Costs and Benefits of Phasing Out Gas In Ontario's Electricity Sector

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EXECUTIVE SUMMARY

This report provides an assessment of the economic and environmental impacts of removing natural gas from Ontario's power generating system. It uses cost and reliability projections developed by the Independent Electricity System Operator (IESO) and shows that the changes will have significant negative economic consequences while yielding only small reductions in air pollutant and greenhouse gas (GHG) emissions.

Role of gas

Most of Ontario's electricity comes from non-emitting nuclear and hydro sources, which for technical and economic reasons are best suited for meeting baseload power needs. Renewable systems like wind and solar are also available on a weather-dependent, intermittent basis, but must be matched by dispatchable capacity for times when they are not available since wind resources can change dramatically hour by hour in Ontario.

Currently natural gas accounts for 28% of Ontario's installed generating capacity but much of the time it is not used and power demand is met with baseload and renewable sources. In 2021 gas only provided 9% of grid-connected energy supply.

Environmental footprint

Ontario's electricity generation system, including its gas component, has a very small environmental footprint. Air pollution emissions from Ontario's electricity sector fell by 98% between 1991 and 2020. The electricity sector currently accounts for between 0.0% and 1.8% of emissions of regulated air contaminants in Ontario depending on the pollutant species. Also Ontario's electricity sector accounts for only about 2% of Ontario's GHG emissions, or about 0.008% of global GHG emissions. Thus eliminating natural gas from the grid would yield no measurable benefits on Ontario's air quality or the global climate.

Economic costs of removing gas

The IESO estimates that attempting a gas phaseout by 2030 would lead to a 60% increase in the consumer cost of electricity and would add a serious risk of blackouts. To deal with blackout risk, electricity-intensive sectors will either need to vacate the province or invest in private generating equipment, such as diesel backup generators, which will generate emissions of their own.

The economic analysis herein employs a large dynamic general equilibrium model of the Canadian economy to examine three scenarios involving the phaseout of gas in Ontario. The first scenario implements the replacement strategy proposed by the IESO, and assumes both that no blackout risk arises and that Quebec is able to supply the needed power imports. The second and third scenarios add in costs associated with, respectively, managing blackout risks and modifying the plan in case Quebec declines to supply the needed power.

The simulations indicate large costs to the Ontario economy under all three scenarios, especially those involving risk of regular blackouts. In this case, and in the scenario in which Quebec cannot supply the needed power, the policy would cause Ontario's GDP to fall between 3.0 and 3.6% below its base case level as of 2030 at a cost of 17,000 to 25,000 jobs. On a per-household basis the direct and indirect costs as of 2030 would be between $2,700 and $3,300 per household in 2030 and the loss of GDP at the national level would be between $6,000 and $7,200 per tonne of GHG reduced.

1. TECHNICAL CHALLENGES OF REPLACING GAS IN ELECTRICITY PRODUCTION

Summary:

- Power system planning requires paying attention to cost, reliability and environmental impact.
- Power grids must meet both baseload and variable power demand throughout the year.
- Gas plays a small but critical role in providing reserve power when wind and solar are operating and meeting the gap between baseload and peak demand at certain times of the year.

1.1 Introduction

This report examines the economic and environmental consequences of phasing out natural gas from Ontario's electricity system. Gas currently plays a small but vital role in meeting system requirements by providing a reliable and highly variable power source. The electricity system in Ontario has a small environmental footprint which reflects decades of investment in pollution control and non-emitting generating capacity. As will be shown, removing natural gas will cause significant cost increases and create risks for system reliability that together risk serious negative economic consequences, yet which will yield very little environmental benefit.

1.2 Ontario's Current Electricity System

It is to be expected that a power system will have more capacity than it typically uses since electricity demand (or "load") is not constant through the year. It varies on a seasonal cycle, peaking in very hot and very cold times of the year and dropping to a minimum in the "shoulder" seasons. It also varies on a daily cycle, peaking in the late afternoon and dropping to a minimum at night. But system load can also vary in unpredictable ways at any time, especially if the weather changes unexpectedly by a few degrees up or down. The system needs to be able to meet the expected peak load when demand is maximized, but a portion of generating capacity will inevitably sit idle when demand is lower.

According to Ontario's Independent Electricity System Operator (IESO) Ontario's currently-installed, transmission system-connected power generation capacity, rated in Megawatts (MW) is as follows[1]:

- Nuclear 13,089 MW (34%)
- Natural Gas[2] 10,482 MW (28%)
- Hydro 8,868 MW (23%)
- Wind 4,883 MW (13%)
- Solar 478 MW (1%)
- Biofuel 296 MW (<1%)

In the year 2021 the energy supply by generator type, rated in Terawatt-hours (TWh) was as follows:

- Nuclear 83.0 TWh (58%)
- Natural Gas 12.2 TWh (9%)
- Hydro 34.2 TWh (24%)
- Wind 12 TWh (8%)
- Solar 0.75 TWh (<1%)
- Biofuel 0.4 TWh (<1%)

1 Source: https://ieso.ca/en/Power-Data/Supply-Overview/Transmission-Connected-Generation accessed February 9, 2023.

2 This total also includes a small amount of oil-fired generation.

Figure 1.1 summarizes the above information, focusing on the top four power sources. Several points stand out. First, 72% of Ontario's generating capacity is non-emitting, and in a typical year such as 2021, over 90% of electricity output is generated by non-emitting sources. Second, nuclear and hydro both relatively outperform their installed capacity portions. Together they account for 57% of installed capacity but supplied 82% of the electricity generated in 2021.

This reflects both technical and economic principles of optimal grid management. Power demand consists of two components: baseload, or the minimum level below which demand never falls, and variable or peaking demand, or the fluctuating additional levels of demand that depend on time of day, time of year, weather, etc. Nuclear and hydro systems are less flexible than gas-fired power plants. Also they have high capital costs but relatively low operating costs. Both considerations imply they should be run on a 24 hour basis as much as is feasible through the year to pay off their construction costs as quickly as possible and to take advantage of their most efficient mode of operation. For this reason they are best deployed to handle baseload power demand.

Gas-fired power plants tend to be cheaper to build but costlier to operate, so there is an economic rationale to allow them to remain idle when not absolutely needed since amortization is not a critical factor. They therefore play a key role in handling peaking power demand. This is reflected in Figure 1.1 which shows that while gas generators account for 28% of installed capacity they only provided 9% of power generation through the year.

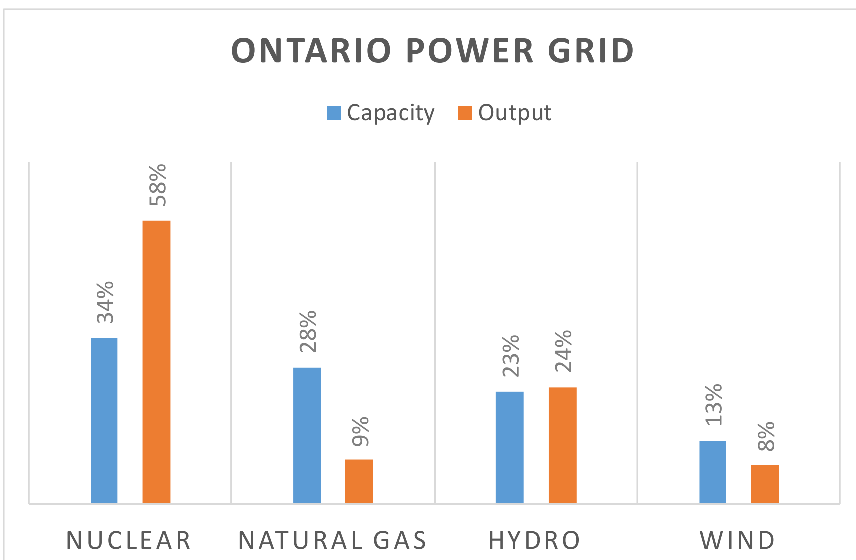

Figure 1.1: Ontario electricity in 2021: top 4 capacity and output types

Wind and solar are inherently intermittent since they are weather-dependent. This puts them in a different category of generator type. Like nuclear and hydro they are costly to build but cheap to operate, but they cannot be relied on to supply baseload power, nor are they dispatchable for the purpose of managing variable loads. To integrate renewables into a grid therefore requires backup capacity with a dispatchable source, and in Ontario this is provided by gas. Battery backup technology is not sufficiently advanced to operate at grid scale, and the systems that are currently available are far more expensive than gas. Figure 1.1 shows that wind turbines make up 13% of installed capacity but only provided 8% of power generation It is important to note that to increase either of these parameters would require *additional* gas capacity to be installed.

