APPENDIX A

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Environmental and Economic Consequences of Ontario's Green Energy Act

by Ross R. McKitrick

in conjunction with the Fraser Institute Centre for Energy and Natural Resource Studies

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April 2013

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Contents

Executive summary

The Ontario Green Energy and Green Economy Act (herein the GEA) was passed in May 2009 with the purpose of addressing environmental concerns and promoting economic growth in Ontario. Its centerpiece is a schedule of subsidized electricity purchase contracts called Feed-in-Tariffs (FITs) that provide long-term guarantees of above-market rates for power generated by wind turbine farms, solar panel installations, bio-energy plants and small hydroelectric generators. Development of these power sources was motivated in part by a stated goal of closing the Lambton and Nanticoke coal-fired power plants.

This report investigates the effect of the GEA on economic competitiveness in Ontario. It focuses on three questions: (1) Will the GEA materially improve environmental quality in Ontario? (2) Is it a cost-effective plan for accomplishing its goals? (3) Are the economic effects on households and leading economic sectors likely to be positive? The answer to each question is unambiguously negative. The specific findings of the report are as follows.

1 It is unlikely the Green Energy Act will yield any environmental improvements other than those that would have happened anyway under policy and technology trends established since the 1970s. Indeed, it is plausible that adding more wind power to the grid will end up increasing overall air emissions from the power generation sector.

As of 2009, air quality in Ontario had improved considerably compared to the 1960s, and showed no tendency to be getting worse. A confidential 2005 cost-benefit analysis for the provincial government, often cited by the Province as a defence of the GEA, in fact predicted that the closure of the coal-fired power plants would yield such tiny effects on air quality as to be unnoticeable in most places.

Because of the fluctuating nature of wind and solar power, adding renewable capacity to the grid requires additional backup power from natural gas plants. Because Ontario currently has a surplus of base-load generating capacity, further additions to base-load in the form of wind or solar power may require removing a nuclear plant from operation and replacing it with a combination of renewable and gas-fired generation, yielding a net increase in air emissions.

2 **The plan implemented under the Green Energy Act is not cost effective. It is currently 10 times more costly than an alternative outlined in a confidential report to the government in 2005 that would have achieved the same environmental goals as closing the coal-fired power plants.**

The province's continued reliance on the confidential 2005 "DSS" analysis in defence of the GEA is misleading since that report did not consider or recommend use of wind or solar energy as a replacement for coal. The analysis by DSS Management Consultants actually shows that a relatively low-cost retrofit option for the coal plants was available that would have yielded environmental improvements (including reductions in greenhouse gases) effectively equivalent to those of closing the plants, at about one tenth the current cost of the GEA, and one seventieth what it will cost if the Province follows its stated plans to completion.

The focus on wind generation is especially inefficient because production peaks when it is least needed and falls off when it is most needed. Surplus power is regularly exported at a considerable financial loss. On average, due to daily and seasonal wind patterns in Ontario, a 1% increase in wind power production coincides with a 1% reduction in consumer power demand. Eighty percent of Ontario's generation of electricity from wind power occurs at times and seasons so far out of phase with demand that the entire output is surplus and is exported at a substantial loss. The Auditor-General of Ontario estimates that the province has already lost close to $2 billion on such exports. Data from the Independent Electricity System Operator shows Ontario now loses, on average, $24,000 per operating hour on such sales, totaling $200 million annually. The loss rate will continue to grow with every new wind turbine installation because the mismatch between the timing of wind-powered generation and Ontario electricity demand is structural.

The wind-power grid is also inherently inefficient due to the fluctuating nature of the power source. Output of Ontario's wind turbines is below one fifth of rated generating capacity about half the time, and below one third of the rated capacity about two thirds of the time. **Because of the unreliability of output, 7MW of rated wind energy are needed to provide a year-round replacement of 1MW of conventional power generating capacity.** Consequently, the cost of achieving the provincial targets for renewable energy in the coming years will be much higher than currently acknowledged.

3 **The Green Energy Act will not create jobs or improve economic growth in Ontario. Its overall effect will be to increase unit production costs, diminish competitiveness, cut the rate of return to capital in key sectors, reduce employment, and make households worse off.**

The claim by the government of Ontario that 50,000 jobs will be created by the GEA was a guess without any basis in formal analysis, and the Province has since admitted both that the vast majority of any GEA-related jobs will be temporary and that the figure of 50,000 does not account for offsetting permanent job losses caused by increases in the price of electricity under the GEA.

Electricity costs for large users in Ontario were moderate compared to surrounding jurisdictions as recently as 2008, but have since risen almost to the highest level in our comparison group. Further price increases of 40% to 50% are forecast, in large part to pay for costs incurred under the GEA. These will result in Ontario being at or near the top end of North American electricity costs over the next few years. Such price increases, were they to occur, would strongly affect the unit cost of production in mining and manufacturing and, to a smaller extent, forestry. I estimate they will drive down the rate of return to capital in manufacturing in Ontario by 29%, in mining by about 13%, and in forestry by about 0.3%, leading to a net loss of investment and employment in the province.

Provincial efforts to shield these industries through energy subsidy programs only transfer the costs onto households, who are already dealing with increases in the price of residential electricity because of GEA-related initiatives. There would also be uncertainty as to whether the Province will remain committed to such subsidy measures in the face of its ongoing budget deficit. There are additional costs to households in regions afflicted with new wind turbine installations arising from lost property values, degradation of the rural environment, and increased health and stress problems. Were these to be taken into account, the overall cost burden of the GEA would be even higher.

1 Introduction

The Green Energy and Green Economy Act (herein the GEA) was passed in May 2009 with the purpose of addressing environmental concerns and promoting economic growth in Ontario. Its centerpiece is a schedule of subsidized electricity purchase contracts, called Feed-in-Tariff rates (FIT), that provide long-term guarantees of above-market rates for power generated by wind turbine farms, solar panel installations, bioenergy, and small hydro generators. The Province of Ontario has stated that the GEA was motivated by three goals: reduction of greenhouse gas emissions, reduction of criterion air contaminants by replacing coal-fired power plants with renewable power generation, and job creation (AGO, 2011: 92). *Environmental and Economic Consequences of Ontario's Green Energy Act* shows that the GEA will impair competitiveness and job creation in Ontario. It also shows that the GEA will not yield meaningful reductions in air pollution, and that much less costly approaches to achieving the same environmental goals could have been taken, and that this was known prior to the Act's introduction.

Section 2.1 sets the context of the GEA by showing that Ontario air quality had already improved dramatically in most respects between 1960 and 2009. The only area in which progress was slow was ground-level ozone, but Section 3.1 shows that the provincial government was informed in 2005 that closing the coal-fired power plants would have only a minuscule effect on this, and a comparable outcome could have been obtained by completing the installation of relatively low-cost scrubbers on the power plants. Combined with purchase of carbon-offset credits, this approach would have yielded an outcome statistically identical to closing the power plants, for well under $800 million per year, about one tenth of the pro-rated costs currently being incurred under the GEA. Section 3.1 shows that the embrace of wind turbines for power generation in Ontario is intrinsically inefficient since the technology operates well below rated capacity, and tends to produce power when it is least needed, requiring it to be exported at a substantial loss. Hence, the planned expansion of wind energy under the GEA is highly cost-inefficient and will, if pursued, raise the costs to provincial households another seven-fold.

Section 4 examines the competitiveness impacts on Ontario, showing that if the projected electricity price increases go through, the rates of return to capital in manufacturing and mining will be impaired, leading either to capital flight and job losses, or requiring the province to make a costly commitment to subsidies, neither of which are in the public interest.

2 The Green Energy Act and Ontario's Air Quality

2.1 Air quality trends in Ontario since the 1960s

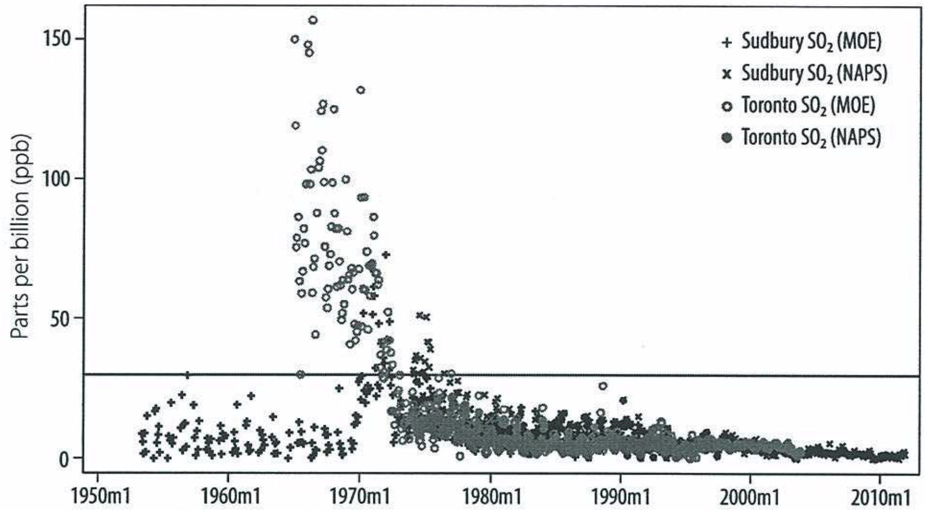
Air quality in Ontario is measured by a network of 40 monitoring stations operated by the Ministry of Environment (MOE).[1] Some of the MOE records also go into the federal National Air Pollution Surveillance (NAPS) system, which has archived records since 1974. The earliest MOE record is a Sudbury sulphur dioxide (SO_2) series spanning 1953 to 1981 (another Sudbury location began in 1974 and continues to the present). A downtown Toronto record extends from 1965 to the present. As shown in **figure 2.1**, SO_2 levels in these archives exhibit a dramatic decline, especially in Toronto, and daily readings now are typically 0 to 5 parts per billion (ppb). SO_2 is now only monitored at five locations in Ontario.

Figure 2.2 shows the MOE and NAPS data for Total Suspended Particulates (TSP) and Particulate Matter smaller than 10 microns (PM_{10}), both measured in $\mu g/m^3$. TSP were measured up to 1997. Except for a spike near the end of the sample, levels had fallen in half by 1990 compared to the 1960s, generally hovering around the Ontario clean-air standard of 60 $\mu g/m^3$. PM_{10} was measured for two years in Ontario around the turn of the century and the levels were much lower than that, through TSP is a broader category than PM_{10}.

Carbon monoxide (CO) is often mentioned as an air pollutant of concern because it is lethal in high doses but, as **figure 2.3** shows, levels in Toronto declined steadily from 1974 to the end of the record in 2004, and in Sudbury it was always quite low. This is especially noteworthy since CO is mainly associated with motor vehicles and the number of cars on the road grew every year of the sample. CO is only measured in four locations in Ontario now and rarely exceeds one part per million (PPM), well below the clean-air standard of 6 ppm.

