Pain without Gain

Shutting Down Coal-Fired Power Plants Would Hurt Ontario

Ross McKitrick, Kenneth Green, & Joel Schwartz
Executive summary

Introduction

Coal-fired power plants operated by the Ontario Power Generation Corporation account for about 25% of Ontario’s electricity supply. The government of Ontario has announced its intention of closing all these plants by 2007. This unusual decision comes at a time of rising power consumption in Ontario, high oil and gas prices, and considerable uncertainty regarding the willingness of the private sector to invest in future development of generating capacity in Ontario.

Closing the coal-fired plants will imperil industrial development in Ontario, increase energy costs, and reduce the reliability of the electricity supply. It will also impose other costs, including job losses at the plants themselves, the need to develop replacement capacity on a compressed timetable, increased use of higher-cost fuels, and the cost of scrapping the installed plants. The arguments in favour of the policy centre on fears about the environmental consequences of operating the coal plants, including increased air pollution and associated health effects, mercury emissions, and climate change. Thus, the decision implies a weighing of potential benefits of reduced emissions against the social and private costs of shutting down the generators.

Surprisingly, despite the large potential impacts of closing the plants, there has been no systematic evaluation of whether this action will confer net benefits on Ontarians. There is no question that coal-fired power plants contribute to Ontario’s air pollution emissions. The question is whether the harm associated with these emissions exceed the social and economic benefits of the electricity they provide. Our review of the evidence suggests that the coal-fired plants have a relatively small environmental impact and that closing them will have large, adverse economic consequences that will fall disproportionately on low-income households. Thus, before phasing out the coal-fired plants, the Government of Ontario has a public duty to exercise due diligence by carefully evaluating the net welfare effects of its electricity generation plans.

This publication provides a survey of key aspects of the Government of Ontario’s proposed plan to phase out coal-fired power plants and our findings are as follows.

1 Assessing the benefits of closing Ontario’s coal-fired power plants

1.1 Despite the continued operation of coal-fired power plants, air quality in Ontario is good and much improved since the 1970s.
1.2 Coal-fired power plants play a small role at present in pollution and smog formation.

1.3 Scientific investigation of links between air pollution and increased health or mortality risk has yielded ambiguous results and suggests that air pollution at current levels and, therefore, air pollution from coal-fired power plants, is not harming Ontarians’ health.

1.4 Mercury at current levels from all sources is unlikely to represent a source of harm to Canadians’ health and reducing coal-based mercury emissions will have little or no effect on environmental mercury levels.

1.5 Closing Ontario’s coal plants is not part of Canada’s plan for Kyoto and combatting climate change.

2 Assessing the costs of closing Ontario’s coal-fired power plants

2.1 Power from coal-fired plants is an abundant, low-cost, and reliable electricity source and is, therefore, an important economic benefit to citizens of Ontario.

2.2 The increased prices for electricity that will result from shutting the coal-fired plants will cause reductions in household real income that fall disproportionately heavily on the poor.

2.3 Low-cost, abundant, electricity is a key factor in long-run economic growth and measures that raise costs or restrict electricity supply will have long-term negative consequences for economic growth.

3 Conclusions

It is a fundamental duty of government to avoid enacting policies that will make people worse off. The burden of proof rests on the Government of Ontario to show that its electricity plan would improve Ontarians’ overall welfare and this could best be done by setting aside its plans to shut the coal plants until a proper, objective benefit-cost analysis has been completed. Overall we conclude:

- Ontarians derive substantial benefits from the operation of the coal-fired power plants, and before shutting them down the Ontario government has a fundamental duty to evaluate whether the costs of such a decision would exceed the benefits; and
- Ontario’s coal plants are likely a net benefit to society, and the decision to close them is unlikely to pass an objective cost-benefit test.

If the Ontario government believes its plan would pass a cost-benefit test, it has a duty to produce convincing evidence to this effect before proceeding to phase out the coal-fired power plants.
Introduction

The government of Ontario has announced its intention to close all coal-fired power plants operated by the Ontario Power Generation Corporation by 2007. Coal-fired plants account for about 25% of Ontario’s electricity supply, which is slightly higher than the national average of 20%. [1] This unusual decision comes at a time of rising power consumption in Ontario, high oil and gas prices, and considerable uncertainty regarding the role of the private sector in the future development of generating capacity in Ontario.

Closing the coal-fired plants will imperil industrial development in Ontario with the result that costs of Ontario’s electricity supply will increase and its reliability will be reduced. Closing the coal-fired plants will also impose other costs, including job losses at the plants themselves, the need to develop replacement capacity on a compressed timetable, increased use of more expensive fuels, and the cost to scrap the existing plants. The arguments in favour of the policy center on fears about the environmental consequences of operating the coal plants, including air pollution and associated health effects, mercury emissions, and climate change. Thus, the decision implies a weighing of potential benefits of reduced emissions against the social and private costs of shutting down the generators.

Evaluating the closures

Surprisingly, despite the large potential impacts of closing the plants, there has been no systematic evaluation of whether this action will confer net benefits on Ontarians. There is no question that coal-fired power plants contribute to Ontario’s air pollution emissions. The question is whether the harm associated with these emissions exceeds the social and economic benefits of the electricity they provide. Our review of the evidence suggests that the coal plants have a relatively small environmental impact and that closing them will have adverse economic consequences that fall disproportionately on low-income households. Thus, before proceeding with the phase-out, the Government of Ontario has a public duty to exercise due diligence by carefully evaluating the net welfare effects of its electricity generation plans.

Plan of this paper

This paper proceeds in three sections. The first examines the environmental benefits of closing the coal plants, and argues that they are likely quite small. The second con-
siders the economic costs of closing the coal plants and argues that they are potentially large. The final section puts forward our conclusions, namely:

- Ontarians derive substantial benefits from the operation of the coal-fired power plants and, before shutting them down, the Ontario government has a fundamental duty to evaluate whether the costs of such a decision would exceed the benefits; and
- Ontario’s coal plants are likely a net benefit to society and the decision to close them is unlikely to pass an objective cost-benefit test.

We arrive at this conclusion while assuming continued use of the current technology for burning coal. We have not examined the impact of adopting options for “clean coal” technologies, which, if economical, would strengthen our conclusions further.
1 Assessing the benefits of closing Ontario’s coal-fired power plants

1.1 Despite the continuing operation of coal-fired power plants, air quality in Ontario is good, and much improved since the 1970s.

Data on air quality are gathered by Environment Canada’s National Air Pollution Surveillance System (NAPS) and updated series from NAPS are published semi-annually by The Fraser Institute in its series, *Environmental Indicators*. Appendix A (page 28 in this publication) contains charts showing monthly average pollution readings from 1973 through the end of 2002 for Windsor, London, Hamilton, Toronto, and Ottawa. These charts and the larger database from which they are drawn [Brown et al., 2004] show the following patterns.

**Carbon dioxide and lead**
In every city, levels of carbon monoxide (CO) and lead are extremely low compared to historical levels and are well below the current standard.

**Sulphur dioxide and nitrogen dioxide**
Likewise, levels of sulphur dioxide (SO₂) and nitrogen dioxide (NO₂) have fallen over time. In many cities, they are now routinely under the most stringent of Environment Canada’s standards.

**Total Suspended Particulates**
Total Suspended Particulates (TSP) fell from relatively high levels in the 1970s to levels close to, or below, the current standard by the mid-1980s. Levels have tended to remain approximately constant since then (see next section for a discussion of particulate emission sources). An exception is Hamilton which, despite ongoing TSP declines, still exceeds Environment Canada standards.

**Ozone**
Ozone levels have stayed relatively constant and have risen slightly recently in some areas, though monthly average levels are generally below the most relevant clean air standard, namely, the “maximum desirable level,” according to Environment Canada. Ozone is not emitted directly but is formed when volatile organic compounds (VOCs) and nitrogen oxides (NOₓ) react in sunlight on warm, sunny days. VOCs come mainly
from cars and natural emissions from vegetation, while NO\textsubscript{x} comes mainly from cars, on- and off-road diesel vehicles, and power plants. For most of the year, ozone is not a noticeable problem but is subject to spikes during the warmer months, especially in the summer, sometimes exceeding air quality standards. There has been some progress in reducing ozone but of all pollutants it has been the most resistant to control efforts. Ozone chemistry is complex and depends on the ratio of VOC to NO\textsubscript{x} in air rather than just on total emissions of these compounds. [Seinfeld, 1989; Fujita, Stockwell et al., 2003; Pun and Seigneur, 2003] Indeed, ozone has risen during the last few years despite reductions in VOC and NO\textsubscript{x}. When the VOC-to-NO\textsubscript{x} ratio is sufficiently low, NO\textsubscript{x} reductions actually increase ozone. Recent evidence from the United States shows that this is the case in many US cities. Due to similar air pollution control policies, Ontario’s cities may be in a similar situation.