Another aspect to consider is the difference between actual and potential output by power source. The installed capacity is rated in MW and output is reported in MW-hours (MWh) or Terawatt-hours (TWh). When capacity is multiplied by 365 days per year times 24 hours per day it yields the maximum potential output if the source operated at full capacity throughout the year. The results are summarized in Table 1.1

	Maximum Potential Generation (TWh)	Actual Generation 2021 (TWh)	Capacity Utilized (%)
Nuclear	115	83	72%
Natural Gas	92	12	13%
Hydro	78	34	44%
Wind	43	12	28%
Solar	4	0.75	18%
Biofuel	3	0.4	15%

Table 1.1: Potential versus actual output by generator type in Ontario, 2021.

Here again nuclear and hydro relatively outperform. Nuclear plants operated at 72% of their maximum possible capacity and hydro facilities at 44% of theirs. Gas, wind and solar tended to yield relatively small fractions of their rated capacity. In the case of wind and solar, capacity utilization is constrained in large part by weather, since the IESO favours these sources when available.

Finally, switching from an annual to an hourly perspective helps illustrate these points. Figure 1.2 presents data obtained from the IESO (IESO 2023) showing hourly output by generator type from midnight on May 3 to 9 AM on May 8, 2023. The top black line shows nuclear power, which clearly operates as a baseload source. The grey line is hydro, which is also reasonably stable but does exhibit some fluctuations. The orange line is gas, representing the main tool to balance load against demand as it goes up and down during the day. The green line represents wind, and it is immediately apparent that it is not constant and can change considerably on short notice,

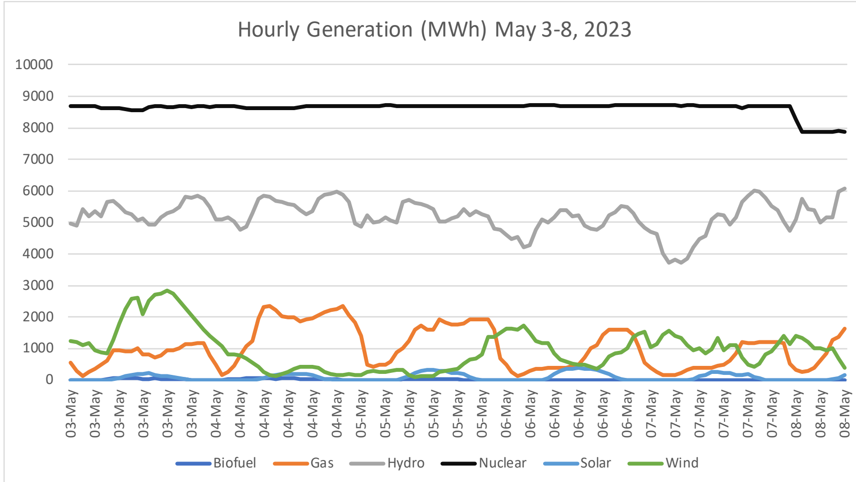

Figure 1.2: Ontario hourly power output (MWh) by source, May 3 to May 8, 2023. Source: IESO (2023).

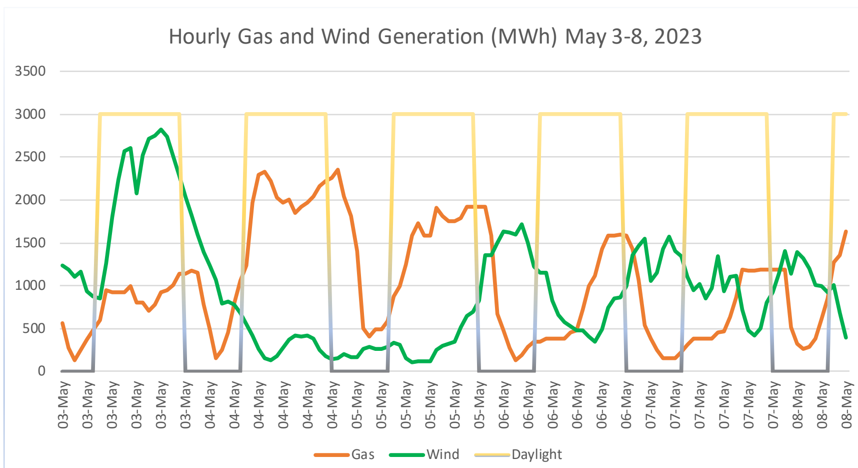

Figure 1.3: Ontario hourly gas and wind power production May 3 to May 8, 2023, compared to daytime/nighttime indicator (yellow denotes daytime, grey denotes nighttime). Source: IESO (2023).

Figure 1.3 focuses on gas and wind to show how they tend to be anticorrelated, repeatedly forming X patterns in which one disappears while the other ramps up. On May 3 wind was available during the day but gas was still required. The wind fell off overnight and gas also tapered off. But on the morning of May 4 the wind disappeared so gas had to ramp up output until nightfall. During the night the wind remained absent, as it did also throughout the first half of the daytime hours on May 5. As night arrived the wind surged and gas quickly tapered off. On May 6 the two power sources again created an X pattern, with wind disappearing and gas ramping up, then overnight wind surged and gas tapered off. On May 7 wind was present until the late afternoon when it suddenly disappeared, and gas ramped up to fill the gap. Finally on the morning of May 8 the wind again slackened and gas ramped up quickly.

Over just this one five day interval, had gas power not been present Ontario would have faced three day-time intervals of significant power shortfalls. The availability and flexibility of natural gas kept the lights on. This also points to a deficiency of plans that rely on battery storage to replace gas. It would be expensive enough trying to create a system that could supply grid-scale power for, say, 12 hours, but there is no guarantee that will be enough if the wind enters a multi-day lull, as happened in early May and as often happens in the summer. A power planner would need storage built to handle the maximum length interval when wind may be absent, which can easily be more than a week.

1.3 Why a Gas Phaseout is Unlikely to be Feasible

To summarize, a reliable and well-run power system must:

- Have a mix of baseload and peaking power sources known to be adequate for all expected levels of system demand throughout the year;
- Limit reliance on intermittent generators to levels matched by reserve dispatchable generation;

Under currently-available technologies all these considerations point to the need for fossil fuel-powered generators to continue being part of the supply mix, while also establishing limits on the usability of wind and solar. It is not possible simply to phase out Ontario's use of natural gas in electricity system management. In fact the availability of natural gas generation is what makes it currently possible to use wind and solar at grid scale.

It is helpful in this regard to consider Germany's experience in the last few years. Under the "Energiewende" policy of the Merkel government Germany invested heavily in wind and solar capacity, but also invested in the Nordstream I and II pipelines from Russia to provide fuel for substantial natural gas capacity. Proponents of renewables frequently claim that wind and solar are now as cheap as or cheaper than coal or natural gas and can be deployed rapidly to meet growing power needs. Yet when the Russia-Ukraine war began and Germany faced a sudden need to wean itself off Russian gas, its response was not to build wind turbines and solar panels but to use coal-fired power[3] and to expedite construction of a new floating liquified natural gas (LNG) import terminal.[4] One of the world's biggest promoters of wind and solar power thus turned to fossil fuels when faced with a sudden need for reliable electricity.