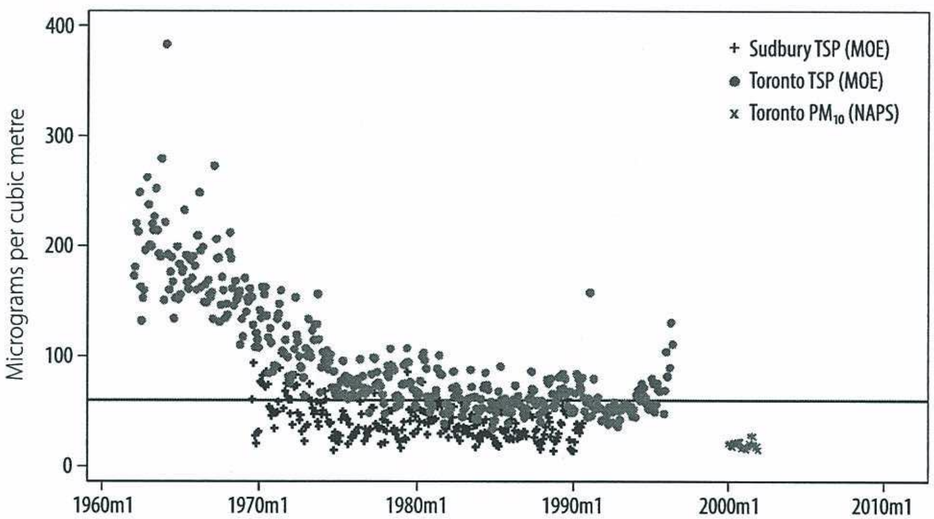
1 Hourly readings are posted online at <www.airqualityontario.com>.

Figure 2.1: Toronto and Sudbury SO_2 concentrations, 1961 to the present



Note: Horizontal line shows the Ontario most stringent air quality standard for SO_2.
Sources: MOE: Ontario Ministry of Environment, unpublished data; NAPS: Environment Canada, 2012.

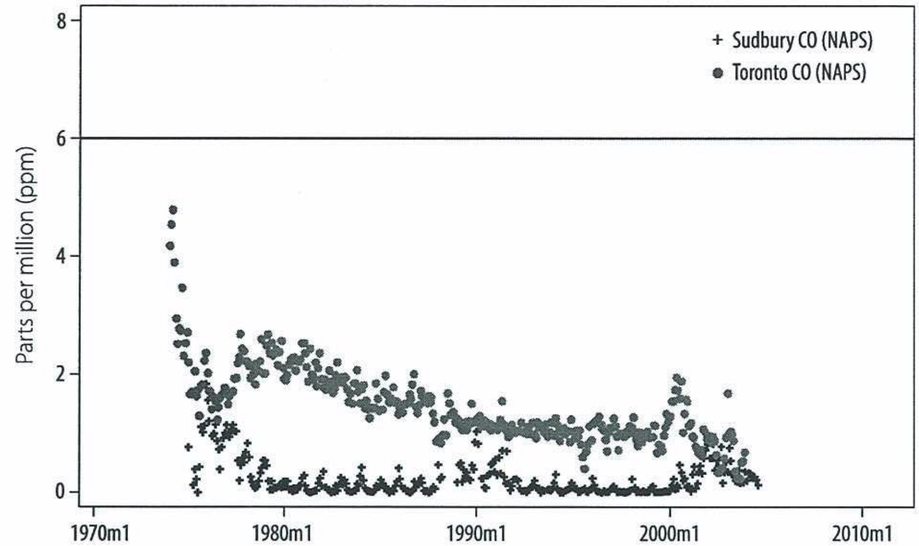
Figure 2.2: Toronto and Sudbury TSP and PM_{10} concentrations, 1965 to 2002



Note: Horizontal line shows the Ontario most stringent air quality standard for Suspended Particulate Matter.
Sources: MOE: Ontario Ministry of Environment, unpublished data; NAPS: Environment Canada, 2012.

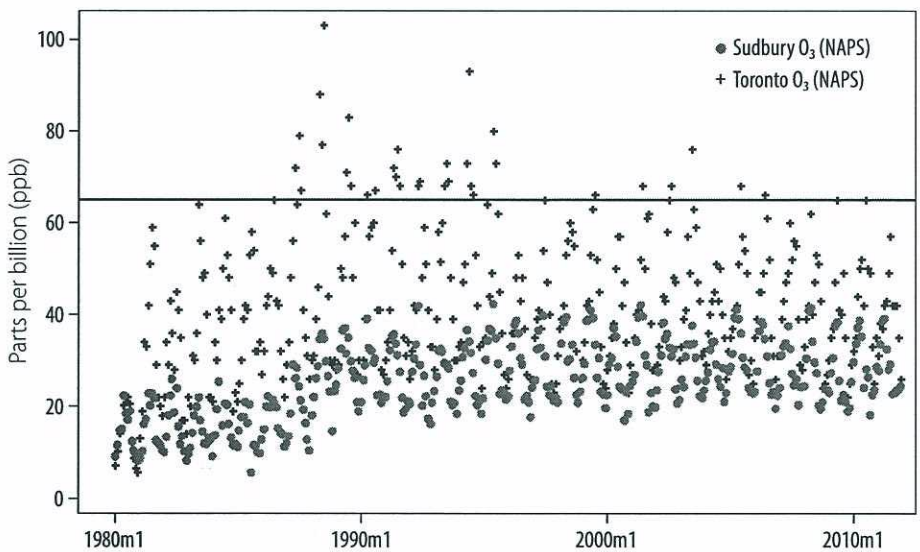
Average ground level ozone (O_3) levels rose slightly from the 1970s to 1990, then remained relatively constant thereafter to the present. Average monthly levels have not exceeded 40 ppb in either Toronto or Sudbury since 1974. Of more concern are the summertime peaks, since ozone formation occurs on hot, still days when conditions are right for the chemical reaction to occur. Figure 2.4 shows the monthly 99th-percentile levels of O_3 in Toronto and Sudbury since 1974 (in other words, the cut-off for the top 1%

Figure 2.3: Toronto and Sudbury CO concentrations, 1974 to the present



Note: Horizontal line shows the Ontario most stringent air quality standard for CO.
Source: NAPS: Environment Canada, 2012.

Figure 2.4: Toronto and Sudbury O_3 monthly 99th percentile concentrations, 1974 to the present



Note: Horizontal line shows the Ontario air quality standard for O_3.
Source: NAPS: Environment Canada, 2012,

of readings in each month). Toronto peak readings were highest in the late 1980s and have declined since then. For the past seven years, they have remained below the Ontario standard of 65 ppb. Sudbury peak ozone levels have remained constant at between 15 and 40 ppb since 1990, well below the clean air standard.

The pattern of improvement in Ontario's air quality is no secret. Every year, the Ontario MOE publishes its report, *Air Quality in Ontario*, presenting a detailed survey of the data and a review of trends, mainly over the previous decade.[2] The 2010 report begins, as many of the previous ones do as well, with the observation: "Overall, air quality has improved significantly over the years, especially for nitrogen dioxide (NO_2), carbon monoxide (CO) and sulphur dioxide (SO_2)—pollutants emitted by vehicles and industry". The 2010 report noted that: "The provincial Ambient Air Quality Criteria (AAQC) for NO_2 and CO were not exceeded at any of the ambient air monitoring locations in Ontario during 2010" (MOE, 2010: i). Nor were 24-hour standards for SO_2 exceeded anywhere, nor were standards for fine particulate ($PM_{2.5}$) exceeded.

2.2 Effects on Ontario's air quality of the coal phase-out

The Province has always focused on the goal of closing the coal-fired power plants as a key rationale for the GEA. For example, the foreword to the Provincial Long-Term Energy Plan states:

> Worst of all, Ontario relied heavily on five air-polluting coal plants. This wasn't just polluting our air, it was polluting our lungs. Doctors, nurses and researchers stated categorically that coal generation was having an impact on health increasing the incidence of various respiratory illnesses. A 2005 study prepared for the government found that the average annual health-related damages due to coal could top $3 billion. For the sake of our well-being, and our children's well-being, we had to put a stop to coal. (Ontario, Ministry of Energy, 2010: 2)

In response to criticisms of the GEA in a report of the Provincial Auditor-General the Province again pointed to the closure of the coal plants as a priority (AGO, 2011: 92).

The Province's reliance on the 2005 study prepared for the Ministry of Energy (DSS, 2005) cited in the quotation above is highly misleading. For one thing, the report neither examined nor recommended adoption of wind, solar, or other renewable energy as a replacement for coal. And, more importantly, it ignores the most important finding of that report, which is that closing the Lambton and Nanticoke power plants would have extremely small effects on Ontario air quality.

This (confidential) report to the Ontario Ministry of Energy (DSS, 2005) was prepared by DSS Management Consultants using air-quality simulations performed by analysts at RWDI Engineering. DSS examined four scenarios for

2 They are available annually since 1998 at <http://airqualityontario.com/press/publications.php>.

the future of Ontario's electricity generating system. Scenario 1 was the base case, a continuation of business-as-usual. Scenarios 2 and 3 examined different combinations of extra nuclear and gas facilities to replace the Lambton and Nanticoke coal-fired power plants, and Scenario 4 looked at completing a retrofit of the coal plants that would entail upgrading its pollution control equipment. None of the scenarios studied considered or recommended investment in wind, solar, or other renewable forms of energy.

DSS found (2005: 72) that shutting down the coal-fired power plants would have extremely small effects on the two air contaminants that currently determine the Ontario Air Quality Index: ground-level ozone (O_3) and PM_{10}. In the City of Toronto, shutting down the power plants would yield a an ozone reduction of only 0.02 parts per billion (PPB), roughly $8/100$ of 1% of average daily readings. This is identical to the predicted reductions under the retrofit scenario. PM_{10} levels would fall by 1.1 $\mu g/m^3$, essentially the same as the reduction under the retrofit scenario (0.8 $\mu g/m^3$) and, again, only a small percentage of average daily levels. The same minuscule changes were projected in 57 locations across the province, except for Haldimand-Norfolk Region, in the vicinity of the Nanticoke plant, where ozone levels would fall by just under 1 ppb and PM_{10} levels by 2.7 $\mu g/m^3$.