**Overall air quality**

Overall, the claim that air pollution is getting worse is not supported by the available data. Looking at the actual pollution levels in urban air, the general situation today is substantially improved compared to that in the 1960s and 1970s, even though the economy has grown considerably over the intervening years.

One potential complication to this story is the presence of sulphate aerosols in the atmosphere. These are ultrafine particles formed when SO\textsubscript{2} gas reacts with either a hydroxyl radical (OH) or hydrogen peroxide (H\textsubscript{2}O\textsubscript{2}). [Stein and Lamb, 2003] Sulphate particles have been implicated in some epidemiological studies as potential threats to health. We do not have measurements of the sulphate component of PM specifically. However, total particulate matter and the gases that help form sulphate (e.g., SO\textsubscript{2}) have been dropping so there is reason to suppose sulphates have declined as well. Data from the United States also show that sulphate levels have steadily declined since data collection began in the late 1980s. [US EPA, 2004] In any case, as is discussed in Section 1.3 below, the toxicological evidence for harm from sulphate particulates is weak.

**1.2 Coal-fired power plants play a small role at present in the formation of pollution and smog.**

Some of the main contaminants covered by the term “air pollution” are sulphur dioxide, carbon monoxide, nitrogen oxides, particulates, and ground-level ozone. According to Ontario government estimates, about one-quarter of current sulphur dioxide emissions are generated by utilities. [Ontario Ministry of Environment, 2004] Carbon monoxide emissions come mostly from transportation sources (85%), as do NO\textsubscript{x} emissions (63%). Utilities contribute about 15% of NO\textsubscript{x} emissions. At high concentrations, NO\textsubscript{2} (one of the two components of NO\textsubscript{x}) can be a direct threat to health but the main
Pain without Gain: Shutting Down Coal-Fired Power Plants Would Hurt Ontario

Concern about NO\textsubscript{x} at current ambient levels is its role in ozone and sulphate formation, since NO\textsubscript{2} and NO\textsubscript{x} levels are relatively low compared to health standards.

Regarding particulate emissions, the US Environmental Protection Agency provides detailed source breakdowns. [US EPA, 2004] On a national basis, as of 1998, natural sources dwarf all others combined. Natural sources are responsible for 5,307,000 short tons of emissions, followed by residential wood-burning fireplaces, which come in a distant second at 411,000 short tons. Coal-burning for industry and generating electric power comes next at 362,000 short tons. Since the US economy is more than twice as coal-intensive as Canada’s, the fraction from power plants may be even lower here. These numbers account only for direct particulate emissions. Half or more of fine particulate matter actually results from gaseous SO\textsubscript{2}, NO\textsubscript{x} and VOCs that get converted to fine particulates through chemical reactions in the atmosphere.

The role of Ontario’s power plants in forming ground-level ozone in Ontario was studied recently in a report by RWDI Consultants. [RWDI, 2004] The RWDI model simulates the region containing the US Northeast and Southern Ontario, computing airflows and pollution levels using estimates of various emission sources, chemical reactions in the atmosphere, and meteorological data. The model was tuned to replicate a high-air-pollution episode in July 1999, then run to simulate what the change in ozone and smog formation during that episode would have been had the coal plants not operated. The results indicated that there would have been almost no difference: the reduction in ozone formation across the region would have been imperceptibly small. The reasons include the fact that most Ontario ozone is attributable to sources other than the thermal power plants, such as transport of pollutants from elsewhere, and other local and regional emissions sources.

1.3 Scientific investigation of links between air pollution and increased health or mortality risk has yielded ambiguous results and does not support attribution of specific harms to the operation of coal plants.

In recent years, much research has examined whether observed pollution levels correlate with health outcomes like premature death, lung disease, coronary disease, infant mortality, low birth weight, asthma, and so forth. These epidemiological studies typically start with data on mortality or morbidity (disease) and distinguish between the “expected” number of deaths and the “excess” number of deaths. The latter count is then compared to pollution levels and other variables to see if there is a correlation. Estimating the “expected” number of deaths requires statistical modeling and expert judgment. Researchers construct a trend model that tries to establish a baseline level of mortality through the time period of the data. The difference between the baseline mortality
level and the observed level is then called the “excess” or premature death rate, and this residual series is compared to pollution rates to see if there is a correlation.

The environmental epidemiology literature, encompassing hundreds of published studies, has asserted a number of conclusions:

**Ambient particulates**  There appears to be a small, positive, and statistically significant correlation between ambient particulate pollution levels and the risk of premature death. For example, studies in the United States report that every increase of 10 µg/m³ in the concentration of particulates is correlated at the national level with an increase in mortality risk of about 0.5% for daily PM variations. There is a 4% increase per 10 µg/m³ for long-term PM exposure and the effects appear even at ambient particulate levels near zero. [Dominici et al., 2002; Pope, Burnett, et al., 2002]

**CO, NOₓ, and ozone**  Elevated levels of carbon monoxide, NOₓ and ozone each correlate with a small, positive, and statistically significant increase in cardiac illness and mortality. [Burnett et al., 1997 and 1998]

**Ozone**  There is substantial evidence showing acute respiratory effects from ozone exposure but limited evidence for chronic respiratory effects related to ozone exposure. [Levy et al., 2001]

Extrapolating from these and similar epidemiological findings, the Ontario Medical Association [OMA, 2001] and the Toronto Board of Public Health [Basrur, 2000; Yaffe, 2004] have claimed that thousands of lives are lost each year in Ontario due to current air-pollution levels. The OMA estimates that 1,900 Ontarians die annually from air pollution and 13,000 go to emergency wards. The Toronto Board of Public Health recently increased its estimate of the annual impacts of air pollution from about 1,000 deaths to 1,700 deaths and from 5,500 hospitalizations to 6,000 hospitalizations.

However, the statistical evidence for harm from current air pollution levels is far more ambiguous than is apparent at first glance. For example, the prominent and widely respected *National Morbidity, Mortality and Air Pollution Study* (NNMAPS) by Dominici et al. [2002] estimated dose-response curves relating PM₁₀ exposure and mortality risk in 88 US cities. The relative risk coefficients are graphed in figure 2 of that paper. Surprisingly, in 20 of the 88 cities studied, increased particulate pollution is associated with reduced mortality risk. Likewise, the study summarizes mortality effects averaged across seven US regions (figure 5 of that paper). In two of the largest regions, the US Southwest and Southeast, increased pollution is associated with lower mortality for PM levels below 60 µg/m³. In the Upper Midwest, PM₁₀ is associated with increased mortality but the effect disappears above 100 µg/m³, suggesting,
implausibly, that the harm from air pollution occurs at low pollution levels and that no additional harm occurs once pollution exceeds 100 µg/m³.

Researchers discount results like these by emphasizing the difference between correlation and causality. No one thinks pollution improves the health of a population or that higher pollution levels are safer than lower levels, so such results are assumed to be spurious. In the survey used by the authors of the technical report for the Ontario Medical Association, anomalous results like these were simply deleted from the sample as examples of spurious correlation. [DSS Management Consultants, 2003: D-13, D18, and D-21] Yet the OMA and the Toronto Public Health Board have no qualms about using the positive correlation coefficients in their models as evidence of causal connections between pollution and health effects. This amounts to cherry-picking the science for results that support a preferred conclusion. [2]

The results that link health effects to pollution levels tend to follow a pattern of being small and inconsistent across locations. Referring again to Dominici et al. [2002], the PM₁₀-mortality association ranges from about −3% (per +10 µg/m³ increase in ambient level) in Little Rock, Arkansas to about +3.2% in Topeka, Kansas. The national average of the city results is about +0.2% and this is the number most often quoted. [3] But, in any estimation exercise where a small effect is being estimated from a noisy data set, the individual estimates need to be viewed with caution. In the case of pollution epidemiology, there is good reason to doubt that the statistical associations represent genuine cause-and-effect relationships and raise the likelihood that the results are not as statistically significant as once thought.

A number of recent studies [Lumley and Sheppard, 2003; Clyde, 2000; Smith et al., 2000; Koop and Tole, 2003; Currie and Niedel, 2004] have shown that findings of positive correlations between pollution and health are very sensitive to model uncertainty. In large epidemiological data sets, there may be thousands or even millions of ways to specify the statistical model used to assess the correlation between pollution and health in the presence of potentially confounding factors (e.g., weather) that affect health and that are often correlated with pollution levels. For example, initial studies using data from Birmingham, Alabama [Schwartz, 1993, 1994] reported that air pollution was associated with increased mortality. But Smith et al. [2000] then showed, using the same data, that small changes in the mathematical models used to estimate the effect of air pollution can cause the apparent effect of air pollution to drop to zero. Clyde [2000] also re-analyzed the Birmingham data using a technique called Bayesian Model Averaging (BMA) that accounts for model uncertainty and found risk coefficients were lower than those initially reported in Schwartz [1993, 1994] and statistically indistinguishable from zero. Likewise, in a recent assessment of model uncertainty using data for Toronto, Koop and Tole [2004] concluded that while weather fluctuations were associated with increased mortality, the measured impact of air pollution was sensitive to the type of model used. They found that while some models yield a
positive point estimate (indicating that an association between pollution and health can be identified within a particular statistical model), there is a large range of models that fit the data and those with the best fit tended to rule out a significant correlation between pollution and health.

