			
	20% CF	25% CF	30% CF
Optimistic Costs: 6% Loan; $20/MWh O&M; Investor Cost: $0.5M/MW			
CARRYING COSTS/MW	$272,000	$272,000	$272,000
O&M/MW	$35,000	$44,000	$53,000
LAND-OWNER BENEFIT/MW	$5000	$5000	$5000
TOTAL COST/MW	$312,000	$321,000	$330,000
TOTAL REVENUE/MW	$237,000	$296,000	$355,000
NET REVENUE (LOSS)/MW	($75,000)	($25,000)	$25,000
RETURN ON INVESTMENT	**-15%**	**-5%**	**5%**
Realistic Costs: 8% Loan; $27/MWh O&M; Investor Cost: $0.5M/MW			
CARRYING COSTS/MW	$298,000	$298,000	$298,000
O&M/MW	$47,000	$59,000	$71,000
LAND-OWNER BENEFIT/MW	$5000	$5000	$5000
TOTAL COST/MW	$350,000	$362,000	$374,000
TOTAL REVENUE/MW	$237,000	$296,000	$355,000
NET REVENUE (LOSS)/MW	($113,000)	($66,000)	($19,000)
RETURN ON INVESTMENT	**-23%**	**-13%**	**-4%**

capacity factor. The return on investment (ROI) analysis is presented on a per annum basis in the table above. The projections are for the first 10 years only. If the WEGS is still operating after 10 years then the equity investors will start to see a significantly higher return on investment.

It is clear from the results of the analysis presented in the table that the most likely financial outcome for the first 10 years of a project is a negative return on investment.

E: A Deeper Analysis

The standard financial model for judging the viability of a project is the combination of net present value (NPV) and internal rate of return (IRR). This has been done for the variables considered above. This analysis, summarized in Table 3 below, accounts for the net revenue over the full 20-year term of the project. The benchmark rate of return has been set at 7.5%. The depreciation has been assumed aggressive to avoid tax payments over the term of the debt financing. The tax rate has been set at 27%. The optimistic case again assumes debt financing of 6% and an O & M cost of $20/MWh. The realistic case assumes 8% and $27/MWh. The analysis confirms that with realistic parameters, including a long term capacity factor of between 20% and 25%, there is unlikely to be any significant return for investors.

Table 3: Net Present Value and Internal Rate of Return

Three Annual Capacity Factor (CF) Scenarios Using Different Cost Assumptions			
	20% CF	25% CF	30% CF
Optimistic Costs: 6% Loan; $20/MWh O&M; Investor Capital Cost: $0.5M/MW			
NPV/MW (Project)	($1,200,000)	($750,000)	($330,000)
IRR (Project)	1.4%	3.7%	5.8%
NPV/MW (Equity)	**($540,000)**	**($120,000)**	**$290,000**
IRR (Equity)	**2.3%**	**6.3%**	**10.6%**
Realistic Costs: 8% Loan; $27/MWh O&M; Investor Capital Cost: $0.5M/MW			
NPV/MW (Project)	($1,500,000)	($1,100,000)	($660,000)
IRR (Project)	0.2%	2.3%	4.3%
NPV/MW (Equity)	**($840,000)**	**($430,000)**	**($40,000)**
IRR (Equity)	**0.3%**	**3.6%**	**7.1%**

NB: The NPV (Project) and IRR (Project) refer to the unlevered case, with no bank financing; these entries are for reference only. The NPV (Equity) and IRR

(Equity) refer to return to the equity holders for the levered case with 80% bank financing. Numbers in brackets are negative

G. Risk Factors

Without even beginning to consider all the environmental and socio-economic factors associated with these projects, the key risk factors for potential investors are:

- long-term capacity factors above 25% are most unlikely;
- the initial cost of development;
- the cost of O&M over a 20-year period;
- the probability that the current rate regime will be maintained (low given current fiscal situation);
- the cost of providing a bond to cover the cost of reclamation (cost not included in the above analysis);
- The possibility that at some sites mitigation measures will be necessary during the bird migratory season, and through the winter in proximity to raptor nesting sites [10];
- the likelihood that turbine noise will be out of compliance at non-participating receptors once the Ministry of the Environments exercises its compliance-testing protocol[1];

Conclusion

It has been demonstrated that the Ontario wind energy generating systems (WEGS) are not financially viable. The reasons include:

- a capacity factor below 30% after a few years of operation;
- a decrease in capacity factor of 2% per annum as the systems age;
- significant risk factors including the high initial development cost, the uncertainty of long-term operation and maintenance, the continuity of the generous feed-in-tariff program, the possible change of government