The report by by DSS Management Consultants used some simple spreadsheet calculations to attach massive health and environmental benefits to these small changes, which led to their conclusion that shutting down Lambton and Nanticoke and replacing them with new nuclear and gas-fired power plants would pass a cost-benefit test. The modeling technique used to compute such large health effects from very small changes is rather implausible (see Green et al., 2002; McKitrick, 2004). For example, it relies on assumed health impacts from current low levels of air pollution that, if applied to the much higher levels observed in the past, would predict that more than 75% of all non-traumatic deaths in Ontario in the late 1960s and early 1970s were due to air pollution rather than the causes reported at the time (such as old age, cancer, stroke, and infectious diseases), and even in some cases it would predict more deaths due to air pollution than there were deaths from all causes. But, notwithstanding the implausible health effects model, the main point to emphasize is that the 2005 report to the Minister of Energy clearly showed that closing the Lambton and Nanticoke coal plants would have very small effects on air quality, and the outcome would be effectively indistinguishable from simply completing the retrofit then underway.

An additional benefit to retaining the pre-2009 generating fleet is that the province's distribution grid is configured to support it. By shutting down generating capacity at existing plant sites and developing new capacity in locations far away from the current grid, the Province must now incur the costs of developing a new transmission system. Figures from the Auditor-General's report (AGO, 2011: 115) show that, of the $2 billion in committed expenditure on transmission grid upgrading, between $1.3 and $1.7 billion is related to new renewables generating capacity. This spending would not have been necessary if the Province had pursued the retrofit option on the existing power plants. And, even with these new transmission projects, the majority of planned renewable power sources will still not be connected and will require even further spending.

2.3 Potential growth in air emissions from expanding renewables

Electricity supply is divided into base-load capacity, which comes from sources like hydroelectric and nuclear that deliver a fixed amount of power that cannot easily be adjusted up or down on short notice, and peak capacity, which can be scaled up and down as system demand changes through the day. Ontario power demand currently averages about 18,000 MW and reaches a maximum annual peak of about 26,000 MW. Using figures from the Ontario Power Authority and the Independent Electricity System Operator, the provincial Auditor-General projects average demand to decline to about 16,000 MW and peak demand to fall to about 24,000 MW (AGO, 2011: 99). Nuclear and hydroelectric facilities alone currently provide 18,000 MW of base-load capacity (Ontario, Ministry of Energy, 2010: 22–26). In addition, Ontario has 9,500 MW of gas capacity as well as 4,500 MW at the coal-fired power plants, much of which is unused. The AGO estimates Ontario will have at least 10,000 MW of surplus generating capacity through 2025 (AGO, 2011: 99).

Not only does Ontario have surplus power, but it has surplus base-load power, and this creates a problem for maintaining grid reliability as wind power expands. The GEA requires the system to buy all available wind energy. Depending on wind conditions, there can be a surge in production that needs to be absorbed. As will be shown below (section 3.2), wind power tends to peak when demand is at a minimum, so it either must displace base-load production or be dumped on the export market at a loss. Currently, the latter is the case, but if the next phase of expansion of the wind fleet is undertaken, the base-load capacity itself will have to be reduced, most likely by taking a nuclear generating unit offline. Calculations by the Ontario Society of Professional Engineers (Acchione, 2012) show that this not only inflates the cost of power generation unnecessarily but, since wind power must be nearly 50% matched by spinning gas-fired power as a backup in case of drops in wind (AGO, 2011: 91), shutting down nuclear facilities and replacing them with wind turbine installations will result in higher greenhouse gas and air pollution emissions. Consequently, further expansion of wind (or solar) power will work against the province's environmental goals.

2.4 Conclusions

- There has been a long-term pattern of improvement in Ontario's air quality beginning at least in the 1980s. By 2000, most types of air contamination had fallen or stabilized at levels below the most stringent provincial air quality standards.
- While Toronto average ozone levels in the 1990s were above those in the 1980s, summertime peak ozone levels declined after 1990 and by 2009 were within the clean air standard. Summertime peak ozone levels were also steady or declining elsewhere in the province, as were fine particulate levels.
- There was no pattern of non-compliance in Ontario with air quality objectives as of 2009 when the Green Energy Act was introduced, nor was there a trend towards non-compliance.
- Data in the DSS report supplied confidentially to the Ontario Ministry of Energy in 2005 estimates that closing down the coal-fired power plants would have yielded such minuscule changes to air quality as to be unnoticeable in most locations. Nearly identical changes could have been obtained using conventional pollution control measures.
- The DSS report did not consider or recommend adoption of wind or solar energy to replace coal, hence its continued citation by the Province as a rationale for this decision is misleading.
- Further expansion of wind power in Ontario will require expensive changes to the transmission grid since the new generating facilities are not in the same locations as the current ones. About $1.5 billion in new spending will be required to accommodate renewable power initiatives under the GEA.
- Ontario not only has surplus power, but has surplus base-load power. Consequently, further expansion of wind generating capacity will likely displace nuclear facilities and lead to an increase in air pollution emissions due to the need for expanded gas-fired backup capacity to match new wind turbine installations.

3 Cost-effectiveness analysis of the GEA path

3.1 Conventional abatement as an alternative to the GEA

Ignoring for a moment the problem of surplus power, we turn to the question of whether switching to renewables (mainly wind) is a cost-effective strategy for achieving environmental improvements associated with closing the coal-fired power plants. DSS Management Consultants (2005) concluded that the average annual financial cost (in $2004) of maintaining and upgrading the existing power generating mix would be $985 million over the 2005 to 2026 horizon, which is $1.09 billion in $2010.[3] Scenario 4, the coal plant retrofit, would yield the emission reductions shown in **table 3.1**, and would raise the annual financial cost to $1.513 billion per year. Thus, for an additional $423 million per year, continuing with the partially completed retrofit and upgrade of the existing power plants would have cut NO_x emissions by about 75%, SO_2 by over 80%, and PM_{10} by 95%, yielding improvements in air quality that were projected to be effectively the same as those from shutting down the plants altogether.

Greenhouse gas costs were also considered by DSS (2005). Their figures show (2005: 32–33) that, if offset credits sufficient to cover annual CO_2 emissions were purchased at $15/tonne, the cost of the retrofit scenario would increase by $394 million per year. This would bring the total cost of the retrofit scenario up to $817 million ($2010) per year. By comparison, the province is now spending far more on GEA-related options that have not even begun to provide the same capacity as the coal-fired power plants. In addition to the $1.3 to 1.7 billion in new grid spending mentioned above, the Ontario government spends over $1.1 billion annually just on the Clean Energy Benefit (Ontario, Ministry of Finance, 2012: line 2905), which only provides partial relief to households to compensate for GEA-related increases in the cost of electricity. According to the Auditor-General of Ontario (AGO, 2011), this benefit offsets about half the additional cost to households arising

3 The January 2004 All-Items Ontario CPI was 103.4 and at January 2010 it was 114.5, implying an inflation factor of 1.107, which is applied throughout this section to convert $2004 to $2010.

Table 3.1: Estimated reductions in air pollutant emissions (grams/kWh) from completing the retrofit on the Lambton and Nanticoke generating stations

Generating Station	Generating Unit	NO_x	SO_2	PM_{10}
Lambton	1	−73%	−87%	−95%
	2	−73%	−87%	−95%
	3*	0*	0*	0*
	4*	0*	0*	0*
Nanticoke	1	−75%	−82%	−95%
	2	−75%	−82%	−95%
	3	−75%	−82%	−95%
	4	−75%	−82%	−95%
	5	−71%	−82%	−95%
	6	−75%	−82%	−95%
	7*	0	−82%	−95%
	8*	0	−82%	−95%

Note: *: units partially or completely retrofit already at the time of the study.
Source: DSS, 2005: 55, 63.

to date from implementation of the GEA, implying that the GEA provisions are already costing Ontario households over $2.2 billion annually. The AGO also estimated (2011: 94) that by 2014 the total cost of the Global Adjustment will be $8.1 billion annually, of which about one third ($2.7 billion) will be attributable to renewable energy contracts. Taking the renewable-related grid spending to be worth $120 million[4] annually, the foregoing considerations add up to just over $5 billion annual costs to Ontario households from the GEA, more than six times the cost of the retrofit option that would have yielded essentially equivalent environmental benefits.

But, the comparison is still not valid, since the renewable power contracts signed under the GEA do not yield anywhere near sufficient power to replace the Lambton and Nanticoke plants. Due to the fluctuating nature of wind generation, new wind-turbine capacity must be matched almost 50% by coal- or gas-fired backup generators. Since the coal plants are slated for closure, this requires new gas generators to be built but, during the last election campaign, the province canceled construction plans for two such plants (owing to political pressure), setting the construction process back and raising the eventual cost by at least $800 million (Carr, 2012, November 28). Adding the annualized cost to the numbers so far yields a $5.1 billion annual burden

4 A 20-year annuity at 5% interest yields a adjustment factor of 12.5, so $1.5 billion total divided by 12.5 implies $120 million annually.

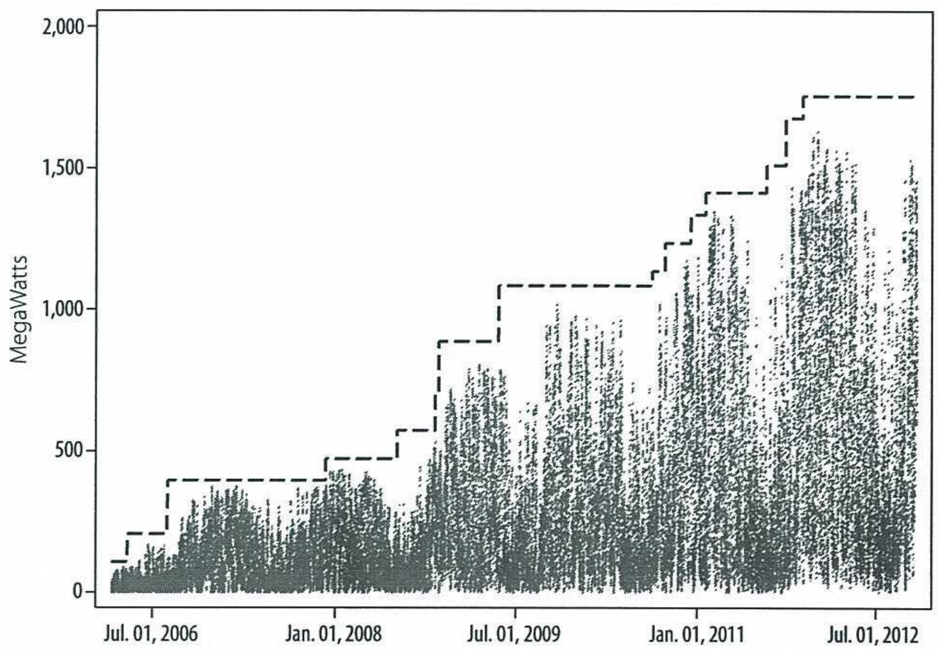
on households from the GEA. And this is just the tip of the iceberg. Structural inefficiencies associated with wind energy mean the costs of replacing the lost generating capacity associated with Lambton and Nanticoke are many multiples of those incurred so far, as is explained in the next section.