Difficulties such as these prompted two epidemiologists to conclude recently: “Estimation of very weak associations in the presence of measurement error and strong confounding is inherently challenging. In this situation, prudent epidemiologists should recognize that residual bias can dominate their results.” [Lumley and Sheppard, 2003]

Recent research is also doing a better job of controlling for confounding factors and the result is that the role of pollution declines in importance. A recent study of pollution and infant mortality in California [Currie and Neidell, 2004] reported a statistically significant relationship between pollution and premature birth. However, after controlling for community socioeconomic characteristics, the pollution effects disappeared. The same thing happened when examining low birth weight and fetal death: the pollution effects disappeared when other controls are added to the model. The only effects that did not disappear were a small but statistically significant association between increased ambient carbon monoxide levels and an increased rate of infant mortality and (in one specification) a small effect of PM$_{10}$ on infant mortality.

Even when taken at face value, studies that report associations between air pollution and health suggest the overall effects are small. For example, when the US Environmental Protection Agency tightened its ozone standard in 1997, it predicted that going from the old standard to the new standard would reduce hospitalizations for asthma attacks by 0.6%, even though the 8-hour standard is substantially more stringent. [EPA, 1996] A recent report sponsored by environmental activists concluded that a complete elimination of pollution from coal-fired power plants would reduce serious respiratory and cardiovascular distress by 0.4% to 1.6%. [Abt Associates, 2000]

**Epidemiological studies and laboratory experiments**

The epidemiological approach should be recognized as having advantages and disadvantages. The main advantage is its ability to process large volumes of data. However, there are some important disadvantages. When seeking a small effect in a noisy data set, the answers are unlikely to be definitive or reliable and contradictory findings will emerge from different researchers and different methodologies with little guidance for choosing some results over others. Also, the data tend to be indirect. Researchers use outdoor ambient air-pollution levels but this may not provide a good measure of actual exposure since people spend a lot of each day indoors. Likewise, health outcomes are measured using hospital admissions or death rates, which can only provide an approximation to the physiological phenomena of interest.
If the epidemiological studies were unaffected by these limitations, then laboratory experiments should readily validate their conclusions but this is not the case. In experimental studies, people and animals are exposed to controlled levels of air contaminants while scientists monitor cardiac and lung functions for responses. There has been considerable work on this, recently summarized in a pair of papers in the journal *Regulatory Toxicology and Pharmacology*. [Green, Crouch, et al., 2002; Green and Armstrong, 2003]

Laboratory studies have shown that high ozone levels can cause respiratory irritation in some people but eliciting these effects at the ozone levels typical of peak levels today required a few hours of exposure along with vigorous exercise. [Horstman, Folinsee, et al., 1990] Laboratory studies with nitrate and sulfate particulate matter have not yielded evidence of toxicity or respiratory problems, even for asthmatics, and even at levels much higher than current ambient levels. [Kleinman, Linn, et al., 1980; Utell, Morrow, et al., 1983; Koenig, Dumler, et al., 1993; Nannini and Hofer, 1997] Studies on hamsters, rats, and dogs involving exposure to particulates up to 1,000 µg/m³ have not produced evidence of interference with cardiac function. Repeated tests of the effects of particulates in commonly observed ambient concentrations have shown they do not harm health. Green and Armstrong conclude:

> It remains the case that no form of ambient PM—other than viruses, bacteria, and biochemical antigens—has been shown, experimentally or clinically, to cause disease or death at concentrations remotely close to US ambient levels. This lack of demonstration is not for lack of trying: hundreds of researchers, in the US and elsewhere, have for years been experimenting with various forms of pollution-derived PM, and none has found clear evidence of significant disease or death at relevant airborne concentrations. [2003: 333]

This stands in contrast to the conclusions of many epidemiological studies and calls into question the assertion that contemporary ambient pollution levels are lethal. A recent *Health Canada Science Assessment* [Health Canada, 1997] that provided background material for the development of new air quality guidelines also pointed out the mismatch between epidemiological and toxicological findings.

Controlled human exposures to acidic and inert particles have not caused significant alterations in pulmonary function in healthy individuals at relatively high levels compared to those generally experienced in the environment . . . There has been no convincing evidence suggesting that subjects with chronic obstructive pulmonary disease (COPD) or the elderly are susceptible populations in terms of pulmonary function responses, although some data show that the pulmonary deposition of ultrafine particles (mass median aerodynamic diameter [MMAD])
0.02–0.24 nm) in COPD patients was higher than in healthy subjects … Overall, the clinical data does not lend much support to the observations seen in the epidemiology studies, particularly to the observations that high ambient particulate concentrations are associated with mortality within hours or a few days at most. It does indicate one susceptible subpopulation, asthmatics, who currently comprise 5% to 8% of the population, a percentage that has been rising in the past decade in Canada as well as in other western countries.

Overall, there is good evidence that ordinary, ambient “fresh” air is not a health hazard, even at current pollution levels. A number of commentators have suggested air pollution levels may be causing increases in the rates of asthma. Recently, the UK government’s Committee on the Medical Effects of Air Pollution studied the question and concluded that this claim is unfounded:

For the most part, [healthy] people will not notice or suffer from any serious or lasting ill effects from levels of pollution that are commonly experienced in the UK, even when levels are described as “high” or “very high” according to the current criteria … Perhaps surprisingly, long term exposure to air pollution is unlikely to be a cause of the increased number of people now suffering from asthma in the UK. [United Kingdom Department of Health, 2004]

Taken together these findings suggest that the harm from current levels of ambient air pollution in Ontario are much smaller than has been asserted by the OMA and Toronto Public Health studies and the studies on which they are based.

1.4 Mercury at current levels from all sources is unlikely to represent a source of harm to Canadians’ health and reducing coal-based mercury emissions will have little or no effect on environmental mercury levels.

Natural sources of mercury in the environment include volcanic eruptions and forest fires. Human sources include processing of metal ores, electricity production, and waste incineration. [Lutter and Irwin, 2002] Recent estimates of worldwide mercury emission sources suggest that human sources account for about 40% of total worldwide annual mercury emissions. [Seigneur, Vijayaraghavan, et al., 2003]

Figure 1, which is drawn from a report by Environment Canada, shows the breakdown of recent man-made mercury emissions in Canada. Electricity generation accounts for about 25% and most of that fraction is attributable to coal. Figure 2 shows the breakdown of mercury emissions by source in Ontario: generation of electricity accounts for about the same fraction (24%) as at the national level.
**Figure 1: Sources of atmospheric mercury emissions in Canada, 2000**

- Base Metal Smelting 25%
- Electricity Generation 25%
- Municipal Waste/Sewage Incineration 6%
- Miscellaneous Industrial 19%
- Electrical Products Industry 5%
- Hazardous/Biomedical Waste Incineration 12%
- Other 8%


**Figure 2: Sources of mercury emissions in Ontario, 2003**

- Electricity Generation 24%
- Incineration 15%
- Municipal 12%
- Iron and Steel 13%
- Cement and Lime 11%
- Pulp and Paper 1%
- Mining and Smelting 2%
- Other 22%

Mercury emissions are already subject to regulations and existing strategies have proven quite effective. According to the Mercury Work Group of the Great Lakes Binational Toxics Strategy, mercury emissions dropped by 83% in Canada between 1988 and 2001. [GLBTS, 2003] In Ontario, mercury releases have been cut by more than 12.8 short tons since 1988. [GLBTS, 2003]

**Mercury emissions and fish populations**

Most human exposure to mercury comes from eating fish. [Mahaffee, Clickner, et al., 2004] The mercury in fish comes from both natural and human sources. Because of the complex ways mercury builds up and breaks down in the environment, it has proven difficult to predict whether or how emission reductions would affect levels of mercury in fish. In a report on the subject to the US Congress, the US Environmental Protection Agency (EPA) concluded that

> it is not possible to quantify the contribution of US anthropogenic emissions relative to other sources of mercury, including natural sources and re-emissions from the global pool, on methylmercury levels in seafood and freshwater fish consumed by the US population. Consequently, the US EPA is unable to predict at this time how much, and over what time period, methylmercury concentrations in fish would decline as a result of actions to control US anthropogenic emissions. [EPA, 1997: 3–4]

The situation is likely to be the same in Canada.