[1] To date, noise regulation relies only upon calculation of the sound pressure level at non-participating homes. The recent Kent-Breeze Environmental Review Tribunal found in favour of Suncor. However, the Tribunal also stressed that "Nevertheless, if the modeling does end up being inaccurate (recognizing the general point that pre-operation modeling has limitations as compared to accurate post-operation field measurements), then adjustments will have to be made to ensure ongoing compliance. The 40 dB limit is a real limit that Suncor must abide by regardless of its modeling exercises." The reasons for expecting non-compliance are: omission of the uncertainty inherent in the noise prediction calculations; omission of turbulent inflow noise from the prediction calculations; the allowance of generous parameters in the prediction calculations; the large number of complaints from those living in proximity to turbines; the number of buy-outs of abandoned homes by wind developers. On August 22, 2011, the Ministry of the Environment unveiled its protocol for compliance testing [11]. It is too early to know the result of applying the protocol.

policy, and the opposition based upon environmental and health concerns.

The Ontario Government, the wind industry and its investors, and the banking industry need to review their present support for wind energy generation in Ontario and to call a halt to future development.

Acknowledgments

The assistance from colleagues with a professional background in finance is very much appreciated.

References

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Appendix A: Capacity Factor of Ontario Wind Energy Generating Facilities

The tables show the monthly capacity factors for the Ontario wind energy generating systems (WEGS) for the years July 2009 to June 2010 and July 2010 to June 2011. The capacity factor is the actual power output divided by the name-plate power; it is given as a percentage. The name-plate power for each WEGS is given in the second row. As an example, consider the July 2009 entry for Amaranth: The average hourly output for that month was 32 MW. Dividing by the nameplate power of 200 MW, we get 16%. The row labeled **Annual Average** is the 12-month average. The source of the numbers used to generate these tables, the hourly output of the Ontario WEGS, is publically available at: http://www.ieso.ca/imoweb/marketdata/windPower.asp.

The IESO hourly power output goes back to 2006. Similar tables to those shown here, for the earlier years, were used to derive Table 1 in this report.

Table 4: Capacity Factor (Efficiency) Given as a Percentage of the Nameplate Power Output: July 2009 – June 2010

Month	Amaranth	Kings-bridge	Port Alma I	Port Burwell	Prince	Ripley	Under-wood	Wolfe Island	Overall
Nameplate (MW)	**200**	**40**	**101**	**99**	**189**	**76**	**182**	**198**	
July	16	11	18	14	15	12	14	14	14
Aug.	18	21	21	17	19	21	21	16	19
Sep.	16	18	21	17	16	17	16	20	18
Oct.	25	35	39	34	29	30	33	32	31
Nov.	23	32	35	25	34	29	28	22	27
Dec.	31	43	41	36	29	37	39	35	35
Jan.	27	39	48	36	28	39	38	27	33
Feb.	24	25	31	23	21	25	24	23	24
Mar.	28	27	37	26	26	28	26	37	29
Apr.	34	38	47	30	31	36	34	29	33
May	24	24	37	27	25	24	22	20	25
June	19	18	27	18	19	18	18	17	19
Annual Average	**24**	**28**	**34**	**25**	**24**	**26**	**26**	**24**	**26**

Table 5: Capacity Factor (Efficiency) Given as a Percentage of the Nameplate Power Output: July 2010 – June 2011

Month	Amaranth	Dillon	Gosfield	Kings-bridge	Port Alma I	Port Alma II	Port Burwell	Prince	Ripley	Talbot	Under-wood	Wolfe Island	Overall
Nameplate (MW)	**200**	**78**	**50**	**40**	**101**	**99**	**99**	**189**	**76**	**99**	**182**	**198**	
July	16			13	16		12	15	14		16	17	16
Aug.	18			17	14		13	22	19		19	20	18
Sep.	29		22	34	31		26	37	33		35	32	32
Oct.	29			35	37		32	31	29		33	32	32
Nov.	32		39	42	40	37	33	44	40		39	33	37
Dec.	26		42	51	47	51	39	31	53		48	34	39
Jan.	27		38	36	38	43	33	25	39	33	36	27	33
Feb.	43	56	55	45	52	58	47	34	50	51	48	42	46
Mar.	27	40	34	31	38	41	26	28	32	35	29	29	31
Apr.	38	40	49	38	49	52	35	31	38	47	38	38	40
May	23	30	31	25	32	35	20	25	26	29	25	30	27
June	20	25	23	19	25	28	18	26	16	22	16	19	21
Annual Average	**28**			**32**	**35**		**28**	**29**	**33**		**32**	**30**	**31**