3.2 Structural inefficiencies of wind energy

Figure 3.1 shows the development of wind energy in Ontario from 2006 to the present, based on figures from the website of the Independent Electricity System Operator (IESO). The dashed line traces out the growing total capacity over time, and the dot pattern shows hourly total production from installed wind turbines. Current total capacity is 1,754 MW. As is clear, output rarely gets close to installed capacity. **Figure 3.2** plots a histogram of hourly output as a fraction of total available capacity. Over the entire period from 2006 to 2012, wind output averaged 27.5% of rated capacity, and since 2009 it averaged 28.7% of rated capacity. Power output was one tenth or less of rated capacity nearly a quarter of the time, and less than a third of rated capacity nearly two thirds of the time.

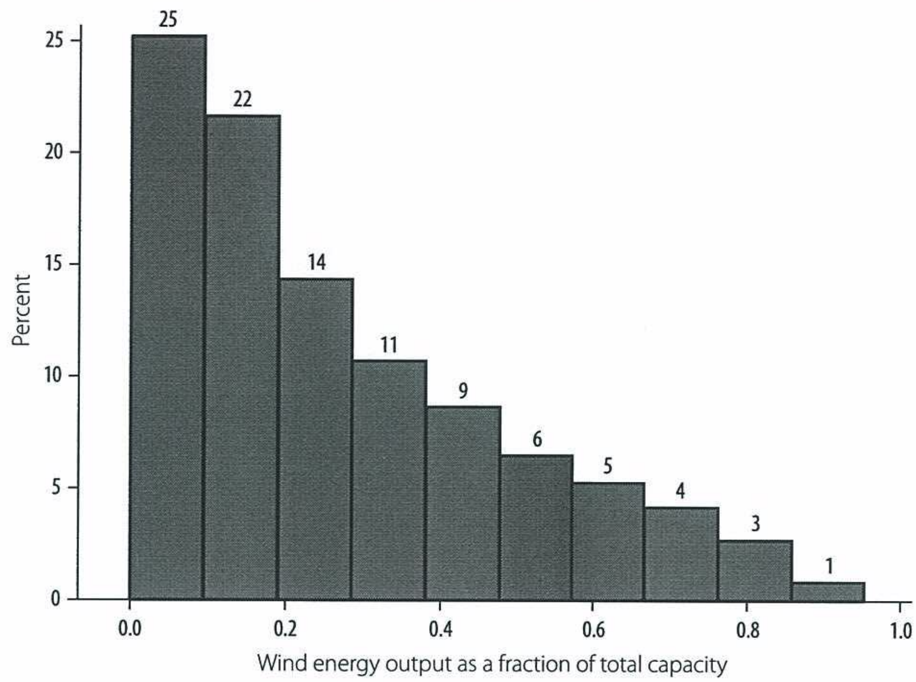
The mismatch between wind energy and demand is structural and unique to wind. As the AGO report noted (2011: 111), wind turbine output declines in the morning while demand is coincidentally ramping up, and rises

Figure 3.1: Development of wind energy production in Ontario



Note: Figure shows hourly output compared to total available capacity.
Sources: IESO, 2012; author's calculations.

Figure 3.2: Percentage histogram showing distribution of hourly wind production in Ontario relative to total capacity

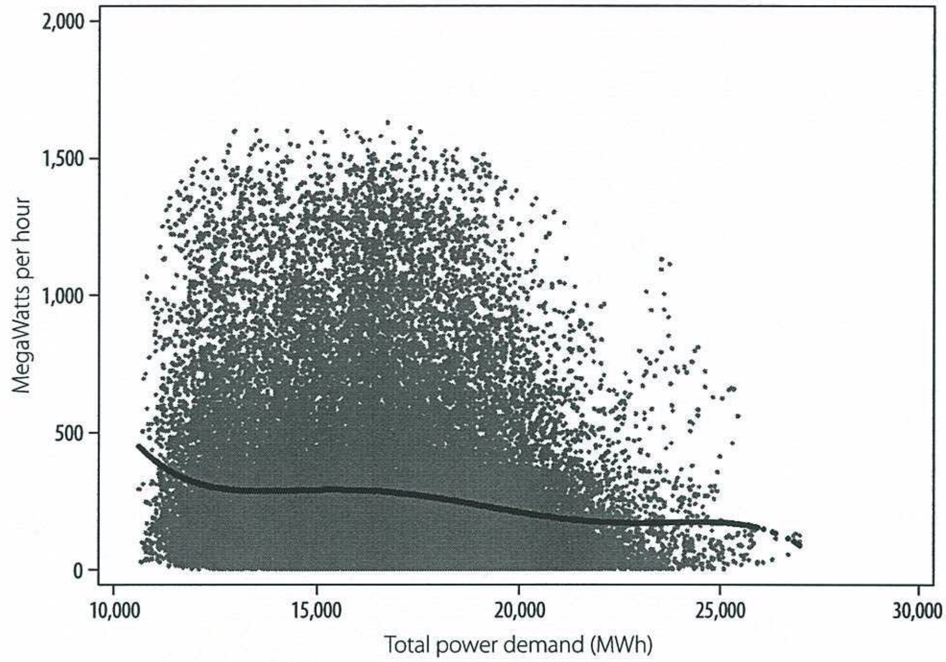


Note: Numbers on top of bars show percentages associated with each bin. Leftmost bar indicates that 25% of the time, output is about 10% of available capacity; two leftmost bars show that 47% of the time output is under 20% of available capacity, and so on.
Sources: IESO, 2012; author's calculations.

in the evening as demand is winding down. Also, wind output peaks in the fall when seasonal demand is minimal because households are typically no longer using air conditioning nor have they yet started up wintertime electric heating systems. **Figure 3.3** shows a scatter plot of total wind production against total Ontario-wide system demand. The black line is a smoothed polynomial regression fit. On average, as power demand increases by 1%, wind production coincidentally declines by 1.1%. This is not a cause-and-effect relationship, but reflects the fact that wind conditions favour power generation at times that coincide with minimal system power demand, and vice versa.

Closing the Lambton and Nanticoke power stations removes a total of about 7,500 MW of generating capacity in Ontario, and wind power is eventually supposed to replace about 4,800 MW (64%) of that (Ontario, Ministry of Energy, 2010). To make an apples-to-apples comparison with the retrofit option we need to take into account the intermittence and seasonal concentration of wind. The output level of a coal-fired power plant is not affected by seasons, and can be varied (up to the rated capacity) by the operator to match variations in demand. But the maximum output level of a wind turbine is not controllable since it depends on wind strength. Over the course of a year, we have seen that output averages just under 30%

Figure 3.3: Total Ontario hourly wind power output (MWh) compared to total system demand, 2006–2012



Sources: IESO, 2012; author's calculations.

of the rated output. Since 2009, the monthly average output fraction has tended to peak in November at 41%, and reaches a minimum in July at 14%. Thus, to be assured of getting a monthly average of 1 MW of power from wind turbines during any month of the year would require a minimum of 2.4 MW of available wind turbine capacity in November, rising to 7.0 MW in July. Consequently, to get 4,800 MWh from wind turbines in July would require installing 33,600 MW in new capacity.

If we aim only to get 4,800 MW of wind energy averaged over the whole year, rather than over each month, we will need 16,000 MW of installed capacity, roughly ten times the amount installed to date. The Province's *Long Term Energy Plan* assumes that 78% of new renewable energy installed between now and 2030 will be wind power (Ontario, Ministry of Energy, 2010: figure 5). Assigning this fraction to the annualized costs of renewable energy estimated above ($5.1 billion) implies a current burden of $4 billion annually to Ontario households. To expand this 10-fold from current levels, even if we ignore the Mississauga gas plant debacle and the costs of transmission line expansion, would imply liabilities rising to $38 billion annually, to replace only 64% of the generating capacity lost with the closure of Lambton and Nanticoke.

An additional problem for Ontario, as highlighted by the AGO report (2011: 112) is the fact that most wind energy in Ontario is surplus to base needs and must be exported at a significant loss per kWh. **Figure 3.4** plots hourly wind production against hourly net exports of electricity since 2009. Ontario is a net exporter when domestic production exceeds demand. The 45° line indicates the level of production below which wind output is less than net exports, in other words, is not needed domestically. Since 2006, 81.6% of the wind energy production in Ontario occurred at times when it was unneeded, in other words when at least as much power production was being dumped on the export market. Since 2009, the fraction was 81.8% and, since 2011, it was 78.5%. Because of the provisions of the Green Energy Act, the system operator is required to buy all available wind power at 13.5¢ per kWh, well above the domestic market price, and prices received for exported power are typically less than 4¢ per kWh (AGO, 2011: 112). They are even negative at times, meaning that the electricity-system operator has to pay other jurisdictions to take the surplus power. The AGO estimated (2011: 112) that from 2005 to 2011 Ontario lost $1.8 billion on these transactions. The IESO data, using the assumption that power is purchased at 13.5¢/kWh and sold at 4¢/kWh when exported, implies that the current wind power system imposed costs of just over $24,000 per hour of operation in 2011, and cost the Province $210 million.[5] This amount must either be added to the provincial deficit or added to ratepayers' bills.