Studies examining the link between mercury deposition and mercury levels in fish have had mixed results. Those looking at small, relatively well-characterized regions have found the strongest relationships. For example, a study of mercury deposition and levels in fish in northern Wisconsin found that declines in the mercury levels in fish tracked declines in mercury deposition. But the relationship was not one-to-one: each 10% decline in deposition was associated with only a 5% decline in mercury levels in fish. [Hrabik and Watras, 2002] One possible reason for this mismatch is that as mercury deposition declined, mercury already in sediments may have been released into the water, offsetting some of the effect of reduced deposition. [Watras, Morrison, et al., 2000]

Researchers in Florida recently searched for a link between mercury deposition and mercury levels in Everglades’ fish. They also found a positive relationship but one that was weaker than that found in Wisconsin. Changes in mercury deposition between 1990 and 2000 accounted for only one-third of the mercury decline observed in fish. The study concluded that other factors besides recent atmospheric mercury deposition might explain much of the variability in mercury levels in fish and that key uncertainties in mercury emissions, transport, and sediment chemistry must be
resolved before a clear cause-and-effect relationship can be established between given mercury sources and levels found in fish. [Atkeson and Pollman, 2002]

Curiously, a recent American epidemiologic study of mercury deposition and fish mercury levels reported a statistically significant inverse relationship between mercury deposition rates and concentrations in fish. [Knuffman and Lutter, 2000] While it is clearly implausible that fish mercury levels are inversely related to deposition, the fact that other variables in the epidemiological model, such as the percent of land under cultivation and the acidity of the water, explained much of the variation in mercury levels in fish suggests there is great uncertainty in the degree to which current mercury deposition is causing elevated mercury levels in fish.

Another key factor in the mercury levels of fish in Ontario is that most mercury deposition in Canada comes from non-Canadian emissions. For example, a recent study of sources of mercury deposition in North America concluded that, at most, 25% to 32% of mercury deposition in North America comes from North American sources. [Seigneur, Vijayaraghavan, et al., 2003] The rest (68% to 75%) was due to natural emissions and man-made emissions in other parts of the world, mainly Asia.

Putting these findings together, it is clear that reductions in Canadian mercury emissions will have at best a small effect on mercury levels in fish. For example, suppose the levels of mercury in fish decline at half the rate that deposition declines. If 32% of mercury deposition in Canada comes from domestic emissions and 25% of these are from coal-fired power plants, the complete elimination of coal-fired power plants would result in an average decline of 4% in the level of mercury in fish. [4] This is an upper bound. Indeed, it is unrealistically high because we implicitly assumed that US mercury emissions have no effect on mercury deposition in Canada, even though the US emits about 10 times as much mercury as Canada. [Seigneur, Vijayaraghavan, et al., 2003]

It is also worth noting that these declines apply only to freshwater fish. Reductions in Canadian mercury emissions will likely have no effect on mercury levels in ocean fish because Canada, which releases about 8 metric tons of mercury emissions annually, contributes far less than 1% of worldwide mercury air emissions, which are between 4,400 and 7,500 metric tons per year. [US EPA, 2004] The levels of mercury in ocean fish may be relatively insensitive to recent man-made mercury emissions in any case. A recent study of trends in mercury levels in tuna collected in 1971 and 1998 concluded that mercury levels had not changed over the time period, despite evidence of increasing worldwide mercury emissions due mainly to increases from Asia. [Kraepiel, Keller, et al., 2003]

Overall, it appears that even large reductions in mercury emissions from power plants could have, at best, a tiny effect on mercury deposition rates and an even smaller effect on mercury levels in fish.
Health effects of mercury

Methylmercury (MeHg) in fish, the form of mercury of concern for health, ultimately comes from current and past man-made emissions and natural emissions. Mercury from all sources can eventually contaminate water bodies, where microbes convert some of it to MeHg, which can accumulate in fish. Fish that are higher on the food chain accumulate progressively greater levels of MeHg.

There is no question that exposure to high levels of mercury can cause serious harm, including cerebral palsy and mental retardation. This was tragically demonstrated by poisoning incidents in Iraq and Japan during the 1970s. [Myers, Davidson, et al., 2003] However, these incidents involved mercury exposures tens of times higher than even highly exposed people experience today in western countries. The question for Canadian power-plant policy is whether current low-level mercury exposure is causing harm.

Three major epidemiologic studies—in the Faroe Islands, the Seychelles, and New Zealand—have assessed the relationship between chronic, low-level mercury exposure in the womb and later performance on cognitive and neurological tests. The study in the Faroe Islands reported associations between higher MeHg levels and reductions in test scores [Grandjean, Weihe, et al., 1997] while the Seychelles study did not. [Myers, Davidson, et al., 2003] In the New Zealand study, the association of mercury with lower neurological test performance occurred only if one child with high mercury exposure was excluded from the analysis. [Crump, Kiellstrom et al., 1998]

The US EPA set its reference dose (RfD) for mercury based on the results of the Faroe Islands study. The RfD is a daily intake of a given chemical that EPA estimates is “likely to be without an appreciable risk of deleterious effects during a lifetime.” [US EPA, 2003] The EPA includes safety factors when setting the RfD. For example, the RfD for mercury is 1⁄15 the level associated with health effects in the Faroe Islands study.

The degree of association between mercury and health outcomes in the Faroe Islands and New Zealand studies is small. Lutter and Mader [2001] estimated the change in scores on various tests used in the studies of the Faroe Islands and New Zealand based on the regression coefficients reported in the studies. [5] To be conservative, they assumed that reduced test scores occur on all tests [6] in all people at any mercury level above the RfD.

For example, reducing mercury levels from twice the RfD down to the RfD—a 50% reduction—would improve test scores by about 1⁄12 to 1⁄30 of a standard deviation. [7] Reducing mercury levels from five times the RfD down to the RfD—an 80% reduction—would improve test scores by about 1⁄5 to 1⁄8 of a standard deviation. [8] These represent relatively small improvements in test performance. In addition, effects were smallest for the most general tests of cognitive and neurological performance (e.g., the McCarthy Perceptual Performance Scales (MPPS)) and largest for the most specific tests (e.g., a test of reaction time). Expressed in terms of typical cognitive developmental paths,
these mercury exposure reductions would amount to children achieving intellectual gains equivalent to about one week to three months in age. [9] Assuming that mercury exposure in Canada is similar to that in the United States, fewer than one in 200 children would be at the upper end of this benefit range. [Schwartz, 2004]

Thus, assuming that everyone experiences harm at mercury levels as low as \( \frac{1}{3} \), or even \( \frac{1}{15} \), the level associated with health effects in the Faroe Islands study, the implications for neurological and cognitive health are small. But it must be emphasized that this hypothetical analysis is an unrealistic “worst case” and the real-world situation is far more benign, even if we continue to take the results from the Faroe Islands and New Zealand at face value.

First, the RfD is based on the Boston Naming Test—a test in which children name objects based on line drawings. Higher mercury exposures were necessary for lower scores to appear on other tests. For many tests, mercury exposure was not at all associated with lower scores. For example, in the New Zealand study, even when the child with the highest mercury exposure was removed from the analysis there was still no relationship between higher mercury exposure and lower test scores on 20 of the 26 tests administered, including the IQ test. [10] In the Faroe Islands study, mercury was associated with lower scores on eight of 20 tests, including tests of attention, but not tests dealing with reasoning. [Grandjean, Budtz-Jorgensen, et al., 1999; Grandjean, Wiehe, et al., 1997]

Second, the analysis by Lutter and Mader discussed above made the intentionally conservative but improbable assumption that everyone in the United States is several times more sensitive to mercury than the people in the Faroe Islands or New Zealand—that is, they assumed harm from mercury even at mercury exposures much lower than the levels associated with harm in the Faroe Islands or New Zealand studies. Yet the rationale for the RfD is based on just the opposite logic: a small percentage of people might be “outliers,” which in this case means they absorb MeHg more readily, excrete it more slowly, detoxify it less effectively, and react to it more strongly than the vast majority of other human beings, including the children in the Faroe Islands and New Zealand studies. Such people are expected to be uncommon, because the odds are small that all of these “negative” traits would occur simultaneously in the same person.

In contrast to the results of the Faroe Islands and New Zealand studies, a study of mothers and children in the Seychelles suggests that mercury exposures similar to levels in the Faroe Islands and New Zealand, and much higher than occur in Canada or other western countries, have no effect on health. [Myers, Davidson, et al., 2003] The Seychelles study followed nearly 800 children through age nine and was comparable to the Faroe Islands study in its statistical power to detect any effects of mercury exposure. [Myers, Davidson, et al., 2003] Furthermore, several lines of evidence suggest that the Seychelles study is more relevant than the Faroe Islands study for understanding the potential effects of mercury on children in western countries such as Canada.
First, the Seychellois get their MeHg from a diet rich in the same types of ocean fish eaten by Americans and Canadians while the Faroese get the vast majority of their MeHg from eating whale meat. [Grandjean, Weihe, et al., 1998; Myers, Davidson, et al., 2003] Thus, the Seychellois are exposed to mercury in a fashion similar to people in Canada.