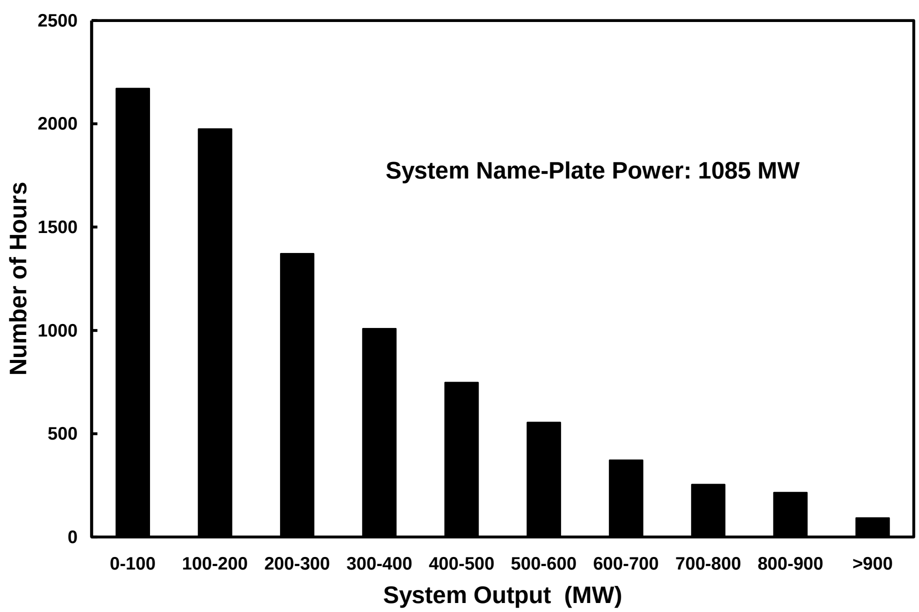
Appendix B: Correction of Capacity Factor for Annual Wind Speed Variation

It is common experience that some years are windier than others, just as some years are wetter or colder. To make sense of the annual average power output of the Ontario WEGS, the averages need to be corrected for the annual average wind speed.

Mathematically, the output of a turbine varies as the cube of the wind speed. This is easy to understand. The kinetic energy density of the atmosphere varies as the square of the wind speed. The volume of air passing through the blade circle varies linearly with the wind speed. Multiply these two factors and the power output varies as the cube of the wind speed. That is, if the wind speed doubles the power increases eight-fold.

There is a limit to the cube law at which the power output flattens off. However, for almost all of the time, turbines operate in the cubic variation range. For instance, the Siemens 2.3 MW turbine obeys the cube law over the range 0 to

Figure 2: Wind Power Output Distribution, July 2009 to June 2010



2.0 MW, or up to 85% of its full power. For the Ontario WEGS, the fraction of time that the output is above 85% is about 1%. This is demonstrated in Figure 2 above. It shows the number of hours during the year July 2009 to June 2010 that the output power was in the range 0 to 100 MW, 100 to 200 MW, and so on. The output was above 900 MW, or 83% of the maximum 1085 MW, for only 92 hours out of the 8760 hours in the year. Therefore we can reliably assume that the annual WEGS power outputs will correlate with the cube of the annual average wind speeds.

A wind speed record for Toronto can be found at: http://toronto.weatherstats.ca/charts/wind_speed-5years.html, with a similar URL for other Canadian cities. Only the records for Toronto go back a full 5 years and therefore Toronto was taken as a proxy for Ontario. The following table reproduces the average wind speeds for the years (July to June) shown. v is the annual average wind speed and v_0 is the five year average (16.87 km/h). As expected, the records show that 2010-2011 was indeed a windy year. The third row in the table is the cube of the ratio of the annual to five-year average wind speed. This is a measure of the extent to which the annual average WEGS power output would have been less than or greater than the five-year average.

Year	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011
v (km/h)	17.08	16.56	16.64	16.50	17.59
$(v/v_0)^3$	1.04	0.94	0.96	0.93	1.13

In order to get a picture of the long-term performance of the Ontario WEGS, the WEGS that have been operating for 3 to 5 years have had their annual capacity factors corrected for this variation in wind speed from year to year. This was done by dividing the annual average capacities in Table 1 of the report by the numbers in the third row of the table above. It is the resulting corrected, or normalized, capacity factors that are plotted in Figure 1 of the report. Once again, I emphasize that all of the numbers used to obtain Figure 1 are in the public domain.