Thus when we ask what it would "cost" to phase out natural gas, we must bear in mind that the answer is not simply a dollar amount, but it is also a set of implications for the reliability of the power grid.

Even if there were great environmental benefits to be expected from removing gas-fired generation from the supply mix the foregoing establishes that it would simply not be feasible if Ontario is to maintain a reliable electricity system. But as the next section shows, shutting down our gas-fired power plants would yield virtually no benefits to Ontario air quality or the global climate anyway.

3 See https://www.montelnews.com/news/1401925/german-20-coal-surge-threatens-climate-goals--agora?mc_cid=a8b173891d

4 See https://www.theguardian.com/world/2022/nov/15/germany-completes-construction-floating-lng-terminal-liquefied-natural-gas-energy

2. LACK OF ENVIRONMENTAL BENEFITS FROM REMOVING GAS

Summary:

- Air pollution emissions from Ontario's electricity sector fell by 98% between 1991 and 2020 and thus are already at very low levels
- The electricity sector currently accounts for between 0.0% and 1.8% of emissions of regulated air contaminants in Ontario
- Ontario's electricity sector accounts for only about 2% of Ontario's greenhouse gas (GHG) emissions, or about 0.008% of global GHG emissions
- Eliminating natural gas from the grid would yield no measurable benefits on Ontario's air quality or the global climate.

2.1 The Impact of the Electricity Sector on Ontario's Air Quality

The Ontario Ministry of the Environment publishes an annual report on the state of air quality in the province (Ontario MOE 2020). Reports from 2002 to 2020 are available at the Ministry-maintained website airqualityontario.com. Ontario monitors and regulates nitrogen oxides (NOx), fine particulate matter (PM2.5)[5] , sulphur oxides (SOx), Volatile Organic Compounds (VOCs), carbon monoxide (CO) and ground-level ozone (O3). The latter is not emitted directly, instead it is formed in the air as a chemical reaction among precursor compounds (NOx and VOCs). Across all measures air quality in Ontario has been steadily improving for many decades. From 2011 to 2020 concentrations of SOx, NOx, PM2.5 and O3 declined by between 13% and 50%, and in 2020 the overall Air Quality Health Index indicated low risk (indicating no air quality problems across 38 monitoring sites) 96% of the time.

Environment and Climate Change Canada provides emissions data by province and sector annually from 1991 to 2020 (Environment and Climate Change Canada 2022a). The emissions profile of the Ontario electricity sector is shown in Figure 1. Total air pollution emissions (in tonnes) from the sector fell by 98% over the 30 year period. The largest reductions occurred prior to the coal phaseout and resulted from installation of pollution control systems. When the coal plants were retired in 2013 emissions of SOx and PM10 fell further while other emission types have continued to decline. As shown in Figure 2, the Ontario electricity sector today is not a significant source of air emissions in Ontario, contributing between 0.0% and 1.8% depending on the pollutant species. Eliminating the remaining natural gas power plants would therefore have no effect at all on ambient particulate matter, carbon monoxide, sulphur or VOC levels and only a very small effect on nitrogen oxides.

5 The notation means particulate matter smaller than 2.5 microns in diameter. This is the most commonly-measured species of particulate matter in ambient air. Emissions monitoring also includes PM10, a larger category of particulates

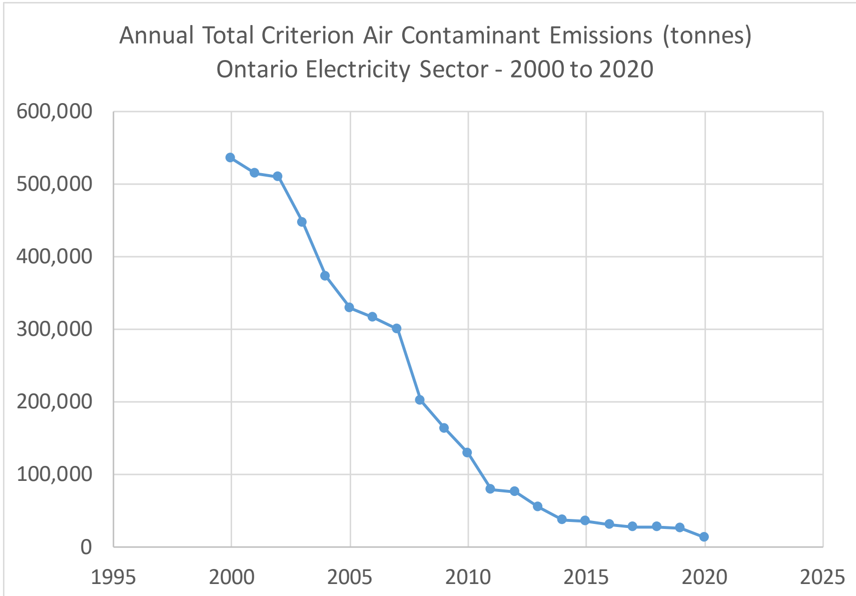

Figure 2.1: Annual Total Criterion Air Contaminants (sum of Carbon Monoxide, Nitrogen Oxides, Sulphur Oxides, Volatile Organic Compounds and PM10)from the Ontario Electricity Sector 2000 to 2020. Data Source: Environment and Climate Change Canada.

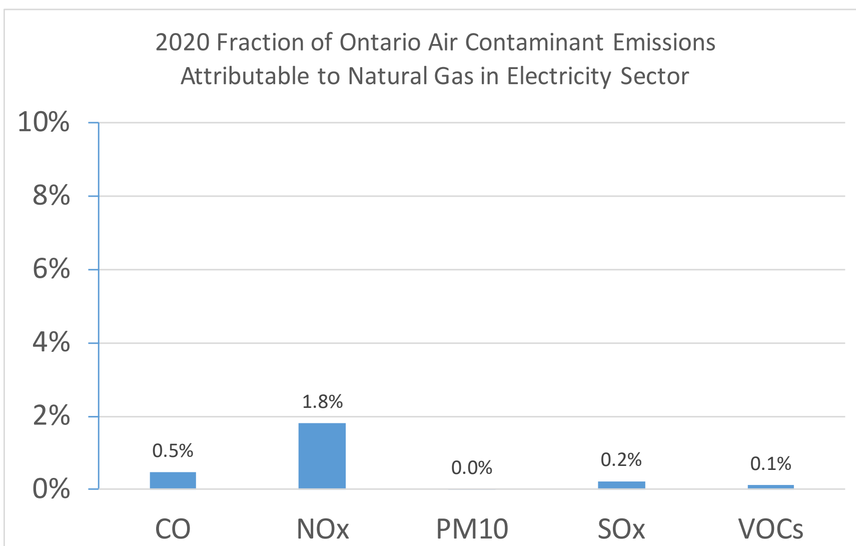

Figure 2.2: Fraction of Total Annual Ontario Air Pollution Emissions Attributable to Electricity Sector in 2020. Data Source: Environment and Climate Change Canada.

2.2 The Contribution of the Electricity Sector to GHG Emissions

Environment and Climate Change Canada (2022b) provides an annual inventory of GHG emissions (mainly carbon dioxide and methane) broken down by province and sector. Figure 3 shows the fraction of Ontario GHG emissions attributable to the Ontario electricity sector since 2015. Electricity's portion currently is 2.1%, of which most would be from the use of natural gas but some is due to the use of diesel backup generators. Ontario accounts for 22% of total Canadian GHG emissions and Canada, in turn accounts for about 1.6% of global GHG emissions[6], so altogether Ontario's use of natural gas for electricity generation contributes just under 0.008% (eight one-thousandths of one percent) of total global GHG emissions. Eliminating use of natural gas in Ontario electricity generation would thus have no detectable effect on global climate change now or in the future.