Second, whale blubber is also high in polychlorinated biphenyls, inorganic mercury, and other contaminants, while the fish eaten by the Seychellois and by Canadians are not. [Myers and Davidson, 2000] This implies that the effects observed in the Faroese study may have been unrelated to MeHg in fish and instead due to other contaminants in the blubber.

Third, although the mercury levels in the Seychellois and the Faroese are similar, the whale blubber eaten by the Faroese has about five times the mercury per unit mass as the fish eaten by the Seychellois. [11] Thus, to the extent mercury is actually causing neurological deficits in the Faroese, it could be due to higher acute exposures to mercury than occur in the Seychelles.

Fourth, the Seychelles study used mercury in maternal hair as the exposure measure, while the Faroe Islands study used mercury in blood from the umbilical cord. [Keiding, Budtz-Jorgensen, et al., 2003] The Faroe Islands study also measured mercury in maternal hair. But, the association of mercury with neurological outcomes by this measure was generally smaller and less statistically significant than was the association with umbilical blood. [Grandjean, Weihe, et al., 1997; Myers and Davidson, 2000] There is some controversy over whether one method is better than the other. [Keiding, Budtz-Jorgensen, et al., 2003] The Faroe Islands researchers argued that blood from the umbilical cord is a better marker of mercury exposure than hair because they found a stronger association between mercury in cord blood and lower test scores. But this appears to be circular reasoning. What matters is which mercury measurement provides a better marker of exposure to the brain, which is where mercury actually has its effects. Mercury levels in maternal hair have been calibrated to fetal brain levels, while mercury levels in blood from the umbilical cord has not. [Cernichiari, Brewer, et al., 1995; Keiding, Budtz-Jorgensen, et al., 2003] Another factor to consider is that blood from the umbilical cord provides a measure of mercury exposure only at birth while maternal hair can be used to assess mercury exposure to a fetus throughout pregnancy. [Keiding, Budtz-Jorgensen, et al., 2003]

Finally, the Faroe Islands population is descended from Scandinavians while the Seychellois are ethnically European and African. [Rice, Schoeny, et al., 2003] Thus, the Seychellois appear to be more diverse and, therefore, may be more representative of the range of variation in response to MeHg.

That the Faroe Islands and Seychelles studies produced opposite results still needs to be explained. However, given the results available, the Seychelles study appears to be more relevant to Canadians and other western populations and the way
in which they are exposed to methylmercury. If so, then no one is being harmed by current mercury emissions and further reductions in mercury would not provide any health benefits even if such reductions do reduce mercury levels in fish.

**Best-case benefits**

Despite the evidence that mercury at current levels is not causing harm, we can estimate the best-case benefits for reducing mercury from Ontario’s coal-fired power plants. As noted above, a complete elimination of mercury from Ontario’s coal plants would, at best, reduce freshwater fish mercury levels by about 4%. Assuming that people with the highest mercury exposures get all of their mercury from freshwater fish, this would result in a 4% reduction in exposure to mercury. Assuming Canadians’ mercury exposure is similar to that of Americans, about 8% of women have mercury levels above EPA’s reference dose and 1 in 270 have mercury levels greater than five times the RfD, which is ¼ the level associated with health effects in the Faroe Islands study. [12] If we assume that mercury causes harm even at these relatively low mercury exposures, then a complete elimination of Ontario’s power-plant mercury emissions would improve neurological test scores of the children with the highest mercury exposures by less than 1/100 of a standard deviation and even less for children with exposures closer to the reference dose. [13] This implies that the absolute upper end of positive benefits to be gained by eliminating coal-based mercury emissions is roughly equivalent to advancing the most exposed child’s cognitive development by a few days.

1.5 **Closing Ontario’s coal-fired plants is not part of Canada’s plan for Kyoto and climate change.**

According to Environment Canada’s inventory of greenhouse-gas emissions [Environment Canada, 2004], the electrical generators powered by fossil fuel in Ontario produced emissions of approximately 41 Megatonnes CO₂-equivalent (MtC) in 2000, which was just under 6% of total Canadian emissions of 726 MtC. Canadian emissions account for about 2% of global emissions. [Marland et al., 2003] Thus, the coal-fired plants in Ontario are responsible for about ⅙ of 1% of global greenhouse-gas emissions and shutting them down will not make a perceptible difference.

In fact, the outcome is even more discouraging since reduced domestic production of energy will necessitate increased imports of electricity from the American northeast, where production relies even more on coal-fired plants than it does in Ontario. So the most likely outcome in the short run will be a transfer of production from Ontario’s coal-fired plants to Ohio’s coal-fired plants, with no overall reduction in greenhouse-gas emissions.
Some might argue that any step—however small—is worth taking. But this argument ignores the need to look at the costs and benefits of proposed measures. If the Ontario government wishes to justify closing the coal-fired plants on the grounds of reducing CO₂ emissions, it must estimate the costs per tonne of such emission reductions, then show whether such reductions could have been achieved at a lower cost through other policy measures. No such case has been made by the Province and, indeed, nowhere in the vast list of measures proposed by the federal government [Government of Canada, 2004; McKitrick and Wigle, 2002] for implementing the Kyoto Protocol is it suggested that closing Ontario's thermal power plants ought to be part of the policy mix.

Beyond that, there are good reasons to question whether the carbon dioxide emitted by the coal plants imposes any economic costs on Canada. The link between CO₂ and the global climate system is profoundly uncertain. [Essex and McKitrick, 2002; Green 2003] Studies that have examined the economic consequences of global warming on Canada [e.g. Reinsborough, 2003] find the effects overall to be very small and possibly beneficial.

**Conclusion**

Air pollution in Ontario has been successfully reduced under existing regulations and is generally much lower than 30 years ago. Current evidence does not provide consistent support for the claim that levels of air pollution are a significant source of risk for death or disease and, in any case, the estimated effects are very small. Nor would reductions in emissions from coal-fired electrical plants lead to a likely change in any health risks associated with mercury exposure. Finally, closure of the coal-fired plants is not part of Canada's Kyoto strategy and would likely only lead to relocation of CO₂ emissions to the United States anyway. Consequently the benefits to health and environment of closing the coal-fired plants are likely very small.
2 Assessing the costs of closing Ontario’s coal-fired power plants

2.1 Coal power is an abundant, low-cost and reliable source of electricity and, therefore, an important economic benefit to citizens of Ontario.

Not all energy sources yield electricity at the same price. In Ontario, the Independent Market Operator (IMO) makes purchases throughout the day for the estimated load requirements over the ensuing hours. The IMO draws just under half of its required power from continually operating hydro and nuclear sources, then relies on “dispatched” sources purchased through the market to meet remaining demand. [14] Suppliers of electricity indicate available quantities and the prices at which their power is offered. The IMO selects suppliers in order of increasing prices and the price at which the supply is sufficient to cover demand is paid to all the successful suppliers. Hence the “market-setting” price is the one charged by the most expensive power source to be selected in a round of purchases. Of the dispatched sources, coal is the preferred option both for reasons of reliability and price. When the additional energy supplied by coal-fired plants is sufficient to clear the market, coal is said to be the “price-setting” fuel, since the price of the coal power determines the overall market cost of electricity. If coal is not sufficient, other power sources are dispatched, including gas and oil. Since these enter the market at higher prices, they are the price setters less often than coal.

As Table 1 shows, coal is the market-clearing power source over half the time and, on average, was provided at about $3.38 per kilowatt-hour, less than half the price of the next available sources, namely oil, gas, “peaking” or storable hydro sources, and, very rarely, additional nuclear.

<table>
<thead>
<tr>
<th>Price-setting fuel (%) of time</th>
<th>Price-setting fuel (% of time)</th>
<th>Average price (cents per KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>56%</td>
<td>$3.38</td>
</tr>
<tr>
<td>Gas</td>
<td>8.3%</td>
<td>$7.64</td>
</tr>
<tr>
<td>Oil</td>
<td>22%</td>
<td>$8.00</td>
</tr>
<tr>
<td>Uranium</td>
<td>0.03%</td>
<td>N/A</td>
</tr>
<tr>
<td>Water</td>
<td>15%</td>
<td>$7.67</td>
</tr>
</tbody>
</table>

Thus, in evaluating the importance of coal power, it is not sufficient merely to note the percentage of generating capacity it represents (about 25%). It is just as important to note the percentage of time that it is the price-setter, which is over 50% of the time. If the coal-fired power plants are shut down, the Independent Market Operator for Ontario will have to turn to more expensive sources to make up for dispatches that currently serve to clear the market more than half the time.

