**"Transforming Ontario's Electricity Paradigm:**

**Lessons Arising from Wind Power Integration"**

Keynote Address for

Professional Engineers of Ontario

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Notwithstanding all of the insults to Ontario's power system imposed by our politicians and some of the underperforming technology choices we have made over the years, it is a profound tribute to our power system's engineers that Ontario has one of the most reliable power systems in the world. Our engineers haven't taken reliability for granted.

Blackouts are rich with lessons. Some blackouts, like the 1998 Quebec and Northeast ice storm, have easily identifiable causes like extreme weather. However, some blackouts are caused by complex interactions of many factors. The California blackouts of 2000-2001 were caused by flawed market rules implemented during an attempt to introduce competition. The European Grid failure of November 2006 was initiated by dispatch errors during a transmission outage and subsequently exacerbated by wind power. The August 2003 blackout in Northeastern North America was initiated by transmission line maintenance failures and exacerbated by myopia among grid dispatchers.

These examples illustrate how maintaining power system reliability and operating efficiently are complex challenges. The profound influence of wider public policy considerations outside of traditional reliability and efficiency concerns makes the job all the tougher.

My presentation today is going to discuss the changes coming to Ontario's power system as a result of the Green Energy Act (GEA). I am going to present results from research on Ontario wind power in aid of my argument that society would benefit if our engineers were more active and effective in the policy arena.

**Impact of Green Energy Act**[1]

Radical change to our power system is underway, rewriting the rules in the fields of administrative law, power system engineering, public administration, and economics. I offer these observations with some humility, particularly since I am not an engineer, lawyer, economist or public administrator.

Where many thoughtful people have endorsed the GEA, I offer a contrary view. My judgment is that if carelessly implemented, the GEA could cause significant economic harm and result in costs high enough to undermine public support for the notion of environmental protection. Engineers could make a great contribution to finding a balanced approach to green energy development but need to be mindful of wider policy picture.

Some historical context reveals how radically the Green Energy Act is re-orienting the very purpose of Ontario's power system. Reliable electricity at minimum cost, produced in compliance with our environmental rules, that was the heart of Ontario's historic electricity policy. Electricity policy debates historically revolved around how this ultimate purpose ought to be pursued. During the period from about 1899 until the early 1920s and again during the 1990s, Ontario debated whether the discipline of competition and private ownership would bring lowest long-run costs to consumers or whether a government-controlled monopoly was the cheaper approach. Many times we debated by how much, if at all, environmental rules on the power sector ought to be tightened. Since the 1980s, we have debated whether nuclear power is or could be a low cost producer. Irrespective of the position policy combatants have taken on the issues, a wide consensus supported the underlying objectives.

The GEA puts us on a completely different path with new objectives unrecognizable within the historic paradigm. The GEA's purposes are to protect the environment and promote green economic development. The underlying philosophy is that we can measure how effective we are in protecting the environment by counting the capacity of so called "renewables" -- wind, biogas, and solar generation. The GEA abandons the concept of economically prudent service to customers. Instead the act seeks to promote the interests of particular, politically determined electricity producers. Where once, lowest cost was a key objective, the government is now about to buy vast renewable output at 2 to 13 times current commodity rates. The government explicit states that it prefers non-competitively procured renewables, and will subsidize more heavily, small-scale, renewable power as compared to most efficiently-sized units. Nowhere does the Act or associated policy statements make clear what limits apply to renewable energy procurement. Where once, transmission investments were considered principally on the basis of cost effectiveness, the new act states that renewable generators have the "right to connect". Where once the Ontario Energy Board operated at some arms length from government, now the OEB is now under close government direction. Taxes to pay some of the direct costs of Ontario government departmental programs will be raised by way of electricity levies without parliamentary approval.

[1] For further analysis of the GEA see: "Ontario's green energy plan: Interference goes green" Financial Post, March 5/'09 by Tom Adams.

**Grid Integration Challenges for Wind Power**

To illustrate the challenges ahead, I want to tour you through some of the research on the renewable technology Ontario's green energy policies rely most heavily upon – wind power.

The policy debate over green energy has been dominated by unsupported assertions. As Leonard Cohen says, "slogans are jamming the airwaves".

Advocates and sometimes even government engineers assure us that wind power is decentralized energy, that wind power can help replace coal, that wind volatility is smoothed by distance[2], and that wind can supply a large fraction of our electricity needs without imposing significant indirect costs on consumers. Although I wish it were otherwise, the data is uncomplimentary to this loose talk.