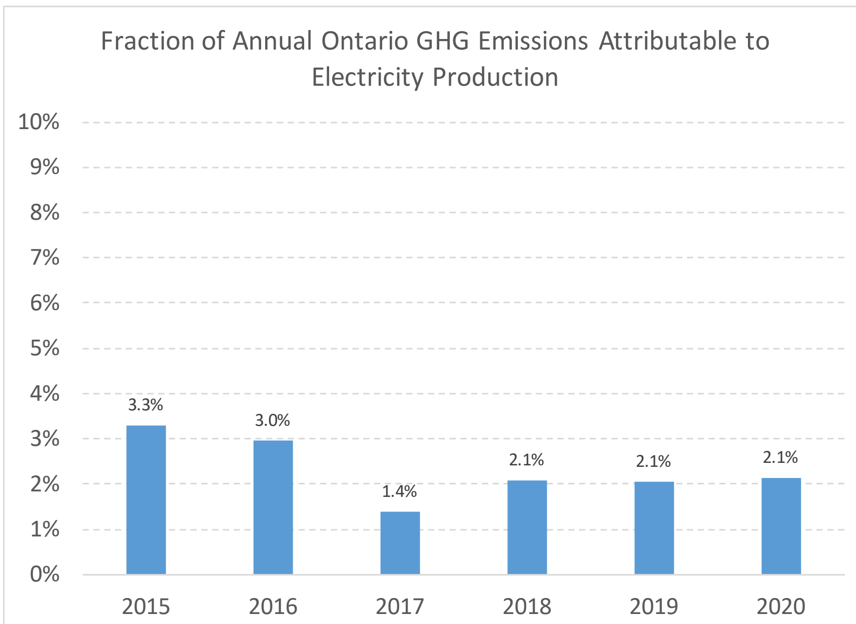

Figure 2.3: Fraction of Ontario GHG Emissions Attributable to Ontario Electricity Sector, 2015-2020.

6 Using the data on CO2 emissions in the BP Statistical Review of World Energy (2022).

3. MODELING THE ECONOMIC IMPACTS OF A GAS PHASEOUT

Summary:

- The IESO estimates attempting a gas phaseout by 2030 would lead to a 60% increase in the con sumer cost of electricity and would add a serious risk of blackouts
- To deal with blackout risk electricity-intensive sectors will need to invest in and operate private generating equipment

3.1 The IESO Plan

The IESO has issued a report (IESO 2021) discussing the technical and financial challenges of developing a new supply mix for Ontario that excludes natural gas. The document makes many of the same points outlined in Section 1 and draws two key conclusions:

- Replacing gas would raise the cost of electricity for residential customers by more than 60%, and
- Because the replacement capacity would lack the reliability of gas the electricity system would experience blackouts.

The 60 percent figure was based on an estimated total investment cost spread out over non-wholesale customers. Since current data (IESO 2022) indicates that wholesale customers consume about 15 percent of Ontario electricity this means the 60% increase for residential customers would translate into a 51% increase if shared across all electricity consumers.

The plan to replace gas generation assumes about 18,600 megawatts (MW) of replacement sources will be procured as follows.

- 6,000 MW (32%) new storage systems to ease intermittency of renewable generation
- 3,600 MW (20%) new demand reduction and energy efficiency mandates
- 3,300 MW (18%) increased imports from Quebec
- 5,400 MW (28%) new wind and solar generation
- 300 MW (2%) new small modular nuclear reactor (SMR)

3.2 Comments on the IESO Gas Replacement Plan

Storage

The IESO (p. 17) admits that the technology behind the first item, new storage, has not been tested at the scale required and will not be available over the time scale being considered. We will nevertheless assume that it will be available, however the components from which it is manufactured will need to be imported. Note also that in Figure 1.2 the typical load being met by gas is about 2,000 MWh. 6,000 MW stored capacity would cover this demand for only 3 hours before needing to be recharged. Finally it should be noted that storage systems do not return an amount of power equivalent to that used for charging. We will assume that the battery system only returns 80 percent of the power injected, which implies a 25% increase in unit costs due to productivity losses.

Demand Management and Energy Efficiency Measures

The second item, demand management and new energy efficiency measures, does not provide replacement generating capacity, instead it involves coercive measures to get existing customers to use less electricity. It is thus inherently unreliable as well as welfare-reducing. If consumers do not respond as planned the result will be a gap between supply and demand with no backup solution.

Recent peer-reviewed research in the US has shown that while energy efficiency measures may have temporary demand-reducing effects, in the longer term they are self-defeating due to the "rebound effect" – later increases in energy consumption that are induced by the cost reductions associated with the efficiency gains themselves. Bruns et al. (2020) showed that within four years the rebound effect offsets 100 percent of the initial consumption reductions. Also as noted in McKitrick and Adams (2016) Ontario's power sector, like utilities in many countries, has a history of overstating its success at achieving reduction in electricity consumption through consumer energy efficiency initiatives.

We will nonetheless assume that the new conservation measures will succeed in reducing energy use, however they necessarily create large deadweight losses. Consumers already have the option of switching to more energy-efficient versions of their existing appliances. But not all appliance types provide the same features or quality. Suppose, for example, that a consumer faces two options when purchasing a dishwasher: model A runs quickly but uses more power, and model B uses less power but runs more slowly. Consumers will weigh the options and make their purchases based on the relative values they attach to the speed and cost of operation. A consumer with a large family, for example, may prefer the speed of model A even though each run will cost more. Buyers will make the choices that seem best to them and the result will be a fleet of dishwashers in the economy reflecting consumer preferences.

Now suppose a regulator bans model A and forces all consumers to buy model B. It would be a mistake to count the potential reduction in electricity use as a social benefit. This is an old but common error in regulatory impact analysis which arises because regulators routinely imagine they are in a position to correct what they view as consumer irrationality (Gayer and Viscusi 2013). The reason consumers chose model A was not that they are stupid and in need of bureaucratic guidance, but because the extra speed of operation was valuable to them—more valuable than the cost of the extra energy needed to run that model. The value of the electricity saved by using model B is therefore a measure of the welfare loss of not being permitted to purchase model A, since the consumer was willing to pay at least that much for the option. If instead of model A being banned outright the government subsidises model B through rebates or credits, the cost of the program provides a direct measure of the welfare losses it must overcome to convince consumers to switch. Thus while we are assuming the new conservation measures will work, we treat the cost of the programs as a deadweight loss.

Imports from Quebec

The next item, increased Quebec imports, is also problematic since Quebec currently has no excess generating capacity and is itself in need of imports to get through the winter. As the IESO plan notes, for this element to work Quebec would have to build new generating capacity of its own, and there is no guarantee they would be willing to do so, especially on the time scale considered. We will run the analysis two ways: first supposing that Quebec supplies the needed power and then supposing it does not.

New Nuclear and Renewables

The only part of the plan involving new capacity procurement yields slightly less than one-third of the required gap, and it is to be obtained from wind, solar and a small nuclear reactor. Ontario's experience with wind and solar has not been encouraging. The fuel sources are inherently intermittent, and wind in Ontario is systematically out of phase with demand. The SMR, if it succeeds, would provide only 2% of the needed capacity. Also the new wind and solar power are not a like-for-like replacement of gas since unless there is sufficient storage they are not able to provide dispatchable power on a 24/365 basis. We will make the heroic assumption that the storage procurement outlined above is sufficient not only for existing wind and solar but for the new procurement as well.

Summary

Overall, the assumptions needed to proceed with the analysis imply the replacement plan is not credible. While it is entirely believable that it would raise the cost of electricity by 60% (or more) there is little chance it will yield a reliable electricity supply.

Nevertheless for the present study we will assume that the plan can be implemented at the cost estimated by the IESO, which means that the simulations herein likely understate the actual difficulty and cost of the gas phaseout plan. We will also accept the warning that it would give rise to substantial risk of blackouts and we will attempt to account for the costs this entails.