It cannot be said that coal is artificially cheap because utilities do not have to pay for pollution control. They are, in fact, required to pay for pollution control in that they must comply with existing pollution control laws. At the Nanticoke and Lambton power plants, for instance, the recent installation of selective catalytic reduction devices on four (of 12) generating units for the control of NO\textsubscript{x} emissions cost $262 million. [15] This investment will have been completely wasted if the plant is shut down.

2.2 Increased electricity prices, which will result from shutting down the coal-fired plants, will cause reductions in household real income that will fall disproportionately upon the poor.

Shutting down the coal-fired plants will force the IMO to obtain electricity from higher-cost sources. The retail selling price is currently regulated [16] and the gap between the supply price and the retail price must be paid by the Ontario government. Since the closure of coal-fired plants will raise the supply price, the subsidy costs to the public treasury will substantially increase unless the regulated retail price is also raised.

All households, regardless of income, have to buy electricity. Higher energy prices imply a higher cost of living in Ontario, reducing household real incomes. Because of the fact that electricity is a necessary commodity in the household budget, people cannot simply cut back consumption in order to adjust to the higher prices. Hence, the amount spent on electricity rises when the price rises. As a result, such changes will have disproportionately large effects on lower-income groups.

In economic terms, demand for electricity is both price-inelastic and income-inelastic. This means that as the price goes up, consumption does not decline by much (except after a very long time lag); and, as income goes up, the amount purchased also rises, but by proportionately less than the increase in income. [Garcia-Cerrutti, 2000; Silk and Joutz, 1997] While people are able to conserve electricity in response to increased costs, data show that demand reductions in response to higher prices are relatively slow and small.

These observations, taken together, imply that increases in electricity prices are economically regressive: they have a proportionately worse effect on low-income households than on high-income households. This can be illustrated with a simple
numerical demand model, as outlined in Appendix B (page 38). The model uses parameter values drawn from the economics literature and is calibrated to demand data from Statistics Canada and the Ontario Government’s *Electricity Conservation and Supply Task Force Report*. It examines the distribution of economic effects across households if the price of electricity were to increase from that implied by the current mix of generating sources in Ontario to the level that would historically be expected if the coal option were not available to the IMO. The increase in average household spending on electricity is shown as a percentage of household income. Since households cannot reduce consumption sufficiently to offset the price increase, the total cost of electricity would rise in all income groups. However, the effect is largest in the lowest-income households. [Figure 3] The increased cost burden starts at almost 1% of income for the poorest group and falls to less than 0.2% for high-income households.

When people discuss the social costs of energy production, even if there were health consequences of the pollution from power generation, it is important to weigh these against the health and social consequences of a drop in disposable income for poor families as a result of closing the coal plants. To put it another way, imagine there were only 10 households in the entire province, one with an income of $10,000, one earning $20,000, and so forth, with the wealthiest earning $100,000. The wealthiest

**Figure 3: Distribution of cost burden (% of household income) that will result from removing coal-fired plants from the electricity grid**

Source: Appendix B (page 38).
households propose shutting down the coal plants because they would like better air quality. But then it is discovered that the costs of doing so would fall most heavily on the poorest three or four households, in the form of higher electricity costs, and furthermore that shutting down the coal plants would not affect air quality much anyway. It is quite conceivable in this example that the ten households would decide among themselves that it would be unfair to proceed with the plan. This is the situation for Ontario, writ larger to several million households. The costs of abandoning the coal component of the electricity supply will fall disproportionately heavily on the poorest households and will have little effect on air pollution, which has already declined over the past few decades and which appears to have a much weaker connection to human health than has previously been thought. This, at the very least, suggests to us that Ontario’s extreme energy policy proposal should be reconsidered and subjected to a careful evaluation of costs, benefits, and distributional consequences.

2.3 **Low-cost, abundant electricity is a key factor in long-run economic growth and measures that raise costs or restrict the supply of electricity will have long-term negative consequences for economic growth.**

Economists have long been interested in the factors that lead to growth in the size of the economy (Gross Domestic Product or GDP). The main factors of production are capital, labour, and energy. The direction of causality between GDP and these factors can be difficult to determine. For example, adding labour to an economy causes its output to rise. But growing economies also attract immigrants so the causality can run in both directions.

There is a similar question about whether energy consumption causes economic growth or economic growth causes higher energy consumption. The distinction is extremely important. If the causality only runs from GDP growth to increased energy consumption, it implies that factors other than the availability of energy determine GDP growth and energy consumption is merely an indirect consequence of the state of the economy. It is on this basis that people have proposed policies like “Demand Side Management” and other conservation policies that seek to reduce energy consumption in a growing economy. The underlying theory is that, if energy consumption is a by-product of GDP growth (but not the other way round), it is not a necessary input to economic growth and the two could be, to some extent, decoupled. That is, it would be possible, through conservation schemes, to have a growing economy while capping or even shrinking the consumption of energy. On the other hand, if the causal relationship goes from growth in energy consumption to growth in GDP, it would imply that a reduction in the availability of energy would limit GDP growth and therefore reduce incomes in the future.
A recent study in *Energy Economics* [Gali and El-Sakka, 2004] examined Canadian data from 1961 to 1997 and found strong evidence that the causality runs in both directions: from growth in energy use to growth in GDP as well as vice versa. That is, while energy use is a by-product of GDP growth it is also an *input* to subsequent economic growth. Policies that deliberately restrict energy consumption will therefore dampen future economic growth and reduce Canadians’ prosperity.

This, however, does not imply that electricity use should be subsidized (or put under a price cap) or that energy sources should be made artificially cheap. Environmental costs associated with energy sources should not be ignored. An appropriate policy response is to evaluate carefully and objectively the social cost of energy sources and factor that into the prices of each commodity, using economic instruments such as pollution taxes or tradable permits. But once these external costs have been added to the commodity price, the level of consumption should be left up to the interplay of demand and supply in the market. Additional measures to reduce energy consumption would be redundant and economically burdensome, regardless of whether they are intended to reduce pollution, conserve resources, or some other social goal. Superfluous measures that deliberately restrict the consumption of energy will, among other things, have long-term deleterious consequences for economic growth.
3 Conclusions

The Government of Ontario is proposing a radical change to the province’s electricity system, namely the shutting down of the network of coal-fired power plants by 2007. These plants make up one-quarter of current generating capacity and are the most economical source of variable power production, setting the market-clearing price over 50% of the time. Removing them from the grid risks far-reaching and severe economic repercussions.

There is no question that coal-fired power plants contribute to Ontario’s air polluting emissions. The question is whether the costs associated with these emissions exceed the social and economic benefits of the electricity they provide. The Province has not performed due diligence on the technical arguments being invoked on behalf of its policy, in particular concerning the health and environmental consequences of operating the coal-fired generators. The Province has also failed to undertake adequate cost-benefit analysis on whether shutting down coal-fired electricity production will confer net benefits on Ontarians or whether there are other policy choices available that could provide the same benefits at lower costs, without risking energy cost increases and interruptions to the province’s power supply.

It is a fundamental duty of government to avoid enacting policies that will make people worse off. The burden of proof rests on the Government of Ontario to show that its electricity plan would improve Ontarians’ overall welfare and this could best be done by setting aside its plans to shut the coal plants until a proper, objective benefit-cost analysis has been completed. Overall we conclude:

- Ontarians derive substantial benefits from the operation of the coal-fired power plants, and before shutting them down the Ontario government has a fundamental duty to evaluate whether the costs of such a decision would exceed the benefits; and
- Ontario’s coal plants are likely a net benefit to society, and the decision to close them is unlikely to pass an objective cost-benefit test.

If the Ontario government believes its plan would pass a cost-benefit test, it has a duty to produce convincing evidence to this effect before proceeding to phase out the coal-fired power plants.
Appendix A: Monthly concentrations of air contaminants in Ontario’s cities

Individual data points in the graphs in this appendix are monthly average concentrations provided by Environment Canada. [Environment Canada, 2003]

Standard indicators of air quality for all but ozone correspond to the “maximum acceptable level” of Health Canada’s National Ambient Air Quality Objectives (NAAQO). The ozone “standard” indicator reflects the value set by Health Canada’s Canada-Wide Standards (CWWs), which apply uniquely to ozone and small particulate matter (PM$_{2.5}$). A monthly average below the standard line does not indicate that there were no exceedances lasting shorter periods of time, such as hours or days. A number of shorter exceedances, however, should they occur, would raise the monthly average.