The numbers examined so far indicate that in the years leading up to 2009 the province had two options for developing the power generating infrastructure, both of which would yield roughly equivalent environmental benefits:

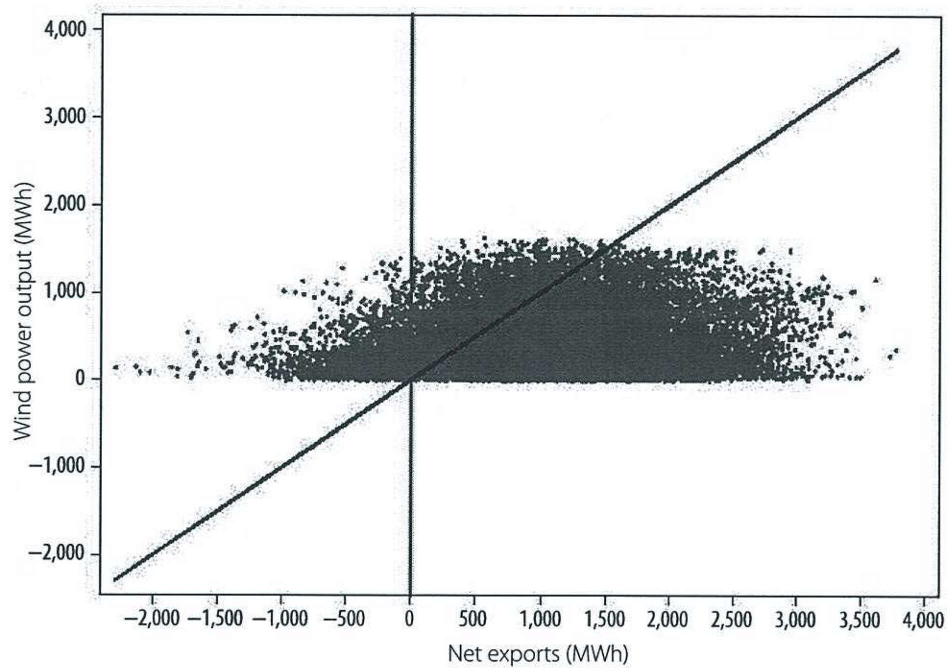
- complete the retrofit of the Lambton and Nanticoke generating stations and purchase carbon offsets at a combined cost of $817 million annually;
- pursue the renewable power strategy under the GEA, which currently costs $5.2 billion annually to supply about one tenth of the eventually intended level of power, and will eventually cost about $38 billion annually if implemented on a scale sufficient to provide 12-month replacement of at most 64% of the capacity lost by closing Lambton and Nanticoke.

On a cost-ratio basis this implies the GEA path is currently ten times costlier than the retrofit option, and will eventually be 73 times costlier if pursued to the point of providing 4,800 MW of year-round generating capacity.[6]

5 The IESO has now confirmed that exports are costing it about $200 million annually, and that these costs are passed on to ratepayers; see Spears, 2013, February 26.

6 ($5.2b ÷ $0.817b) ÷ 0.64 = 9.9; ($38b ÷ $0.817b) ÷ 0.64 = 72.6.

Figure 3.4: Ontario wind power output compared to net electricity exports, 2009–2012



Note: 45° line shows level below which wind power is less than net exports; that is, is not needed in Ontario that hour.
Sources: IESO, 2012; author's calculations.

Summary

- The 2005 report by DSS Management Consultants routinely cited by the Province in defence of its decision to implement the GEA never recommended renewable power. It outlined a plan based on retrofitting the existing power plants that would yield effectively identical environmental benefits to phasing out coal at a cost of about one tenth of what is currently being spent on renewable energy.

- Wind power in Ontario is heavily concentrated at times of the year when demand is at a minimum, and declines during times when demand is rising. Consequently about 80% of Ontario wind energy is generated at times when there is no demand for it domestically, requiring it to be exported at a loss of about 9¢/kWh, at an annual cost of about $200 million. The Ontario power system loses about $24,000 every hour wind turbines operate.

- Wind turbines operate at about 27% of rated capacity on average over the year, falling to 14% during the peak demand periods in summer. Hence, to replace 1 MW of coal power with year-round wind power will require 7 MW of new wind capacity.

- Based on the observed costs of the small amount of renewable (mainly wind) generation installed to date, to achieve 4,800 MW of year-round generating capacity from renewables will end up costing about 73 times the annual cost of the retrofit option.

- This calculation does not take into account the economic harm from higher industrial power costs, nor the loss of property values and quality of life from installation of wind turbines in rural areas.

4 Economic impacts on mining, manufacturing, and forestry

4.1 Lack of provincial analysis

This section considers the economic impacts of the electricity price increases under the GEA. Unfortunately, the government of Ontario provides no numbers to compare against, since it did not conduct its own analysis prior to bringing in the Act. The Auditor-General of Ontario (AGO, 2011) has criticized the carelessness of the process behind the adoption of the GEA:

> Because the ministerial directions were quite specific about what was to be done, both the Ministry and the OPA directed their energies to implementing the Minister's requested actions as quickly as possible. *As a result, no comprehensive business-case evaluation was done* to objectively evaluate the impacts of the billion-dollar commitment. Such an evaluation would typically include assessing the prospective economic and environmental effects of such a massive investment in renewable energy on future electricity prices, direct and indirect job creation or losses, greenhouse gas emissions, and other variables.(AGO, 2011: 89, emphasis added).

The AGO report goes on to say:

> Billions of dollars were committed to renewable energy without fully evaluating the impact, the trade-offs, and the alternatives through a comprehensive business-case analysis. Specifically, the OPA, the OEB, and the IESO acknowledged that
>
> - no independent, objective, expert investigation had been done to examine the potential effects of renewable-energy policies on prices, job creation, and greenhouse gas emissions; and
> - no thorough and professional cost/benefit analysis had been conducted to identify potentially cleaner, more economically productive, and cost-effective alternatives to renewable energy, such as energy imports and increased conservation. (AGO, 2011: 97)

The analysis in this section attempts partially to remedy that by undertaking a basic economic evaluation of the effects of the price increases that will be required to support the GEA. Other authors have also attempted to fill in the gaps left by the Province's failure to provide a proper analysis of its own policy. Angevine et al. (2012) reported simulations from a Statistics Canada Input-Output model that predicted the GEA provisions would lead to an overall employment drop of 2,200 to 2,500 Full-Time-Equivalent jobs in Ontario. The Ontario Task Force on Competitiveness, Productivity and Economic Progress (2010) estimated that each of the jobs claimed to have been created under the GEA would cost the province $42,000 per worker, and noted that German experience with similar feed-in-tariff subsidies led only to short-term job creation, followed by longer term decline as the effects of higher electricity costs began to emerge.[7] The model developed in this section focuses on predicting the impact on unit costs and the return to capital should the forecast increase in electricity prices come to pass in the years ahead.

4.2 Comparison of electricity costs between Ontario and other jurisdictions

The AGO report (2011) indicates that by 2014, the Global Adjustment will likely be 6¢ per kilowatt hour (kWh). Since, prior to 2006, the retail price in Ontario used to be about 5¢/kWh, this reflects a doubling of electricity costs in under a decade, mitigated somewhat by an expected reduction of the wholesale generating price to about 3¢/kWh.

A comparison of Ontario electricity prices to those of other jurisdictions shows how much the prices faced by large power users have worsened in relative terms. Table 4.1 lists average costs in ¢/kWh inclusive of taxes for Toronto, Ottawa and nine other North American cities. In 2008, Toronto and Ottawa were in the middle of the range when ranked by rates for large power consumers and residential customers. But, by 2012 these two cities had become the second- and third-most expensive after yielding the second- and third-largest price increases in each category.

It is noteworthy that New York was roughly twice as expensive as Toronto in 2008 for medium- and large-demand power users but, by 2012, the differential for medium-sized power users was just over 50%, and 9% for large power users. Also, the US Energy Information Administration points out that because natural gas prices in the United States are declining, so are electricity prices, and this trend will continue over the next few years (EIA, 2012).

7 A similar failure of green energy subsidies to create jobs has been noted in California; see Carroll, 2013, February 27.

Table 4.1: Comparison of electricity rates in 11 North American cities for residential, medium, and large consumers, 2008 and 2012

City	Province	Residential	Medium	Large
			2008 (¢/kWh)	
Winnipeg	Manitoba	7.38	5.70	3.55
Vancouver	British Columbia	7.55	6.02	4.31
Montreal	Quebec	7.69	8.02	5.05
Regina	Saskatchewan	12.55	9.79	6.16
Nashville	Tennessee	9.45	9.15	6.56
Toronto	**Ontario**	**11.72**	**10.08**	**8.88**
Ottawa	**Ontario**	**11.14**	**9.98**	**9.09**
Chicago	Illinois	12.72	12.79	9.77
Edmonton	Alberta	14.12	12.76	10.18
Boston	Massachusetts	19.12	17.64	15.17
New York	New York	22.93	20.10	16.83
			2012 (¢/kWh)	
Winnipeg	Manitoba	8.54	6.58	3.92
Montreal	Quebec	7.77	8.27	5.18
Chicago	Illinois	13.60	7.98	6.12
Regina	Saskatchewan	14.42	10.94	6.84
Edmonton	Alberta	13.55	11.63	7.32
Vancouver	British Columbia	9.42	7.92	7.38
Nashville	Tennessee	10.29	9.72	7.44
Boston	Massachusetts	16.45	13.00	10.45
Toronto	**Ontario**	**13.81**	**12.91**	**11.82**
Ottawa	**Ontario**	**13.37**	**12.91**	**11.95**
New York	New York	24.54	19.52	12.88
			% change	
Winnipeg	Manitoba	15.7%	15.4%	10.4%
Montreal	Quebec	1.0%	3.1%	2.6%
Chicago	Illinois	6.9%	−37.6%	−37.4%
Regina	Saskatchewan	14.9%	11.7%	11.0%
Edmonton	Alberta	−4.0%	-8.9%	−28.1%
Vancouver	British Columbia	24.8%	31.6%	71.2%
Nashville	Tennessee	8.9%	6.2%	13.4%
Boston	Massachusetts	−14.0%	−26.3%	−31.1%
Toronto	**Ontario**	**17.8%**	**28.1%**	**33.1%**
Ottawa	**Ontario**	**20.0%**	**29.4%**	**31.5%**
New York	New York	7.0%	−2.9%	−23.5%

Note: medium consumer: power demand = 1,000 kW; large consumer: power demand = 50,000 kW.
Source: Hydro Quebec (2008, 2012).

Based on projections by the AGO (2011), as well as a detailed analysis by Sharp (2012), electricity costs in Ontario for users in all categories are expected to rise by between 40% and 60% by 2015. This will put Ontario's cities into the most expensive category in North America, wiping out a relative cost advantage that persisted up to about 2008.

In an attempt to avoid these price shocks, the Province has recently announced a conditional subsidy program for large industrial power users in Ontario. The proposal requires users to commit to substantial additional hiring in exchange for subsidies to reduce electricity rates. There are several problems with this proposal. First, its implementation has been repeatedly delayed and, like much else in the GEA, the costs have not been calculated. Since the province is facing a serious deficit problem as it is, there is some difficulty making a credible commitment to a new, open-ended subsidy program. Second, the requirement to add unintended hiring imposes direct costs on firms that will, depending on how stringently they are enforced, offset the benefit of the subsidy. Third, the announcement of the subsidy adds yet another distortion to the Ontario energy pricing mix. Feed-in-Tariff (FIT) rates distort the energy-supply decision by inducing excess production of unnecessary and costly wind power, then the Clean Energy Benefit and the large-user subsidy distort the consumption decision in a partially offsetting way. These price distortions waste tax revenues and create excess burdens throughout the economy. The analysis in this section proceeds on the assumption that electricity prices will rise by 50%, since the measures proposed to partially offset this increase in some sectors will impose other costs, and may only be temporary in any event.