3.3 Modeling Assumptions and Scenarios

We will implement the IESO plan under three scenarios:

1. The cost of electricity rises as projected by the IESO, Quebec supplies the needed extra power and no additional measures are needed to deal with blackout risks;
2. The cost of electricity rises as projected by the IESO, Quebec supplies the needed extra power and key sectors incur costs and productivity declines associated with mitigating blackout risks;
3. The cost of electricity rises as projected by the IESO, Quebec does not supply the needed extra power, and key sectors incur costs and productivity declines associated with mitigat ing blackout risks.

Scenario 1: The overall cost is assumed to be 51% of the cost of supplying electricity without the gas phaseout. The replacement budget thus created is denoted RB and is allocated to plan components according to the fraction of the supply gap each one is required to cover. Under the first assumption the supply gap is dealt with as follows:

- New storage systems (32% of RB) of which about two-thirds (20%) is spent on imports, one-eighth (4%) is spent on outputs of the Ontario Other Manufacturing sector and the remainder (8%) is a deadweight loss due to power losses;
- Quebec supplies the needed power (18% of RB);
- Behavioural mandates work as planned (20% of RB) but the cost represents an economic dead weight loss;
- New generating capacity is procured (30% of RB) of which 5% is spent on the domestic construction industry and 25% goes to international imports.

This scenario is only provided to isolate the economic costs of the increase in power prices, but since it does not take into account the effects of supply disruptions it provides an incomplete picture of the overall economic effects.

Scenario 2: This Scenario includes all the costs of Scenario 1 plus assumed costs for certain goods-producing sectors of having to deal with blackout risk. There is little empirical guidance about how to model the blackout risk. From the data shown in Figure 1.3, a blackout risk can arise at any time if the IESO must rely on wind power with no gas backup, since the wind can and does routinely change rapidly on an unpredictable basis. That is the case currently and would be even more of an issue under the IESO plan since even more wind would be added to the grid. Households that need to protect against loss of power would have to purchase and install standby generators and/or battery systems. For businesses, installation of such systems is even costlier but would be a necessity to continue operations in Ontario since even occasional blackouts can be quite damaging to industrial operations.

We will ignore the costs incurred by households and assume only that that the following industrial sectors need to allocate resources to procure standby backup power: Other (non-hydrocarbon) Mining, Construction, Food Production, Semi-durables, Refined Fuels, Other Petrochemicals, Cement and Concrete, Automotive Parts and Assembly, and Other Manufacturing. We will assume the required expenditures lead to a cost increase equal to 1% of annual total revenue every year from 2030 onwards.

Scenario 3: This Scenario includes all the costs of Scenario 2, but it is additionally assumed that Quebec is unable or unwilling to supply the power requested of it. As a result, 18% of the supply gap needs to come from other places. Half of that is assumed to come from new wind and solar installations installed by the Ontario construction industry and half of which is dealt with by imposing yet more conservation and demand management programs with attendant deadweight losses.

It is assumed herein that the major types of generating capacity remain the same between now and 2050, in other words no new low-cost, non-emitting, fully dispatchable power source is invented. If such a technology were to appear, the present analysis would be made irrelevant. The simulations assume the federal carbon price applies in Ontario, but does not impose other GHG measures such as the federal Emissions Reductions Plan or the Clean Fuels Standard, so as to isolate the effect of the gas phaseout proposal.

The LFXCM6 model is explained in the Appendix (see also McKitrick 2023). The core of the model is an 11 region (10 provinces plus combined territories) 26 sector computable general equilibrium (CGE) model of the Canadian economy with considerable energy sector detail. Labour supply is determined within the model based on current prices and the responsiveness of labour supply to market wages. Every market clears each period, including the labour and capital markets. This means there is no permanent unemployment, so the numbers reported here as “job losses” refer to permanent reductions in the demand for labour on the assumption that excess labour is cleared out of the market by reductions in wages and movement of workers out of the province. Actual unemployment during the transition to the new equilibrium would typically be higher than the job losses reported herein but is not counted in the simulations. Government labour demand is assumed to be based on an annually-fixed budget for hiring, so a reduction in the market wage of, say, x%, would be offset by an x% increase in the number of workers hired.

4. ECONOMIC IMPACTS

Tables 4.1 and 4.2 and Figures 4.1 to 4.5 summarize the economic implications of the three natural gas phaseout scenarios as simulated in the LFXCM6 model. As shown in Table 4.1 Ontario real GDP falls by 1.1% compared to the base case under the most optimistic scenario, and by 3.6% under the more realistic Scenario 3.[7] The largest job losses (about 25,000) are associated with Scenario 2; Scenario 3 involves some domestic substitution in place of imported Quebec hydro which adds to employment in-province, although in all three cases the employment effects are net negative. Percent real GDP losses per worker are shown and range from 1.0% in the best case to 3.4% in Scenario 3.

Ontario 2030:	Scenario 1	Scenario 2	Scenario 3
Real GDP (%)	-1.1	-3.0	-3.6
Employment (jobs)	-7,767	-24,909	-17,162
Employment (%)	-0.1	-0.3	-0.2
Real GDP per Worker (%)	-1.0	-2.7	-3.4
Cost per household ($)	$1,037	$2,715	$3,337
Real Industrial Output (%)	-0.3	-0.9	-0.8
Real Exports (%)	-0.5	-1.5	-1.7
Real Imports (%)	2.3	3.3	3.8
GHG Emissions (%)	-1.9	-2.9	-2.9
GDP loss across Canada per tonne abatement	$3,033	$6,085	$7,239

Table 4.1: Main macroeconomic effects of gas phaseout in Ontario as of 2030, relative to base case.

Under Scenario 1 the income losses per employed person are $696. Using the estimate of 1.49 employed persons[8] per household this implies costs per household of $1,037, close to but slightly below the estimate from the IESO of a $1,200 annual cost per household of the gas phaseout. This estimate only takes into account the real income loss of the electricity cost increase and the indirect cost effects on other goods, it does not take into account additional costs associated with mitigating against blackouts and finding an alternative power supply in case Quebec can't supply the expected exports. Once those effects are added in the cost per household more than doubles to $2,715 (Scenario 2) and $3,337 (Scenario 3).

Table 4.1 shows that the GDP loss arises due to a smaller drop in Industrial Output combined with a decline in exports and a rise in imports. The gas phaseout directly reduces provincial GHG emissions by just under two percent. In Scenarios 2 and 3 the reduction in output and consumer spending reduces GHG emissions by another 1.0%. The economic costs of these reductions are large on a per-tonne basis. The final row of Table 3.1 shows that the abatement costs begin at $3,033 per tonne in Scenario 1 and rise to $7,239 per tonne in Scenario 3.

Table 4.2 provides additional detail on the policy impacts by sector. Not surprisingly the industry experiencing the largest output decline is Electricity (-14.2% under Scenarios 2 and 3) followed by Other Utilities including Gas Distribution (-8.2% under Scenario 3). Among manufacturing sectors the largest Scenario 3

7 Equivalently, the economy grows by 27.6% from 2025 to 2030 under Scenario 3 versus 29.0% without the policy.

8 From Statistics Canada tables T-14-10-0420-01 and T-31-10-0045-01.

losses are in Refined Fuels (-2.5%), Other Petrochemicals (-2.0%), Air, Rail and Bus Transportation (-2.0%), Trucking Courier and Storage (-1.8%), Agriculture, Fishing and Trapping(-1.2%) and Automotive Parts and Assembly (-1.2%).