Reliable, economical grid integration of wind power is easier in some places than in others. Quebec has a large hydro-electric fleet with seasonal storage, whereas Ontario's hydro-electric fleet is proportionally less than a third of Quebec's and has limited storage capacity already very efficiently optimized. Ontario is one of the most nuclear-reliant jurisdictions in the world, and our nuclear like wind power is not suited for load following. Denmark's transmission interconnects with neighbours are almost three times greater than Ontario's in percentage terms and being developed more rapidly than in Ontario.[3,4] Another factor in Denmark's favour is that summer, when wind output is lowest, is the lowest season of demand, whereas in Ontario our seasonal demand is out of sync with wind. Glibly importing analysis and conclusions from other jurisdictions without examining the context is regrettably the norm.

What does the wind data say about the challenges ahead for Ontario? Much of what I am going to present is from a paper I co-authored with my colleague Francois Cadieux.[5] Our paper will be presented at the upcoming Climate Change Technology Conference at McMaster next week. Whereas many similar studies rely on simulated production data, our paper analyses hourly actual production data from all of Ontario's large wind farms, the first of which went into service in March 2006.

Getting wind power to consumers when they want it will be a challenge. Unfortunately wind and load are out of sync across several dimensions.

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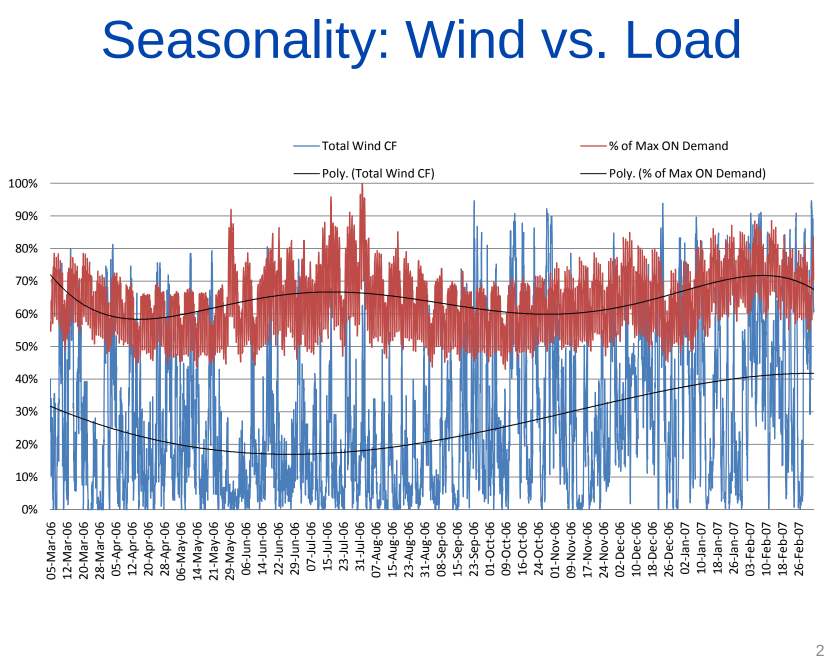
[2] The IESO states: "The geographic diversity of Ontario wind resources, as more sites are commissioned, should mitigate some of the risk associated with wind speed variability." 18-Month Outlook, January '09 to June '10. Note that this statement was dropped in the IESO's update of the 18-Month Outlook for the period April 09 to September '10.

[3] According to "Wind power in Denmark", Dr V.C. Mason (December 2008), Denmark's transmission interconnection capacity is equal to 42% of its installed generation capacity.

[4] Nameplate import capability in Ontario at winter rating is approximately 5,380 MW vs. installed generation capacity at February 2009 of 33,121 MW as per data in the IESO 18 Month Outlook, March 16, 2009.

[5] "Wind Power In Ontario: Quantifying The Benefits of Geographic Diversity", by Tom Adams and Francois Cadieux, (forthcoming).