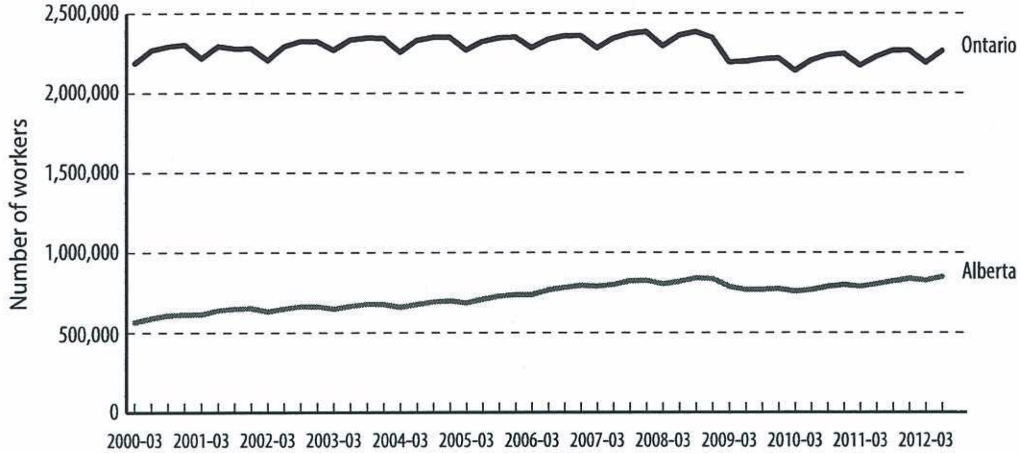
4.3 Effects on competitiveness

Overall employment has been stagnant in Ontario for a decade. **Figure 4.1** shows the evolution of total industrial employment in Ontario and, for comparison, Alberta since 2000. This graph includes all employment in forestry, extraction, utilities, construction, manufacturing, wholesale and retail trade, and transportation. While employment in Ontario remained static, in Alberta employment grew by about 50% from 2000 to 2012.

The hardest-hit sectors in Ontario were manufacturing and forestry, in which employment fell by 30% and 50%, respectively. **Figure 4.2** shows employment indexes by sector since 2000. The job losses in forestry and manufacturing offset gains in other sectors. Over the 13 years from 2000 to 2012, total employment in Ontario grew only 3.5%.

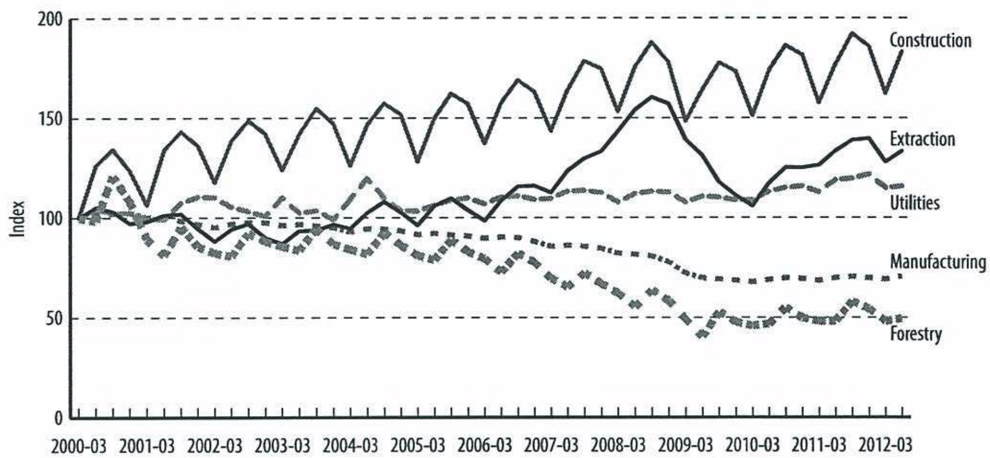
Hence the situation for Ontario employers for the past 10 to 15 years can be described as challenging. Manufacturing was traditionally the largest employer in the province and as of 2000 had almost 80% more employees

Figure 4.1: Total industrial employment in Ontario and Alberta, 2000–2012



Source: Statistics Canada (CANSIM) Employment series; author's calculations.

Figure 4.2: Employment indexes by sector in Ontario, 2000–2012



Note: first quarter 2000 = 100.
Source: Statistics Canada (CANSIM) Employment series; author's calculations.

than the retail trade sector. Its decline over the subsequent 12 years was so steep that it now has a smaller workforce than the retail sector.

The prospect for growth in any sector depends ultimately on the return to investment. Basic economic theory tells us that sectors that earn high rates of return on capital attract investment and expand, creating new employment opportunities. Similarly, where the rate of return on investment declines, so does investment, and employment in turn stagnates or declines. To assess the likelihood that the GEA will lead to gains or losses in employment in manufacturing and other major sectors, we need to assess the likely effects on the return to investment. The next section employs an econometric model to do this, and shows that in each of mining, manufacturing, and forestry, the rate of return to capital will likely fall, leading to net job losses.

These losses will be of a permanent nature, persisting as long as energy prices remain elevated. The AGO report notes that, with regard to the province's claim that 50,000 jobs would be created by the GEA, 75% of them would be temporary construction jobs lasting at most a few years, and the province did not account for jobs lost in other sectors as a result of higher energy costs when arriving at the 50,000 figure (2011: 117–118). The AGO report cited studies from Europe that green-energy schemes led to job losses in other sectors two to four times larger than the employment gains in the renewables sector. The Ministry of Energy admitted (2011: 118) that it had not estimated potential job losses in other sectors, nor calculated the costs per renewable-energy job.

4.4 Estimated cost effects of GEA on the mining, manufacturing, and forestry sectors

Deriving quantitative estimates of the impact of a 50% increase in electricity prices on the mining, manufacturing, and forestry sectors requires estimating an econometric model of input demands per unit of output, then using the estimated parameters to predict the effects on unit costs. Input-output data are available from Statistics Canada for the 1961-to-2008 interval, but only for the country as a whole, so it is here assumed that the essential features of the Ontario industries are captured by data at the national level.

The econometric modeling work is described in the Appendix (p. 30). In general, an overall increase in unit costs can be predicted to have several short-run and long-run impacts. The short-run impacts are:

- loss of competitiveness in national and international markets;
- diminished profitability in the sector;
- downward pressure on wages and reduced returns for investors.

The long-run impacts derive from reduced profitability and competitiveness. At the margin, investment capital will exit the sector in response to a permanent loss in profitability. This will reinforce the short-run losses until a long-run equilibrium point is reached, in which marginal operators have left the industry and the remaining operators are able to generate competitive returns for investors at the new, higher operating costs.

An increase in the price of electricity can be expected to lead to decreased electricity demand, although the direct effects are unlikely to be large since energy demand elasticities tend to be small. There will also be cross-price effects, such that a short-run increase in labour demand might even be observed, since labour and energy are substitutes. However, this is with reference to a preliminary outcome in which output remains constant and firms substitute away from the input that has become relatively more costly. The second-order effect is that the overall cost of production has risen, so the firm's output must fall as it gets priced out of markets at the margin. Also, with a reduced rate of return, capital will exit. This will lead to reduced demand for labour. The long-run effect on employment will therefore reflect the offsetting impacts of these changes and may, in principle, be positive or negative; but, for an input price shock of this size, it is very unlikely to be positive. The elasticities resulting from the estimation exercise are listed in **table 4.2**.

The largest elasticities are associated with labour demand. As expected, own-price energy-demand elasticities are smaller, especially in manufacturing where a 10% increase in the cost of energy leads only to a 0.6% reduction in demand in the short run. The largest own- and cross-price effects on energy demand are in the mining sector, which suggests it will experience the largest unit-cost effects from an electricity price shock. The cross-price effects between energy and other inputs are small across all three industries.

To set the stage for the empirical results, I first examine some historical trends related to electricity and energy in manufacturing, mining, and forestry in Canada. **Figure 4.3** shows the reduction from 1961 to 2008 in energy per unit of output by sector. The graph is constructed so that each sector's index equals 1.0 in 1975. Each sector's energy efficiency showed substantial improvements over the 33 years after 1975. The energy needed to produce a unit of output fell by 55% in the mining sector, 62% in manufacturing, and 65% in forestry.

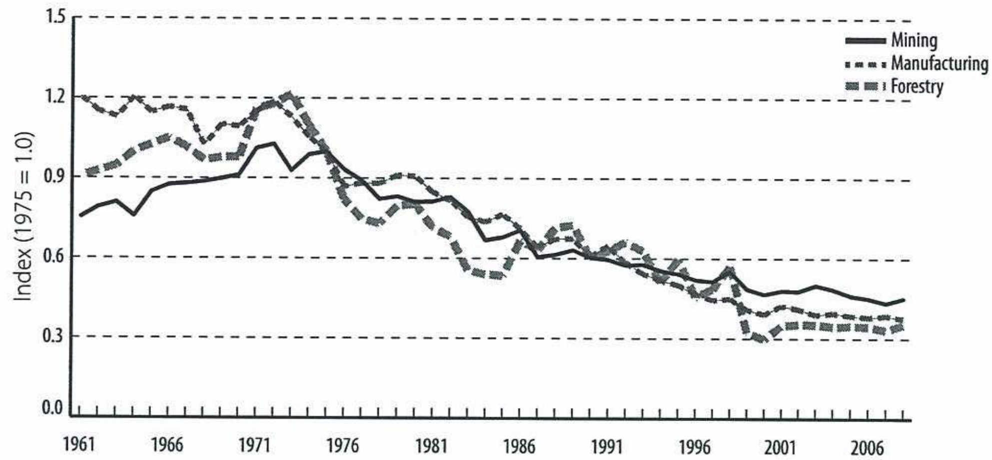
Spending on electricity as a proportion of total energy use is shown in **figure 4.4**. The forestry sector obtains about 90% of its energy from fuels, rather than electricity purchases, which leads us to predict that it will experience the

Table 4.2: Own- and cross-price elasticities relating input-output ratios to input prices for three Canadian industries

Elasticity	Mining	Manufacturing	Forestry
σ_{LL}	−0.467	−0.345	−0.566
σ_{LE}	0.348	0.102	0.162
σ_{LO}	−0.063	0.099	0.152
σ_{EE}	−0.273	−0.061	−0.207
σ_{EO}	0.093	0.013	−0.029
σ_{OO}	−0.012	−0.018	−0.229