	Scenario 1		Scenario 2		Scenario 3	
Sector	Output	Capital Demand	Output	Capital Demand	Output	Capital Demand
1 Agriculture, Fishing and Trapping	-0.5	0.3	-1.1	-0.1	-1.2	0.1
2 Forestry and Logging	0.1	0.0	-0.6	-0.4	-0.6	-0.1
3 Oil Sands	0.0	0.0	0.0	0.0	0.0	0.0
4 Conventional Crude Oil	-1.4	-1.3	-2.3	-2.0	-2.4	-1.8
5 Natural Gas	-2.0	-1.9	-2.9	-2.6	-2.9	-2.2
6 Oil and Gas Support Activities	-0.8	-0.8	-1.1	-0.8	-1.0	-0.5
7 Coal	0.0	0.0	0.0	0.0	0.0	0.0
8 Other Mining	-0.2	0.3	-1.1	-0.4	-1.1	-0.1
9 Electricity	-13.6	-13.7	-14.2	-14.1	-14.2	-14.0
10 Other Utilities incl Gas Distribution	-7.5	-7.3	-8.1	-7.7	-8.2	-7.6
11 Construction	0.9	0.7	0.1	0.2	1.9	2.2
12 Food Production	-0.2	-0.2	-1.0	-0.7	-1.0	-0.5
13 Semi-durables	-0.2	0.1	-1.1	-0.5	-1.0	-0.1
14 Refined Fuels	-1.6	-1.6	-2.5	-2.3	-2.5	-2.1
15 Other Petrochemicals	-1.3	-1.0	-2.1	-1.5	-2.0	-1.2
16 Cement and Concrete	0.7	0.9	-0.6	0.0	0.8	1.7
17 Automotive Parts and Assembly	-0.1	-0.2	-1.1	-0.8	-1.2	-0.7
18 Other Manufacturing	0.4	0.4	-0.4	0.0	-0.2	0.4
19 Wholesale and Retail Sales	-0.1	-0.2	-0.6	-0.5	-0.6	-0.3
20 Air, Rail & Bus Transportation	-1.2	-1.3	-1.9	-1.7	-2.0	-1.5
21 Gas Pipelines	-4.0	-4.0	-4.7	-4.5	-4.7	-4.3
22 Crude Pipelines	-1.6	-1.6	-2.4	-2.2	-2.4	-2.0
23 Trucking, Courier and Storage	-1.1	-1.3	-1.8	-1.7	-1.8	-1.4
24 MBFITPS*	-0.1	-0.2	-0.4	-0.3	-0.4	-0.1
25 Education & Health	-0.2	-0.2	-0.5	-0.4	-0.6	-0.2
26 Entertainment and Misc	-0.1	-0.2	-0.7	-0.5	-0.8	-0.3
27 Government	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.2: Percent changes by sector in output and capital demand, as of 2030, relative to base case. * Media, Banking, Finance, Information Technology and other Professional Services.

As shown in Figure 4.1 the worst relative impacts on GDP occur in the first year of the policy, then the economy recovers toward baseline, although it never gets there. Under scenario 3 real GDP falls by 3.6% in 2030 but recovers to 2.2% below base case by 2050.

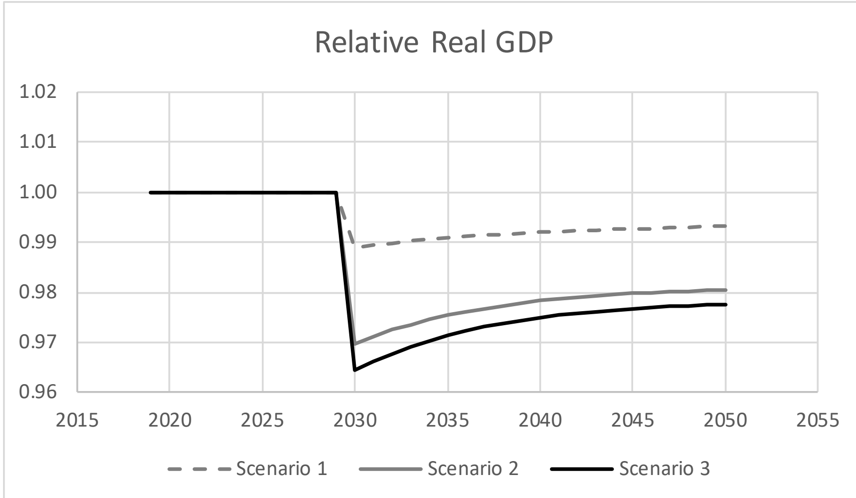

Figure 4.1: Relative real GDP in Ontario 2019 – 2050 (base case = 1.0) under the 3 scenarios.

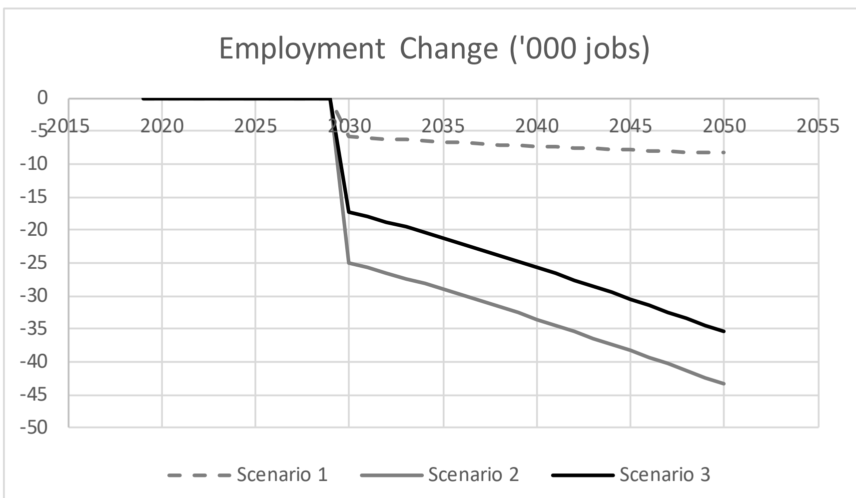

Figure 4.2: Change in total employment in Ontario under 3 scenarios, 2019-2050.

Figure 4.2 shows that job losses are worst under Scenario 2, with an immediate loss of nearly 25,000 jobs. Also the losses get worse every year thereafter. The Cost per Worker (Figure 4.3) is highest in the first year of the policy ($2,240 in Scenario 3) then settles down to just over $1,800 per year in 2050.

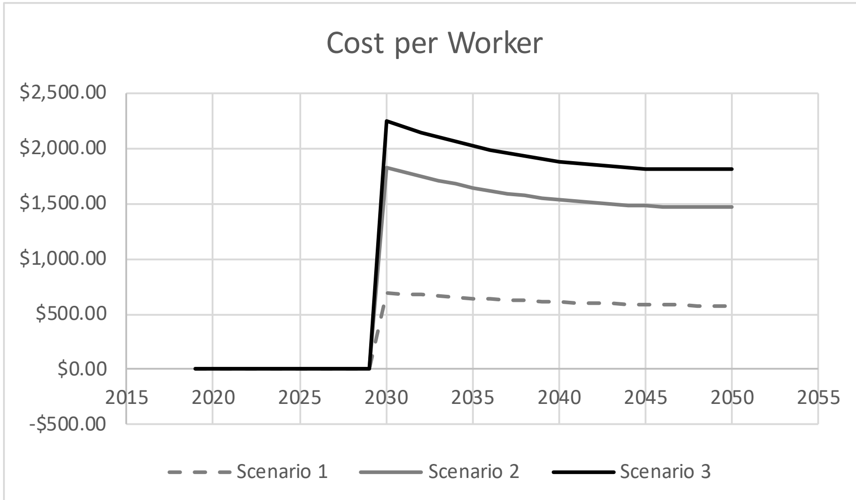

Figure 4.3: Cost per worker ($) of the gas phaseout under 3 scenarios, 2019-2050.