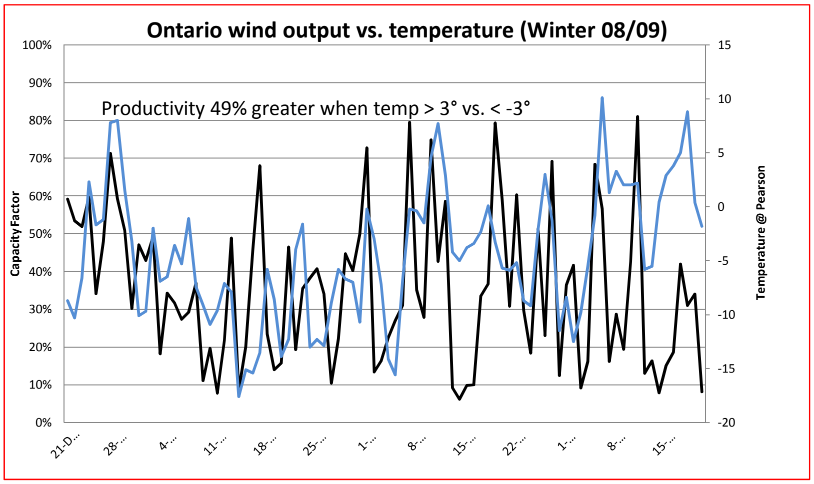
This graph shows load (red) and wind output (blue) over an annual period normalized and with their respective polynomial trend lines. Wind output is highest in winter and lowest in summer whereas load tends to be highest in summer with a secondary peak in winter and valleys in spring and fall.




The next graph shows average daily Ontario wind capacity factor (black) and average daily temperature at Toronto's Pearson Airport (blue) over the last winter. The good news is that Ontario is windy in winter, a season of high demand. The bad news is that Ontario's wind output in each of the last three years was concentrated on the warmer days, when demand tends to be lower.[6]

[6] The wind vs. temperature correlations for the last three winters are: Winter 06/07 = positive 12.0%, Winter 07/08 = positive 20.6%, and Winter 08/09 = positive 27.5%. Consider these results with caution because only three years of experience have been completed. Historical records and model-based studies should be checked for this relationship.

# Winter: Warm = Windy (so far)

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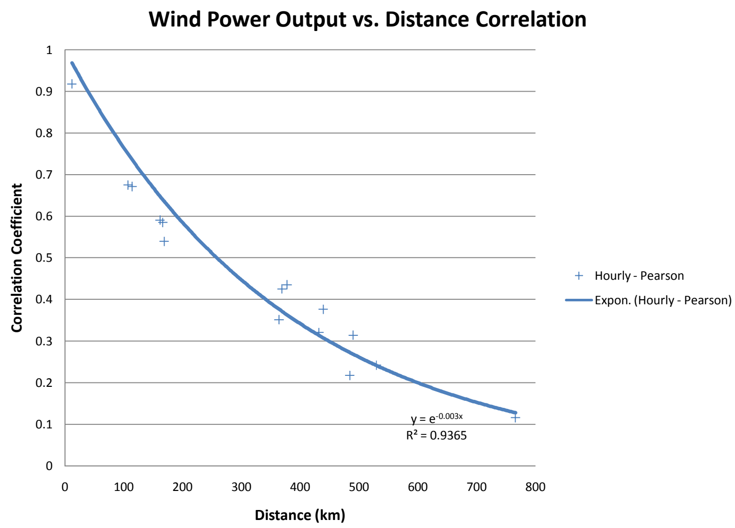
Other researchers have identified that Ontario tends to get most of our wind output at the wrong time of day and that the daily wind pattern tends to decline in morning when load is rising and ramp up in evening when load is declining.[7]

Wind output volatility is another challenge. To quote Leonard Cohen again "Everybody knows", in this case that distance smoothes output. Even the IESO says so. Unfortunately distance provides little smoothing benefit:

[7] Rowland, I.H. and Jernigan, C, Wind power in Ontario: Its contribution to the electricity grid, *Bulletin of Science, Technology & Society*, Vol. 28, Number 6, December 2008.