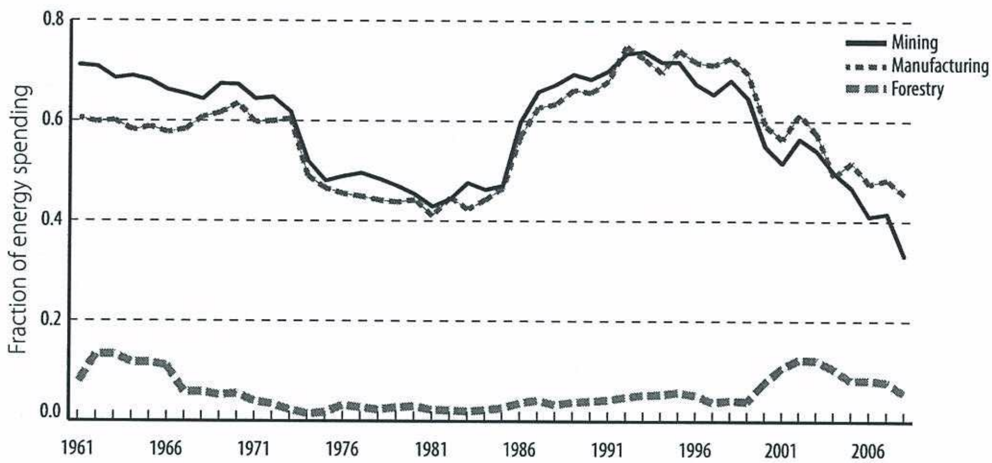
Codes for subscripts: *L*: labour per unit of output; *E*: energy per unit of output; *O*: other inputs per unit of output. Each entry shows the percentage change in first subscript (e.g., labour per unit of output) resulting from a 1% change in the price of the second subscript. For instance, a 1% increase in the price of energy would, other things being equal, increase demand for labour per unit of output in mining by 0.348%. Other cross-price elasticities follow by symmetry.

Figure 4.3: Energy required per unit of output for three Canadian industries, 1961–2008



Sources: Statistics Canada (CANSIM); author's calculations.

Figure 4.4: Spending on electricity as a fraction of total energy spending for three Canadian industries, 1961–2008

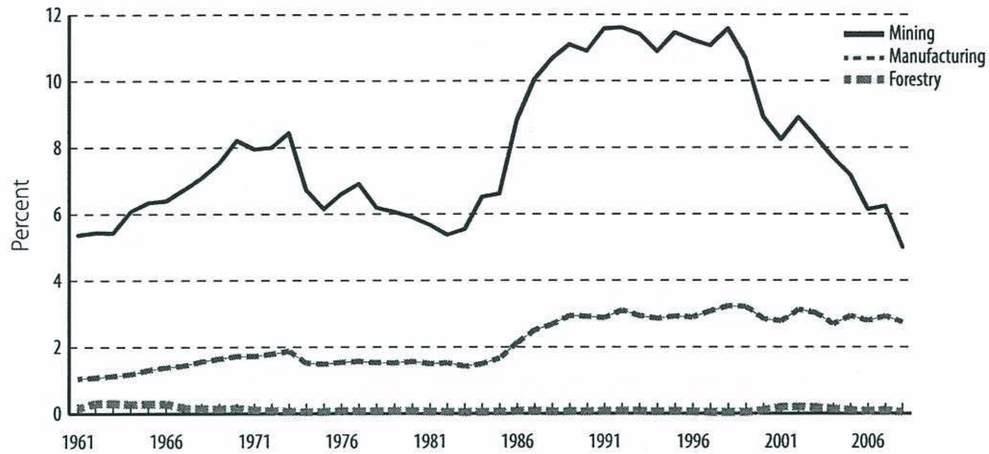


Sources: Statistics Canada (CANSIM); author's calculations.

smallest unit-cost impacts of the three sectors from an increase in electricity prices. Mining and forestry historically spent between 40% and 70% of their energy budgets on electricity, but since 2000 that fraction has fallen to 33% in the case of mining, while it was at 45% in the case of manufacturing as of the end of the sample. Hence, these two sectors can be predicted to exhibit larger impacts from increased electricity prices, although the final effect will depend on the input elasticities.

Figure 4.5 shows the results from the econometric model. As anticipated, the electricity price shock will have the largest effect on unit costs in the mining sector, followed by the manufacturing sector, and then forestry. Based on the input-output characteristics of Canadian industries as of 2008,

Figure 4.5: Estimated percentage increase in short-run unit costs resulting from a 50% increase in electricity price for three Canadian industries, by year from 1961 to 2008



Source: Statistics Canada (CANSIM); author's calculations.

the electricity cost increases forecast for Ontario under the Green Energy Act will increase unit costs of production by 5.0% in mining, by 2.7% in manufacturing, and by 0.04% in forestry. While the vulnerability of the manufacturing sector is below that of mining, the two have been converging in recent years. The mining sector's exposure to a unit cost shock through major electricity price hikes has fallen by about half since the 1990s, while that in manufacturing has held steady.

Finally, we can compute the effect on the industry rates of return using a simple model of capital shares. Suppose that the cost of production c is 80% of the selling price p and the profit rate π is 20%, or in other words $\pi = 0.2p$ and $c = 0.8p$. Then since $\pi = p - c$, we can compute the percentage change in profit per unit resulting from a 1% change in costs as follows:

$$\%\Delta\pi/_{\%\Delta c} = {}^{\partial\pi}/_{\partial c} \times {}^{c}/_{\pi} = -{}^{c}/_{\pi} = -{}^{0.8p}/_{0.2p} = -4.$$

Thus, in an industry with a 20% margin on sales, a 3% unit cost increase will lead to a $-4 \times 3\% = -12\%$ change in the profit margin. In the same way, if the margin is only 10%, the reduction in profitability per unit from a 3% increase in unit costs is $3 \times -{}^{0.9}/_{.1} = 27\%$

According to the Statistics Canada Input-Output Tables (381-0028), the operating surplus for Ontario forestry firms averaged 11% of total costs in 2009 (the most recent year available), while for mining it averaged 28% and for manufacturing it averaged 8.6%. Combining these with the unit-cost elasticities estimated above implies that the rates of return in forestry, mining, and manufacturing will drop, respectively, by 0.3%, 12.9%, and 28.7% as a result of a 50% increase in electricity prices, as shown in **table 4.3**.

Table 4.3 Changes in unit costs and rates of return to capital in Ontario as a result of 50% increase in electricity costs

	Percentage change in unit costs due to 50% increase in electricity price	Percentage change in rate of return to capital
Mining	+5.0%	−12.9%
Manufacturing	+2.7%	−28.7%
Forestry	+0.04%	−0.3%

Source: author's calculations (see Appendix, p. 30).

Summary

The proposed modifications to the Ontario electricity system are expected to lead to a 50% increase in the price of electricity in the coming years. While the Province might try to cushion the blow with subsidy programs, they have not succeeded in doing so to date, the measures announced so far impose other costs (namely requirements for surplus hiring), and under conditions of a major deficit crisis there is diminished credibility to a long-term commitment for such spending. Hence, it is worth examining the potential effects on major sectors of a 50% increase in electricity costs. The short-run competitiveness effects of this rate increase can be estimated as follows:

- the mining sector will experience a 5% increase in the cost of production per unit of output, manufacturing 3%, and forestry less than 0.1%;
- based on 2009 operating surplus rates, this translates into expected reductions in the rate of return to capital of 0.3% in forestry, 12.9% in mining, and 28.7% in manufacturing.

Of particular note is the decline in the rate of return to manufacturing in Ontario, since this will exacerbate a long-term pattern of decline in that sector. The overall reductions in output and employment will depend on the number of firms that need to exit each sector in order to bring the marginal rate of return back to a competitive level.

5 Concluding comments

From the analyses above, we can draw the following conclusions.

1 As of 2009, air quality in Ontario had improved considerably compared to the 1960s, and showed no tendency to be getting worse. A confidential 2005 cost-benefit analysis for the provincial government, often cited by the Province as a defence of the GEA, in fact predicted that the closure of the coal-fired power plants would yield such tiny improvements to air quality as to be unnoticeable in most places.

2 The plan implemented under the Green Energy Act is already 10 times more costly per year than an alternative retrofit plan examined in 2005 that would have yielded the same environmental benefits as closing the coal-fired power plants. And, the GEA-based plan has so far only yielded a fraction of the electricity necessary to replace the coal-fired power plants. Expansion of renewables up to the scale outlined in the Long Term Energy Plan would make the GEA strategy 73 times more costly than the retrofit option.

3 Eighty percent of Ontario's wind power generation occurs at times and seasons so far out of phase with demand that the entire output is surplus and is exported at a substantial loss. The province has already lost close to $2 billion on such exports and currently loses, on average, $24,000 per operating hour on such sales, totaling $200 million annually. The loss rate will continue to grow with every new wind turbine installation, because the mismatch between the timing of wind-powered generation and Ontario electricity demand is structural.

4 Output of Ontario's wind turbines is below one-fifth of rated generating capacity about half the time, and below one-third of the rated capacity about two-thirds of the time. Due to fluctuating output, 7 MW of rated wind energy are needed to replace 1 MW of conventional power generating capacity. Consequently the cost of achieving the provincial targets for wind energy in the coming years will be far greater than has been acknowledged or, alternatively, will entail relying on sources that are unreliable depending on the season.

5 Electricity prices for large users in Ontario are now among the highest in North America and are expected to increase by 40% to 50% further, in large part to pay for costs incurred under the GEA. As a result, the effect of the Green Energy Act on Ontario industry will be to increase unit costs, diminish competitiveness, cut the rate of return to capital in key sectors, reduce employment, and make households worse off. The rate of return to capital in manufacturing will drop by about 29% if the projected increases in electricity prices are realized. The rate of return in mining will drop by about 13% and in forestry by about 0.3%.

6 The Province's claim that 50,000 jobs will be created by the GEA was unsupported by any formal analysis, and the Province has since admitted both that the vast majority of any GEA-related jobs will be temporary, and that the 50,000 figure does not account for offsetting permanent job losses due to electricity price increases under the GEA. Consequently, the claim has no basis in fact.

7 In regions afflicted by the proliferation of wind turbine installations, there are additional costs to households due to lost property values, rural environmental degradation, and increased health and stress problems. These have not been taken into account in this analysis but, were they to be considered, the overall cost burden of the GEA would be even higher.