Cities shown
- Hamilton
- London
- Ottawa
- Toronto
- Windsor

Air contaminants shown
- CO (carbon monoxide)
- NO$_2$ (nitrogen dioxide)
- O$_3$ (ground-level ozone)
- SO$_2$ (sulphur dioxide)
- TSP (Total Suspended Particulates)

Availability of historical data
- CO January 1974 – December 2002
- NO$_2$ January 1974 – December 2001
- O$_3$ January 1974 – December 2002
- SO$_2$ January 1974 – December 2002

Note  Graphs for lead are not shown. Since the mid-1980s, due to the ban on lead in gasoline and paint, atmospheric lead levels have dropped to zero in all the cities monitored.
Hamilton

Concentration of CO—trend in Hamilton, 1974–2002

13.1 ppm—NAAQO maximum acceptable level (8-hour average)

Concentration of NO₂—trend in Hamilton, 1974–2001

53 ppb—NAAQO maximum acceptable level (annual)


65 ppb—Canada-wide Standard
Pain without Gain: Shutting Down Coal-Fired Power Plants Would Hurt Ontario

Concentration of $SO_2$—trend in Hamilton, 1974–2002

Concentration of TSP—trend in Hamilton, 1974–1999
London


Concentration of NO₂—trend in London, 1974–2001

Ottawa

**Concentration of CO—trend in Ottawa, 1974–2002**

- 13.1 ppm—NAAQO maximum acceptable level (8-hour average)

**Concentration of NO₂—trend in Ottawa, 1975–2001**

- 53 ppb—NAAQO maximum acceptable level (annual)

**Concentration of O₃—trend in Ottawa, 1976–2002**

- 65 ppb—Canada-wide Standard
Concentration of $SO_2$—trend in Ottawa, 1974–2002

Concentration of TSP—trend in Ottawa, 1974–1998
Toronto

Concentration of CO—trend in Toronto, 1974–2002

Concentration of NO₂—trend in Toronto, 1974–2001

Concentration of O₃—trend in Toronto, 1974–2002

13.1 ppm—NAAQO maximum acceptable level (8-hour average)

53 ppb—NAAQO maximum acceptable level (annual)

65 ppb—Canada-wide Standard
Concentration of SO₂—trend in Toronto, 1974–2002

Concentration of TSP—trend in Toronto, 1974–1999
Windsor

Concentration of CO—trend in Windsor, 1974–2002

13.1 ppm—NAAQO maximum acceptable level (8-hour average)

Concentration of NO₂—trend in Windsor, 1974–2001

53 ppb—NAAQO maximum acceptable level (annual)

Concentration of O₃—trend in Windsor, 1974–2002

65 ppb—Canada-wide Standard
Concentration of SO₂—trend in Windsor, 1974–2002

Concentration of TSP—trend in Windsor, 1974–1999
Appendix B: Cost distribution model

The price of electricity in Ontario under the current mix of base and dispatched energy sources is estimated to be 7.7 cents per kWh; without coal it would rise to 8.8 cents per kWh. [ECSTF, 2004]

**Demand equation**

The demand equation is assumed to be a constant-elasticity function of price and income:

\[ D = A \times P^\alpha Y^\beta \]  

(1)

where \( \alpha \) is the own-price elasticity of demand for electricity \( (D) \), \( \beta \) is the income elasticity of demand, \( P \) is the market price, \( Y \) is income and \( A \) is a scale parameter. Garcia-Cerrutti [2000] estimates short-run own-price elasticities of 0.13 to 0.17 and income elasticities of 0.12 to 0.15 but notes other published elasticity estimates are typically higher than these. Silk and Joutz (1997) estimate long-run price and income elasticities of -0.5 and +0.5 respectively. For this simulation, we assume a price elasticity of 0.2 and an income elasticity of 0.4. Note that the lower each elasticity is assumed to be, the more regressive the outcome.

**Household expenditure**

The household expenditure on electricity is

\[ P \times D = A \times P^{\alpha+1} Y^\beta \]  

(2)

and the budget share for electricity is

\[ \frac{P \times D}{Y} = A \times P^{\alpha+1} Y^{\beta-1} \]  

(3).

The economy was divided up into income levels with steps of $10,000. The proportion of households in each level was taken from the 2000 Canadian Census. The parameter \( A \) was set so that the average consumption of electricity per capita was approximately 17,700 kWh, corresponding to the Canadian average as reported by the Canadian Electricity Association [http://www.canelect.ca/english/electricity_in_canada_snapshot_Economy_2.html] (October 19, 2004).

At a price of $0.077/kWh, the implied levels of demand, spending, and household budget shares are as follows.
Pain without Gain: Shutting Down Coal-Fired Power Plants Would Hurt Ontario

With the coal supply removed from the grid, the average price rises to $0.088/kWh, yielding new demand levels, spending and budget shares:

<table>
<thead>
<tr>
<th>Income</th>
<th>Price</th>
<th>Quantity</th>
<th>Cost</th>
<th>Budget share</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10,000</td>
<td>$0.0880</td>
<td>10,810</td>
<td>$951</td>
<td>9.5</td>
</tr>
<tr>
<td>$20,000</td>
<td>$0.0880</td>
<td>14,264</td>
<td>$1,255</td>
<td>6.3</td>
</tr>
<tr>
<td>$30,000</td>
<td>$0.0880</td>
<td>16,775</td>
<td>$1,476</td>
<td>4.9</td>
</tr>
<tr>
<td>$40,000</td>
<td>$0.0880</td>
<td>18,821</td>
<td>$1,656</td>
<td>4.1</td>
</tr>
<tr>
<td>$50,000</td>
<td>$0.0880</td>
<td>20,578</td>
<td>$1,811</td>
<td>3.6</td>
</tr>
<tr>
<td>$60,000</td>
<td>$0.0880</td>
<td>22,135</td>
<td>$1,948</td>
<td>3.2</td>
</tr>
<tr>
<td>$70,000</td>
<td>$0.0880</td>
<td>23,543</td>
<td>$2,072</td>
<td>3.0</td>
</tr>
<tr>
<td>$80,000</td>
<td>$0.0880</td>
<td>24,835</td>
<td>$2,185</td>
<td>2.7</td>
</tr>
<tr>
<td>$90,000</td>
<td>$0.0880</td>
<td>26,033</td>
<td>$2,291</td>
<td>2.5</td>
</tr>
<tr>
<td>$100,000</td>
<td>$0.0880</td>
<td>27,153</td>
<td>$2,389</td>
<td>2.4</td>
</tr>
<tr>
<td>$110,000</td>
<td>$0.0880</td>
<td>28,208</td>
<td>$2,482</td>
<td>2.3</td>
</tr>
<tr>
<td>$120,000</td>
<td>$0.0880</td>
<td>29,207</td>
<td>$2,570</td>
<td>2.1</td>
</tr>
<tr>
<td>$130,000</td>
<td>$0.0880</td>
<td>30,158</td>
<td>$2,654</td>
<td>2.0</td>
</tr>
<tr>
<td>$140,000</td>
<td>$0.0880</td>
<td>31,065</td>
<td>$2,734</td>
<td>2.0</td>
</tr>
<tr>
<td>$150,000</td>
<td>$0.0880</td>
<td>31,934</td>
<td>$2,810</td>
<td>1.9</td>
</tr>
<tr>
<td>$160,000</td>
<td>$0.0880</td>
<td>32,769</td>
<td>$2,884</td>
<td>1.8</td>
</tr>
<tr>
<td>$170,000</td>
<td>$0.0880</td>
<td>33,574</td>
<td>$2,954</td>
<td>1.7</td>
</tr>
<tr>
<td>$180,000</td>
<td>$0.0880</td>
<td>34,350</td>
<td>$3,023</td>
<td>1.7</td>
</tr>
<tr>
<td>$190,000</td>
<td>$0.0880</td>
<td>35,101</td>
<td>$3,089</td>
<td>1.6</td>
</tr>
<tr>
<td>$200,000</td>
<td>$0.0880</td>
<td>35,829</td>
<td>$3,153</td>
<td>1.6</td>
</tr>
</tbody>
</table>

The increase in household costs expressed as a proportion of income are as follows:
### Table

<table>
<thead>
<tr>
<th>income</th>
<th>increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10,000</td>
<td>0.96%</td>
</tr>
<tr>
<td>$20,000</td>
<td>0.64%</td>
</tr>
<tr>
<td>$30,000</td>
<td>0.50%</td>
</tr>
<tr>
<td>$40,000</td>
<td>0.42%</td>
</tr>
<tr>
<td>$50,000</td>
<td>0.37%</td>
</tr>
<tr>
<td>$60,000</td>
<td>0.33%</td>
</tr>
<tr>
<td>$70,000</td>
<td>0.30%</td>
</tr>
<tr>
<td>$80,000</td>
<td>0.28%</td>
</tr>
<tr>
<td>$90,000</td>
<td>0.26%</td>
</tr>
<tr>
<td>$100,000</td>
<td>0.24%</td>
</tr>
</tbody>
</table>

### Additional Text

The data in these tables are graphed in figure 3, page 24.
Notes

1 See Canadian Electricity Association <http://www.canelect.ca/english/electricity_in_canada_snapshot_Demand.html>.

2 There are other, serious, flaws in the models used by the OMA and the Basrur study that detract from their plausibility. For instance the Toronto Public Health model predicts such high death rates from pollution that, using the observed pollution levels from the 1960s it would attribute at least half and, in one case, more than 100%, of monthly deaths in Toronto to air pollution. See McKitrick, 2004.