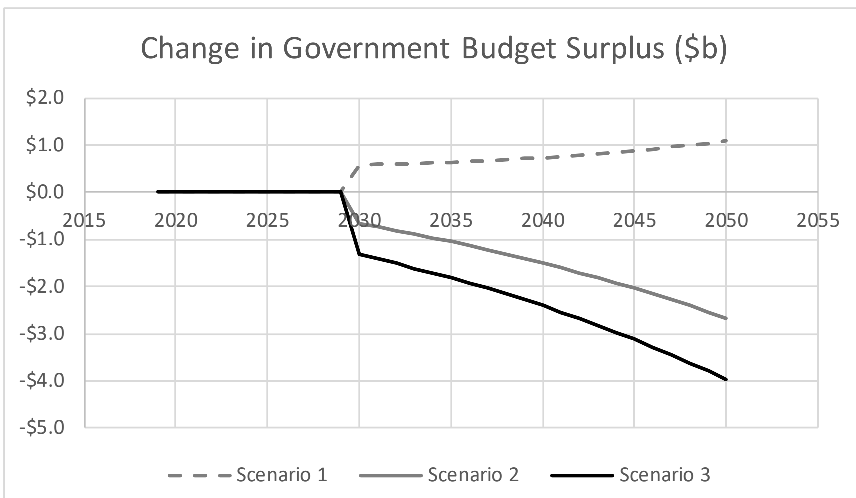

Figure 4.4: Change in Ontario consolidated government budget surplus under 3 scenarios, 2019-2050.

Figure 4.4 shows that the consolidated (combined federal and provincial) Ontario government budget surplus grows under Scenario 1, but experiences a net decline under Scenarios 2 and 3. Figure 4.5 shows that GHG emissions decline as a result of the policy, but the cuts are rather modest. GHG Emissions in 2030 fall compared to base case by between 1.9% and 2.9% depending on the scenario. Under Scenarios 2 and 3 the emission cuts approach 3.4% by 2050. Part of the decline in GHG emissions is due to the contraction of economic output rather than the closure of gas generating plants themselves.

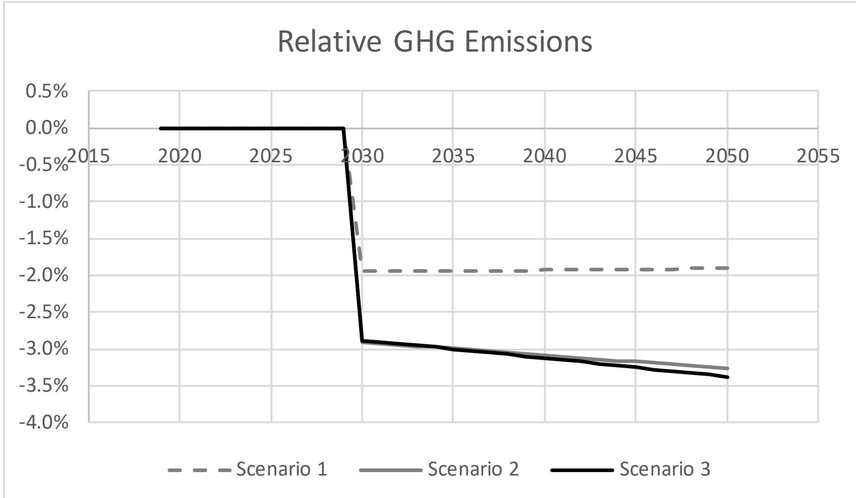

Figure 4.5: Change in Ontario GHG emissions (%) 2019 – 2050 under 3 scenarios, 2019-2050.

Model computations taking into account costs (measured as loss of GDP) across Canada show that the costs of the gas phaseout are between $3,000 and $7,200 per tonne of GHG reduced in 2030 depending on the scenario. As of 2050 the range reduces to between $2,200 and $3,300 depending on scenario. These amounts are, of course, at least an order of magnitude higher than the proposed federal carbon price schedule, which is currently at $65 per tonne and is scheduled to reach $170 per tonne by 2030, rates which reflect the federal Government's current thinking on the environmental costs associated with GHG emissions. This mismatch between marginal costs and benefits indicates the inefficiency of the gas phase-out as an element of Canada's climate policy mix.

5. SUMMARY

Natural gas currently plays a small but vital role in Ontario's electricity grid. As indicated by the IESO (2021) under current technologies there are serious technical obstacles to phasing it out of the supply mix. We have shown herein furthermore that there would be virtually no environmental benefits, either for air quality or the climate, of doing so. Based on the IESO estimates of the rate impacts on consumers and the creation of significant risks of supply disruptions, we assess that there would be large negative economic impacts. Under scenarios which account for the possibility that Quebec declines to invest in new power generation capacity the policy would cause Ontario's GDP to fall between 3.0 and 3.6% below its base case level as of 2030 at a cost of 17,000 to 25,000 jobs. The direct and indirect costs as of 2030 would be between $2,700 and $3,300 per household in 2030 and the loss of GDP at the national level taking into account costs of reduced system reliability would be between $6,000 and $7,200 per tonne of GHG reduced, which is at least an order of magnitude higher than the federal government's estimate of the economic benefits of GHG emission reduction.

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7. ABOUT THE AUTHOR

Ross McKitrick holds a Ph.D. in economics from the University of British Columbia (1996) and is a Professor of Economics at the University of Guelph in Guelph, Ontario. He is the author of *Economic Analysis of Environmental Policy* published by the University of Toronto Press in 2010. He has been actively studying climate change, climate policy and environmental economics since the mid-1990s. He built and published one of the first national-scale Computable General Equilibrium models for analysing the effect of carbon taxes on the Canadian economy in the 1990s. His academic research publications have appeared the *Journal of Environmental Economics and Management, The Canadian Journal of Economics, Canadian Public Policy, Journal of the Royal Statistical Society, Energy Economics, Journal of Forecasting, Climatic Change, Climate Change Economics, Proceedings of the National Academy of Science, Journal of Geophysical Research, Climate Dynamics, Environmental Economics and Policy Studies,* and many other highly-ranked outlets. He has also written policy analyses for the Fraser Institute (where he is a Senior Fellow), the CD Howe Institute, the University of Calgary School of Public Policy and other Canadian and international think tanks. Professor McKitrick appears frequently in Canadian and international media and is a regular contributor to the Financial Post Comment page. His writings and other outputs are available at rossmckitrick.com.

This report was reviewed by 4 independent experts whose input is hereby gratefully acknowledged. All errors are the responsibility of the author alone.

APPENDIX: MODELING STRATEGY

This Report employs the LFX Canadian Model Version 6 (LFX-CM6). A detailed description of the model is provided in McKitrick (2022) and McKitrick (2023). Briefly, LFX-CM6 is a dynamic model of the Canadian economy that resolves annual provincial-level economic activity into 26 industries, plus final demand sectors including households, governments, trade and fixed capital formation (investment). The sectors are:

1. Agriculture Fishing and Trapping
2. Forestry and LogginG
3. Oil Sands
4. Conventional Crude Oil
5. Natural Gas
6. Oil and Gas Support Activities
7. Coal
8. Other Mining
9. Electricity
10. Other Utilities incl Gas Distribution
11. Construction
12. Food Production
13. Semi-durables
14. Refined Fuels
15. Other Petrochemicals
16. Cement and Concrete
17. Automotive Parts and Assembly
18. Other Manufacturing
19. Wholesale and Retail Sales
20. Air Rail & Bus Transportation
21. Gas Pipelines
22. Crude Pipelines
23. Trucking Courier and Storage
24. Media, Banking, Finance, Information and related Professional Services
25. Education and Health
26. Entertainment, Travel, Restaurants and Miscellaneous Services.

The list of commodities is the same and all outputs are assigned to the corresponding sector. Petroleum products are distinguished between fuels and those used for non-combustion applications. The model resolves output, capital demand, labour demand and intermediate input demand for every commodity in every sector for each province, calibrated so as to reproduce the 2019 provincial-level Canadian input-output tables.