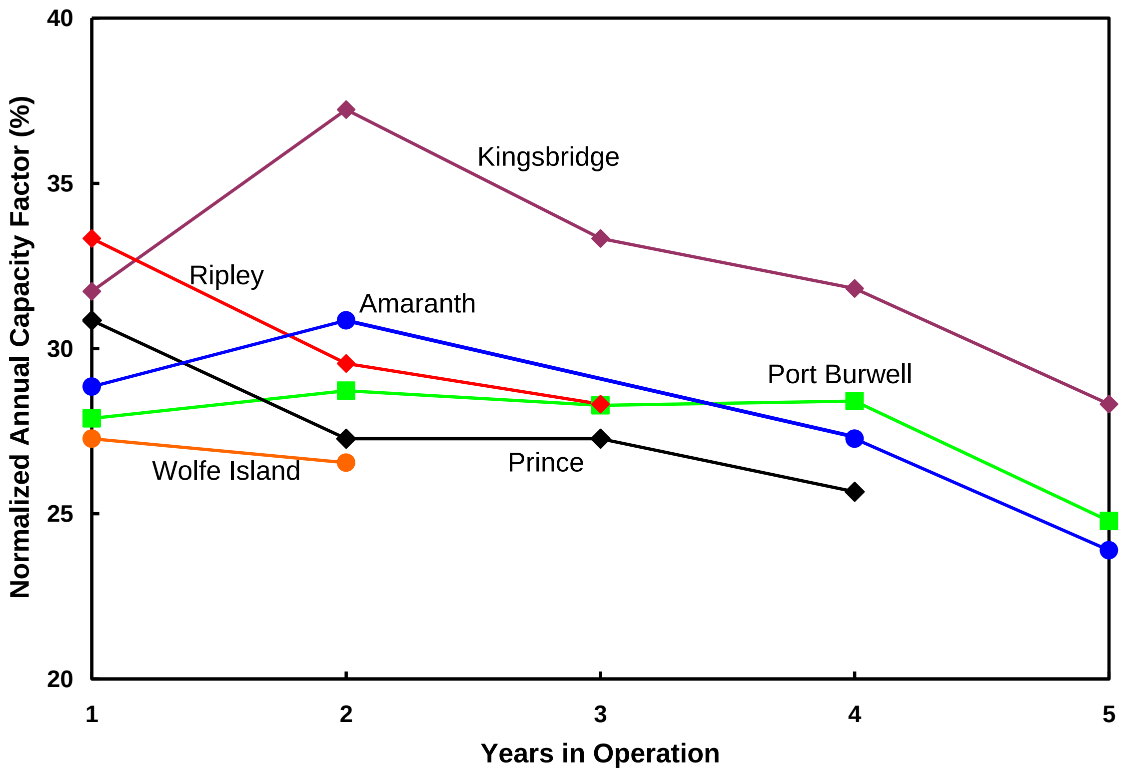
A possible criticism is that Toronto may be an arbitrary choice for the proxy for Ontario. It was done because only Toronto has records going back 5 years. To investigate to what extent this introduces uncertainty, a comparison was made with the cities for which the records go back 3 years. The five cities, widely spaced, were Hamilton, Kingston, North Bay, Ottawa and Thunder Bay. The table below compares the ratio $(v/v_0)^3$ for Toronto and the average of the five cities.

Year	2008-2009	2009-2010	2010-2011
$(v/v_0)^3$ Toronto	0.96	0.93	1.13
$(v/v_0)^3$ Five Cities	0.99	0.88	1.13

The general trend is similar, with 2010-2011 being significantly windier than the previous year. The combined results for the 5 cities and Toronto, for the past three years, can be used to revise the normalized capacity factor graph, Figure 1 of the report. This revision is shown as Figure 3 below. The performance of the

Ontario WEGS remains the same; after a year or two, the normalized capacity factor trends down by about 2% per year.

Figure 3: Normalized Capacity Factor for Ontario WEGS as a Function of Years of Service: Revised to Include Recent Wind Speed Records from 5 Cities.



My colleague, Wayne Gulden, repeated the above analysis for the Danish WEGS using wind speed data for Copenhagen. Over the years 2004 to 2008 the normalized annual average capacity factor decreased from 28% to 21%. A linear regression analysis showed a decrease of 1.5%/annum. Over this period there was little change in the total nameplate power (3.1 GW) suggesting that the analysis was looking at the true aging of the WEGS. Over the period 2008 to 2010, the total nameplate power was increased by 20% and the normalized capacity factor increased to 23%, possibly reflecting the higher capacity factor for the new turbines.