3 Recent discovery of a computational error resulted in the overall average being revised downward to +0.2%; see <http://www.biostat.jhsph.edu/biostat/research/update.main.html>.

4 32% × 25% × 50% = 4%.

5 The regression coefficient represents the size of the statistical association between mercury exposure and test score. It takes the form of a number equal to the expected change in a test score for a given change in mercury exposure. [Lutter and Mader, 2001]

6 That is, all tests for which a statistically significant association was reported between mercury exposure and test score.

7 Calculated by linear interpolation of Lutter and Mader’s estimates for the “low” and “medium” exposure categories in table 2 of their paper.

8 Calculated by linear interpolation of Lutter and Mader’s estimates for the “medium” and “high” exposure categories in table 2 of their paper.


10 A fine point is that, even with removal of the child with the highest exposure level, the fact that six tests resulted in a statistically significant mercury association should be treated with caution. The significance levels were not adjusted for multiple comparisons and are therefore biased toward unrealistically high statistical significance (i.e., unrealistically low p values). [Crump, Kjellstrom, Shipp et al., 1998]

11 The shark eaten by New Zealanders has about seven times the mercury concentration as the fish eaten by the Seychellois. [Myers, Davidson, Cox, et al., 2003]

12 For mercury exposure in the United States, see United States Centers for Disease Control, 2003; Schwartz, 2004.


16 The fixed price for low-volume users is 4.7 cents/kWh up to 750 kWh and 5.5 cents/kWh for amounts beyond that.
References


About the authors

Kenneth Green

Kenneth Green Directs the Centre for Studies in Risk, Regulation, and Environment at The Fraser Institute. He holds a B.S. in Biology from the University of California, Los Angeles, an M.S. in Genetics (molecular) from San Diego State University, and a Doctorate in Environmental Science and Engineering (D.Env.) from the University of California, Los Angeles. Since starting out in public policy analysis in 1992, Dr Green has been the author or co-author of over 135 publications about environmental science and policy, including articles in science journals and conference proceedings; policy studies; encyclopedia and book chapters; newspaper columns; and a textbook for Junior- and High-school students on the subject of climate change. He has given over 50 speeches on environmental science and policy issues in three countries, including academic conference presentations, seminars to high-school and college students, and briefings to policy-makers. Prior to joining The Fraser Institute in 2002, Dr Green was Chief Scientist of California’s Reason Foundation. He has testified before numerous legislative and regulatory bodies in the United States, including the US House and Senate. His policy analysis was used in briefings before the US Supreme Court deliberations over the 1997 tightening of the US National Ambient Air Quality Standards.

Ross McKitrick

Ross McKitrick holds a B.A. in economics from Queen’s University and an M.A. and Ph.D. in economics from the University of British Columbia. He was appointed Assistant Professor in the Department of Economics at the University of Guelph in 1996 and Associate Professor in 2000. His area of specialization is environmental economics and policy analysis. He has published scholarly articles in The Journal of Environmental Economics and Management, Economic Modeling, The Canadian Journal of Economics, Environmental and Resource Economics, Climate Research and other journals, as well as commentaries in newspapers and other public forums. His current areas of research include empirical modeling of the relationship between economic growth and pollution emissions; long-range forecasting of carbon-dioxide emissions; and the climate-change policy debate. Professor McKitrick has made invited academic presentations in Canada, the United States and Europe, as well as professional briefings to the Canadian Parliamentary Finance Committee, and to government staff at the US Congress and Senate. In the fall of 2002, he was appointed as a Senior Fellow of The Fraser Institute in Vancouver, British Columbia.
Joel Schwartz is a visiting scholar at the American Enterprise Institute, where he studies air pollution, transportation, regulatory policy, and chemical risks. He is the author of the AEI study, *No Way Back: Why Air Pollution Will Continue to Decline* and is currently working on the forthcoming AEI book, *Air Quality in America: A Dose of Reality on Air Pollution Levels, Trends, and Health Risks*. Before coming to AEI, Mr. Schwartz directed the Reason Public Policy Institute’s Air Quality Project. Prior to joining Reason, he was Executive Officer of the California Inspection and Maintenance Review Committee, a government agency charged with evaluating California’s vehicle emissions inspection program and making recommendations to the legislature and Governor on program improvements. He has also worked at the RAND Corporation, the South Coast Air Quality Management District, and the Coalition for Clean Air. Mr. Schwartz received his bachelor’s degree in chemistry from Cornell University and his master’s degree in planetary science from the California Institute of Technology. He was a German Marshall Fund fellow in 1993, during which he studied European approaches to transportation and air quality policy. He lives and works in Sacramento, California.

Acknowledgments

The authors are grateful to Lise Tole, Roy Hrab, and Marlo Lewis for their comments when reviewing this paper.

Ross McKitrick would personally like to thank Mark Jaccard, Geoffrey Pearce, and Mary Ellen Richardson, who answered queries on some technical points pertaining to the Canadian energy sector. The views in this document are the authors’ own. None of those consulted or who reviewed the study bear any responsibility for any errors that may exist in the report. Some of the material in this paper, particularly regarding mercury, has been previously published in *Schwartz, 2004*.  

Fraser Institute Digital Publication

January 2005
About this publication

*Fraser Institute Digital Publications* are published from time to time by The Fraser Institute (Vancouver, British Columbia, Canada) to provide, in a format easily accessible on-line, timely and comprehensive studies of current issues in economics and public policy.

**Distribution**

These publications are available from [http://www.fraserinstitute.ca](http://www.fraserinstitute.ca) in Portable Document Format (PDF) and can be read with Adobe Acrobat® or with Adobe Reader®, which is available free of charge from Adobe Systems Inc. To down-load Adobe Reader, go to this link: [http://www.adobe.com/products/acrobat/readstep2.html](http://www.adobe.com/products/acrobat/readstep2.html) with your Browser. We encourage you to install the most recent version.

**Disclaimer**

The authors of this publication have worked independently and opinions expressed by them are, therefore, their own, and do not necessarily reflect the opinions of the members or the trustees of The Fraser Institute.

**Copyright**

Copyright© 2005 by The Fraser Institute. All rights reserved. No part of this publication may be reproduced in any manner whatsoever without written permission except in the case of brief passages quoted in critical articles and reviews.

**Date of issue**

January 2005

**How to use the interactive features in this document**

When you read this document on screen in Adobe Acrobat® or Adobe Reader®, references in the text to tables, figures, notes, and hyperlinks that display in blue and a distinct typeface (e.g., [Table 3] or [12]) are active links. Clicking on them will take you to the item to which they refer. To return to the passage you were reading, click the button at the bottom the window, or type Alt + Left Arrow if you use Microsoft Windows® or Command + Left Arrow if you use Apple Mac OS X or earlier. If you have questions or comments about the interactive features, please contact Lindsey Thomas Martin via e-mail: lindseym@fraserinstitute.ca.

**Editing, design, and production**

Lindsey Thomas Martin
About The Fraser Institute

The Fraser Institute is an independent Canadian economic and social research and educational organization. It has as its objective the redirection of public attention to the role of competitive markets in providing for the well-being of Canadians. Where markets work, the Institute’s interest lies in trying to discover prospects for improvement. Where markets do not work, its interest lies in finding the reasons. Where competitive markets have been replaced by government control, the interest of the Institute lies in documenting objectively the nature of the improvement or deterioration resulting from government intervention. The work of the Institute is assisted by an Editorial Advisory Board of internationally renowned economists. The Fraser Institute is a national, federally chartered, non-profit organization financed by the sale of its publications and the tax-deductible contributions from its members, from foundations, and from other supporters; it receives no government funding.

Membership

For information about membership, please write to:

Development Department, The Fraser Institute,
Fourth Floor, 1770 Burrard Street,
Vancouver, British Columbia, V6J 3G7 Canada;
or contact the Development Department:
in Vancouver
♦ via telephone: 604.688.0221 ext. 586; via fax: 604.688.8539
♦ via e-mail: membership@fraserinstitute.ca
in Calgary
♦ via telephone: 403.216.7175 or, toll-free 1.866.716.7175;
♦ via fax: 403.234.9010; via e-mail: barrym@fraserinstitute.ca.
in Toronto
♦ via telephone: 416.363.6575;
♦ via fax: 416.934.1639.

Media

For media enquiries, please contact Suzanne Walters, Director of Communications, via e-mail: suzannew@fraserinstitute.ca; via telephone: 604.714.4582.

Ordering publications

For information about ordering the printed publications of The Fraser Institute, please contact the publications coordinator via e-mail: sales@fraserinstitute.ca; via telephone: 604.688.0221 ext. 580 or, toll free, 1.800.665.3558 ext. 580; via fax: 604.688.8539.