The model belongs to the class known as Computable General Equilibrium, or CGE. One important feature of CGE models is that all markets are forced to clear each period. While employment can go up or down in response to market conditions, there is no unemployment: instead wages are assumed to adjust sufficiently to equate the supply and demand of labour. The capital market and all goods and service markets likewise clear. The model also solves for an interest rate that clears the investment and savings markets, and an exchange rate that clears the current and capital accounts (which govern international goods and services trade and international financial flows).

Capital Stocks and Investment

An important innovation of the LFX-CM6 which distinguishes it from previous versions of the LFX model is that investment and the capital stock now evolve over time based on market conditions. Static CGE models assume capital is fixed or, in some cases, can adjust within a region but not across borders, nor over time. In LFX-CM6 each sector in each province determines its annual demand for capital based on existing market prices including the user cost of capital. The user cost of capital is defined as the purchase cost of capital, less the potential resale value after accounting for discounting and depreciation. Sector-specific capital demands are added up nationally and compared to the pre-existing national capital stock. The price of capital adjusts to clear the market for fixed capital. Gross fixed capital formation across all sectors is undertaken in response to current and anticipated capital needs using a Tobin's-q model. The expected capital demand is based on growth of the labour supply and changes in the market value of capital. Also taken into account in this step is any adjustment to real interest rates necessary to equate savings and investment, which affects the user cost of capital. Capital stocks throughout the economy are updated recursively to account for depreciation and investment.

Regulatory Compliance Costs

An important feature of the LFX model is its ability to track regulatory compliance costs. It is a routine matter in a CGE model to track tax costs. When a tax is imposed on the sale of a good or service it drives a wedge between the price paid by a buyer and the price received by a seller. That wedge, when multiplied by the market quantity, is remitted to the government where it shows up as revenue.

A regulatory intervention drives up the cost for firms to produce a good or service and can be thought of as being like a tax except that the wedge created between the original and modified seller's cost is not remitted to the government, instead it is either lost to decreased productivity or remitted as a forced purchase from another sector. For example, in the absence of regulation, the carbon intensity of liquid fuels is based on industry optimization between use of crude oil and various additives, including ethanol. When the government imposes a requirement to reduce liquid fuel carbon intensity by blending in more ethanol, this causes producer unit costs to increase. Some of the increase arises from forced purchases of alternative inputs to the refining process, which the LFX model takes into account. Those show up as benefits in, for example, the ethanol industry, but impose costs elsewhere, including on consumers who must spend more on fuel than before to go the same distance. When buyers purchase sufficient fuel to make a road trip of a specific length, the fuel cost is higher than it would have been without the regulation. However, the higher fuel cost doesn't entirely accrue to the producers because their production costs rise, instead some is lost to market inefficiency. The presumed benefit is derived from the environmental effects of reduced carbon intensity. The regulatory costs are traced in LFX model based on estimating the effects on production costs associated with specified regulatory targets.

Similar effects arise in response to, for example, energy efficiency regulations. One difference between CGE models and engineering-based ("bottom-up") simulation tools is the recognition that regulatory measures cannot, in principle, reduce overall production costs or save consumers money across their entire budget by forcing them to make purchases they would not otherwise have chosen to make. Imposing energy efficiency requirements might save consumers or firms money on a specific type of energy consumption, but not overall. Based on the assumption that households already optimize their spending, energy efficiency rules require new spending on goods and services that exceeds the value of the energy savings (otherwise the firm or consumer would already have made the investment). In addition, improvements in energy efficiency do not automatically translate into reductions in energy demand. If the cost of driving a car or heating a home goes down, consumers respond in part by driving more or raising the thermostat, the so-called “rebound effect.”.

Energy Use and GHGs

The LFX-CM6 model has sufficient energy sector detail to track Canadian production and consumption of fossil fuels (conventional crude, oil sands crude, natural gas, coal and refined fuels). CO2 and methane emission coefficients (including fugitive emissions from agriculture) are computed by comparing Canadian GHG emission inventory estimates to model-resolved sectoral input and output quantities so as to reproduce the 2019 emission inventory.

Cautions to the reader regarding modeling approach

Any model-based simulation, including the present one, should be thought of as a complex ‘if-then’ statement. If certain conditions hold, then certain outcomes can be expected. Among the classes of economic models, the CGE approach has specific strengths and weaknesses that should be kept in mind. A strength is that it imposes full macroeconomic closure, which means all transactions must balance and all agents must operate within a budget constraint, so there can be no ‘free lunches’. Related to this is the assumption that economic agents (households and firms) are optimizers, so they automatically make the best use of the resources available to them without needing to be told to do so by a government or regulatory agency. For this reason, regulatory or other policy interventions in a CGE economy cannot make everyone better off simultaneously: they can make some people better off, or increase outputs in some sectors, but only at the cost of making others worse off or forcing down production elsewhere.

A weakness of the CGE modeling framework is that it does not track or measure conventional unemployment. References to job losses refer to equilibrium changes; in other words, reductions in employment after the labour market has cleared following an external shock. When a policy change happens that reduces demand for labour in one part of the economy, it is assumed that those workers either find employment elsewhere or withdraw voluntarily from the job market. The costs incurred during this transition are not counted in the economic assessment. Usually the reallocation of workers requires the wage rate to decline, which means hiring in other parts of the economy will increase.

CGE models also do not simulate or measure inflation. At their core, CGE models can be thought of as barter economies without any money, where one commodity serves as the trading currency and everything is priced in units of it. Money only serves as a medium of exchange and any policy change that leaves the price ratios unchanged (such as doubling all prices at once) would have no effect in the model economy.

Another caution regarding CGE models is that outcomes within specific sectors are sensitive not only to the numerical parameters chosen for the underlying functions but also to the functional forms themselves. Construction of large macroeconomic models which attempt to resolve industry- and provincial-level detail, as the LFX-CM6 does, requires substantial data resources to provide reasonable parameter values. The more data are available the more flexible can be the functional structure of the model, but even with Canada’s extensive collection of input-output tables and national accounts, creating a tractable and stable functional structure requires imposing some arbitrary restrictions that limit the realism of the simulations. Moreover, modeling economic dynamics is notoriously difficult and the underlying theory is far from settled. Application of rational expectations theory, for instance, increases the computational burden exponentially and would make it effectively impossible to achieve the provincial and sectoral detail shown here. To resolve the tradeoff between sectoral detail and fidelity to economic theory, some of the behavioural equations related to economic dynamics, such as household savings, fixed capital formation and international lending, are based on linearized empirical approximations rather than full theoretical derivations.

Factor markets in CGE models (capital and labour) tend to be represented much more simply than markets for goods and services. This is not because the variations in labour types, for example skilled versus unskilled labour, or college-educated versus non-college educated workers, are economically unimportant, but because of the difficulty of obtaining the data required to disaggregate the labour supply function. Labour is supplied by households and every different labour supply function must be paired with the associated consumption and savings models. To do this properly would require data on goods and service transactions to be broken down, not only by commodity, but also by the skill or education level of the purchaser. Hence the LFX-CM5, like many other CGE models, assumes there is only one type of worker and one type of capital, which can be interchanged among provinces and sectors.

Modifications to the model aimed at improving realism may increase or decrease projected net costs. This is especially so regarding investment and growth over long horizons such as those considered herein. Large policy shocks can trigger unforeseen innovations that partially or fully counteract the short run economic losses. Policy-induced technological change is by no means unknown but it is also not guaranteed, nor is it free. Since research and development is costly, technological innovation aimed at reducing compliance costs associated with new regulations may crowd out other forms of innovation. In general economic theory would suggest the net effects of such crowding out will be negative over the long run, but the size of such effects are difficult to estimate.

Finally, some policies are easier to model than others. The LFX-CM6 can accommodate a lot of detail on taxes, subsidies, tariffs and so forth. But regulatory targets are much more difficult to handle, especially when, as is the case with the Ontario gas phaseout proposal, there is little detail about what the compliance options will be.