# Ontario Correlation vs. Distance

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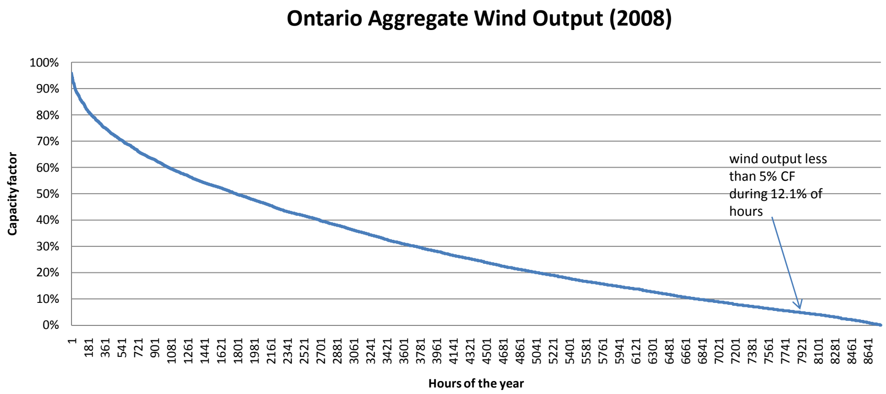
Considering hourly correlation coefficients, 250 km cuts the cross correlation by only 50%. No matter how far apart they are, wind farms in Ontario east of Wawa will be positively correlated. This means that the more wind capacity we add, the more output volatility the aggregate fleet will yield. Adding a distant wind farm fills the valleys of average output and drops the standard deviation of output a little but also increases the peaks of output. If output swings or peaks are challenging the system, distance doesn't help.

The wind advocates often claim "there is little overall impact if the wind stops blowing in one particular place, as it is always blowing somewhere else" (www.whywind.org) “there is little overall impact if the wind stops blowing in one particular place, as it is always blowing somewhere else” (www.whywind.org)

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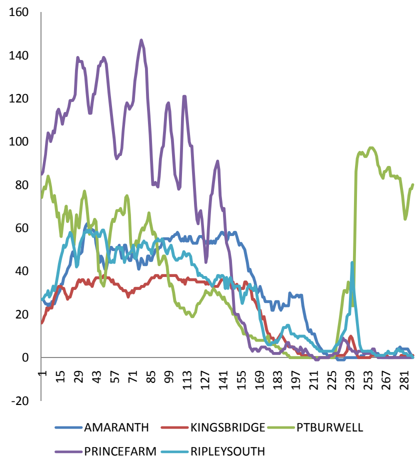
This graph shows Ontario’s aggregate output for all large wind farms in service over the full year. About 1/8$^{th}$ of the time, there was virtually no output from the fleet.

Some wind power advocates might say that at smaller time intervals, distance does achieve smoothing. That question has not been studied in Ontario systematically, but based on spot checks of data, we know that the generalization has exceptions.

## Sometimes Distance Doesn't Help (@ 5 min resolution)




| | Amaranth | Kings bridge | Pt Burwell | Prince |
|---|---|---|---|---|
| Kings bridge | 94% | | | |
| Pt Burwell | -13% | 2% | | |
| Prince | 73% | 82% | 31% | |
| Rip South | 85% | 93% | 13% | 90% |

6

Feb. 1, '08 was a day of high cumulative absolute hourly delta. The axes shown are output (MW) and 5 minute intervals over 24 hours. On this particular day, we see big, fast swings in output coordinated across wind farms far distant from eachother. Kingsbridge, Ripley South and Amaranth are located close to each other in Southwest Ontario and Prince is located just west of Sault St. Marie – at least 360 kilometers away. As Ontario's wind reliance grows, this behavior could potentially impact grid reliability. We cannot assume low correlations at short intervals.

Official Ontario -- the OPA and the IESO -- are now grappling with these issue. Here are some of the unanswered questions they face.

## Unknowns

How much balancing generation will wind require?

How often, large, and predictable are largest fast wind ramps?

How large will the wind fleet have to grow before it impacts requirements for automatic generation control?

Will wind power have regional impacts on ancillary service requirements?

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Some of the uncertainty in official Ontario is simply a function of the pace of change associated with the GEA and uncertainty about its impacts.

**Conclusion**

When considering wind's consumer impacts, incremental transmission, energy storage, ramping generation requirements, and grid reliability service costs (e.g. AGC, OR) are insignificant at low capacity but rise in significance as capacity rises. Some of these factors are also significant in terms of wind power's ultimate environmental footprint. No one in Ontario can realistically estimate these factors right now, in part because the commercial impact of the GEA is still very difficult to estimate but also in part because much more technical homework is needed.

Power systems are delicate. They need a healthy policy environment well fertilized with informed judgment and criticism to be able to flourish. Fed too many slogans, they can become disported.

Ontario's power system is now indisputably a political plaything. The regulatory and technical agencies that administer the power system have limited room for independent action.

For those who might engage in the policy process, I urge you to keep in view the big picture. Encourage cross-qualification. Urge the engineering schools that haven't already done so to put public policy prominently into their curriculum.

Keeping the lights on is not a purely technical question.