Appendix Technical details of econometric model estimation for section 2

According to economic theory (e.g., Varian 1984), the function relating a firm's short-run total costs C to the vector of input costs and the output level can be written

$$C = c\,(\boldsymbol{p}, t, y) \qquad \text{(A.1)}$$

where, in this case, $\boldsymbol{p} = \{p_l, p_e, p_o\}$ is the vector of input prices of, respectively, labour l, energy e, and other inputs o; t is a time index capturing technical progress and y is the output level. Capital is assumed to be exogenous, making this a short-run analysis. By Sheppard's lemma the input demand equations v_i can be computed using the first derivatives of (A.1) with respect to the corresponding prices. If we additionally assume constant returns to scale, we can express inputs per unit of output as functions of prices and technology:

$$\frac{v_i}{y_i} = \frac{\partial c(\boldsymbol{p},t)}{\partial p_i} \qquad \text{(A.2)}$$

where $i = (l, e, o)$. I used a reduced-form translog cost function to obtain the system

$$Log\,(^{l}\!/_{y}) = a_{10} + a_{11}\,log(p_l) + a_{12}\,log(p_e) + a_{13}\,log(p_o) + a_{1t}\,t + e_1$$

$$Log\,(^{e}\!/_{y}) = a_{20} + a_{12}\,log(p_l) + a_{22}\,log(p_e) + a_{23}\,log(p_o) + a_{2t}\,t + e_2$$

$$Log\,(^{o}\!/_{y}) = a_{30} + a_{13}\,log(p_l) + a_{23}\,log(p_e) + a_{33}\,log(p_o) + a_{3t}\,t + e_3 \qquad \text{(A.3)}$$

where e_i, $i = (1, 2, 3)$ are the random terms. Note that the cross-price elasticity terms (a_{ij}, $i = (1, 2, 3)$, $j = (1, 2, 3)$) form a matrix $\boldsymbol{A}$ upon which symmetry was imposed. Also, the restriction $a_{1t} + a_{2t} + a_{3t} = 0$ was imposed to be consistent with the linear homogeneity property of the cost function. All variables are time-series but the time index is ignored for notational simplicity, as are the sector subscripts in (A.3). For the system (A.3) to be a valid cost function, the matrix $\boldsymbol{A}$ must be negative semidefinite, which can be confirmed by examining the eigenvalues after estimation: each one must be less than or equal to zero. The estimation of system (A.3) was done using seemingly unrelated regressions subject to the linear constraints mentioned above. In the estimation on the mining sector, two of the three eigenvalues were negative and one was slightly positive (0.034) representing a slight deviation from the curvature condition. In the other two sectors, the eigenvalues were all zero or negative. Since imposing a curvature condition on the translog removes its flexibility as an elasticity estimator, the slight indication of nonconcavity in the mining sector model was ignored. No correction was applied for autocorrelation in (2.3), so the resulting standard errors were likely biased upwards. However, the model was used for parameter estimation rather than hypothesis testing, and the least squares coefficients are unbiased even in the presence of serially correlated errors, so there was no need to address this.

The data were obtained from the CANSIM Input-Output accounts (CANSIM table 381-0014). Total spending in current dollars in each sector on all inputs, energy (natural gas, motor fuels, and electricity), and labour (wages, salaries, and supplementary income) were aggregated into the categories labour, energy, and other. Input shares were obtained by dividing each input category into the total nominal inputs. To obtain price indexes, real input quantity series (including capital services) for the same categories were obtained for each industry from the Statistics Canada multifactor productivity accounts (CANSIM table 383-0022). These were turned into index form by dividing through by the 1961 value, then the nominal input series were divided by the quantity index. This series in turn was normalized so the 1961 value equals 1, and this was used as the price index. The technology index t was defined as the year. Real output series were also obtained from the multifactor productivity accounts. This yielded a complete set of data for estimating the system (A.3).

Because (A.3) is in log-log form, the coefficients in $\boldsymbol{A}$, denoted a_{ij}, are the elasticities relating, respectively, labour, energy and other inputs per unit of output to the respective prices. These estimates are listed in **table 4.2.** I denote the input-per unit output term using capital letters (e.g., $L = {}^{l}\!/_{y}$). The unit cost function can be written as the sum of prices times optimized input levels:

$$c\,(p, t) = p_l L^* + p_e E^* + p_o O^*$$

where * denotes the local optimum value. Differentiating this expression with respect to p_e gives

$$\frac{\partial c}{\partial p_e} = \frac{a_{12} p_l L^* + a_{22} p_e E^* + a_{23} p_o O^*}{p_e} + E^* \qquad \text{(A.4)}$$

Equation (A.4) can be converted into elasticity form σ_{cpe} by multiplying by $p_e \div c$, yielding for each sector a measure of the percent change in unit costs resulting from a 1% increase in the price of energy. This is converted into an estimate of the variable d^j_{50}, which is the percentage increase in unit costs of production in sector *j* resulting from a 50% increase in the price of electricity, by multiplying σ_{cpe} by the nominal share of electricity in energy expenditures (denoted w_{el}), times 50:

$$d^j_{50} = 50 \times w^j_{el} \times \sigma^j_{cpe} \qquad \text{(A.5)}$$

where we have added the superscript *j* to each term to emphasize that this is a sector-specific estimate.

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About the author

Ross R. McKitrick

Ross R. McKitrick is a Professor of Economics at the University of Guelph and Senior Fellow of the Fraser Institute. He specializes in environmental economics. He has published many studies on the economic analysis of pollution policy, economic growth and air pollution trends, climate policy options, the measurement of global warming, and statistical methods in paleoclimatology. His latest book is *Economic Analysis of Environmental Policy*, published by University of Toronto Press (Fall 2010). He has also published numerous invited book chapters, newspaper and magazine essays, and think-tank reports.

In 2003, his (coauthored) book, *Taken by Storm: The Troubled Science, Policy and Politics of Global Warming*, won the $10,000 Donner Prize for the best book on Canadian Public Policy.

Professor McKitrick has been cited in media around the world as an expert on the science and policy of global warming. He has made invited academic presentations in Canada, the United States, and Europe, and has testified before the US Congress and the Canadian Parliamentary Finance and Environment Committees. In 2006, he was one of 12 experts from around the world asked to brief a panel of the US National Academy of Sciences on paleoclimate reconstruction methodology.

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APPENDIX B

Xcel Energy. 2013.
Underground Transmission Lines, pg 2
Factsheet published on Website <www.powerfortheplains.com/resources/fact-sheets/index.asp>

Right-of-way and structures

345 kV transmission lines generally require a 150-foot easement that can continue to be used for most existing activities, such as farming. Underground transmission structures require a completely clear right-of-way (ROW) of approximately 60 feet (no farming activity within the 60-foot ROW).

Technical issues

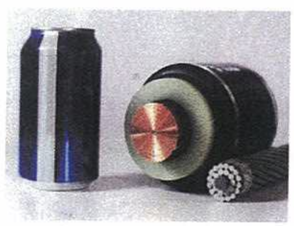
Cable. The most commonly used underground cable systems are solid dielectric and high-pressure fluid-filled. Solid dielectric cable is buried in wide trenches about six feet deep and installed in concrete-encased duct banks. For a fluid-filled system, once the cable has been installed in a steel pipe, the pipe is filled with a synthetic oil or gas and pressurized. This type of system is also trenched and covered with specialized backfill, sand or other type of soil.

Heat. Transmission lines generate heat when conducting electricity. Overhead lines are naturally cooled by air. Special effort must be taken to cool underground lines. If oil is used in a fluid-filled cable system, the oil helps cool the cable. All underground transmission lines should be covered by an engineered thermal backfill to help dissipate heat.

Repair and maintenance. Underground transmission lines can take much longer to repair than overhead lines. Estimates show that locating and repairing faults can take between two and six weeks. Overhead lines can generally be repaired in a matter of hours or days after a fault occurs.

Electric and magnetic fields

Like overhead transmission lines, underground transmission lines also emit electric and magnetic fields. At three feet above ground, the magnetic field within an underground transmission line's 60-foot ROW is comparable to the magnetic field 75 feet from an overhead transmission line.



A solid dielectric underground cable is significantly larger than a standard conductor that hangs from an overhead structure.

Transmission lines are installed in concrete-encased duct banks.

APPENDIX C

Creces, Gerard. 2013.
Front page photo and article headlined "Turbine fire cause still undetermined"
Published in *Huron County Focus* – Community newspaper. Friday, April 12, 2013 issue.
Article also published in *Goderich Signal-Star* Wednesday, April 10, 2013

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Turbine fire cause still undetermined

2 Huron County Focus • Friday, April 12, 2013

Community

Turbine fire cause still undetermined

Third-party investigator coming from Denmark

Gerard Creces
Goderich Signal-Star

An early morning fire at an industrial wind turbine off Golf Course Road Tuesday, April 2, is currently under investigation by Capital Power.

At around 1 a.m. April 2, the fire department responded to a turbine on fire at Golf Course Road near Loyal Line. The root cause is under investigation, however the fire had burned itself out by 3 a.m. according to Dan Hayden of Capital Power.

The turbine blades and nacelle (the square box off the blade that houses the generator) were severely damaged in the fire. However, many of the hydraulic hoses remain intact, the rubber burnt but the braiding holding out.

"Personally, I'm surprised the damage isn't worse," Hayden said. "We don't have quantities yet, but the majority of gear and hydraulic oil remains up there. The investigation will continue and give us more clear details over the next few days."

The Ministry of the Environment was on site the day after the fire to investigate for oil spills, though none were found. Debris from the blade itself was found downwind of the turbine. Larger pieces (about the size of this newspaper) were found within 200 meters, however smaller pieces were located up to 400 meters away. All pieces were found in the same field as the turbine and cleanup crews have been combing for debris. As of Friday, about 10 garbage bags full have been found.

"The waste is being sorted and disposed of appropriately," Hayden said. "The blade material is landfill acceptable however, we will ensure it is disposed of properly following local regulations.

The turbine is part of the Kingsbridge 1 project occupying much of the Ashfield-Colborne-Wawanosh landscape.

Hayden said the fire is extremely rare - the incident is the first of its kind in Ontario.

However, priorities are to ensure employee and public the safety, make sure the damage is contained to the turbine site.

Later Tuesday, Hayden went to ACW Council to inform them of the details, and on April 4, met with Huron County Emergency Response Committee meeting.

He has been in touch with municipal, federal and provincial government representatives.

"We're trying to be open and in touch with people," Hayden said. "If they have any questions, please let us know.

A third-party investigator from Denmark will be coming to inspect the site.

The turbine is a Vestas V80 1.8MW model, which houses three computers from top to bottom. The base computer has been removed for analysis, and Hayden noted as soon as the turbine's computer detected a problem, it shut itself down and stopped turning as well as disconnected from the power grid.

"Basically, the turbine was running. Something went wrong inside the turbine and instantly when the computer recognized a problem it was shut down," he said.

Sensors on the door at the turbine show no exit or entry the night of the fire.

While the fire has created a flurry of speculation, Hayden said as a community member it means a lot to make sure the facts are clear.

Damage estimates are expected to come within the next week, however they were unavailable as of press time.