Out with the coal, in with the new

National benefits of an accelerated phase-out of coal-fired power

November 2016

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Production management: Kelly O'Connor
Editor: Roberta Franchuck
Authors: Benjamin Israël, Erin Flanagan
Contributors: Eli Angen, Sara Hastings-Simon
Cover design: Steven Cretney

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Pembina Institute
219 19 Street NW
Calgary, AB
Canada T2N 2H9
Phone: 403-269-3344

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Executive summary

This report illustrates the environmental and health benefits of a national accelerated phase-out of coal-fired electricity by 2030. Our analysis is derived from the federal government's Regulatory Impact Analysis Statement (RIAS) made available following the development of its existing regulation for coal-fired power in 2012. Our analysis builds on the RIAS by interpolating a "benefit factor", represented as avoided health impacts per unit of coal-fired power generation reduced. This value is then extrapolated to determine the air quality and health benefits possible from the phase-out of all coal-fired power facilities by 2030. Since it would cut ten years from the current existing federal timeline (which allows some facilities to continue operating well past 2040), an accelerated phase-out would bring nation-wide health, climate and economic benefits.

A national coal phase-out no later than 2030 would more than double the benefits obtained by society through the Government of Canada's 2012 regulation. By accelerating the national phase-out of coal-fired power to 2030, 1,008 premature deaths, 871 ER visits, and health outcomes valued at nearly $5 billion (including health and lower productivity costs) would be avoided between 2015 and 2035.

The combustion of coal for electricity generation results in carbon and air pollution impacts, both of which result in health and economic damages that are ultimately borne by society. Fortunately, alternative technologies, coupled with energy efficiency programs, have made it feasible to eliminate emissions from coal-fired power. Coal phase-out policies of this nature are being pursued around the globe — especially across OECD countries — and have already been successfully implemented in Ontario, and announced in Alberta.

The federal government should join global and provincial leaders and commit to an accelerated phase-out schedule for Canada's coal-fired electricity. More specifically, the government should reduce the allowed end-of-life for coal plants down to 40 years, with no later than a 2030 end-date for unabated[1] coal-fired power. In accelerating the national transition away from coal-fired power, Canadians will experience important health and climate benefits, extending over generations.

[1] Throughout this report, *unabated* coal-fired generation refers to coal-fired power that is not equipped with technologies that remove, or drastically reduce, greenhouse gas emissions.

1. Introduction

As a 19th-century break-through technology, burning coal to produce electricity propelled massive improvements in the productivity and well-being of society. But in the 21st century, its continued use is much less revolutionary: coal combustion has well-known health and environmental consequences. Burning coal contributes to heart diseases and respiratory illnesses including lung cancer, neurodevelopmental effects, and premature deaths. Further, it exacerbates the problem of climate change in an era of renewed global cooperation to curb carbon emissions. These consequences simply cannot be justified in the face of reliable and cost-effective alternative forms of electricity generation, such as renewable energy, and energy conservation.

When accounting for full costs, including those borne by society, it is all too clear that burning coal to produce electricity is not in Canada's national interest. Throughout this paper, we make the case that a commitment to accelerate Canada's phase-out of coal-fired power by 2030 must be a cornerstone element of the first ministers' upcoming national climate change plan. A commitment of this nature is a first step to getting Canada on track to achieve its 2030 emissions reduction target, and would secure important health and economic benefits nation-wide.

This paper is structured as follows: section 2 outlines the state of coal-fired power facilities across Canada, section 3 evaluates the health and climate impacts of coal-fired power, section 4 discusses the federal government's cost-benefit analysis that informed the 2012 federal regulations, section 5 expands on this analysis to determine the incremental benefits to a 2030 phase-out, and section 6 illustrates the health, climate and diplomatic benefits to such a commitment.

2. The state of coal-fired electricity in Canada

Coal-fired power has long been an important source of electricity in Canada, particularly in provinces without access to significant sources of hydroelectricity. But, while it has historically been marketed as a "cheap" option for generating electricity, burning coal for electricity has many hidden costs. With its carbon and air pollution combined, the negative effects of coal combustion are unmatched and stand an order of magnitude higher than other common power sources.[2]

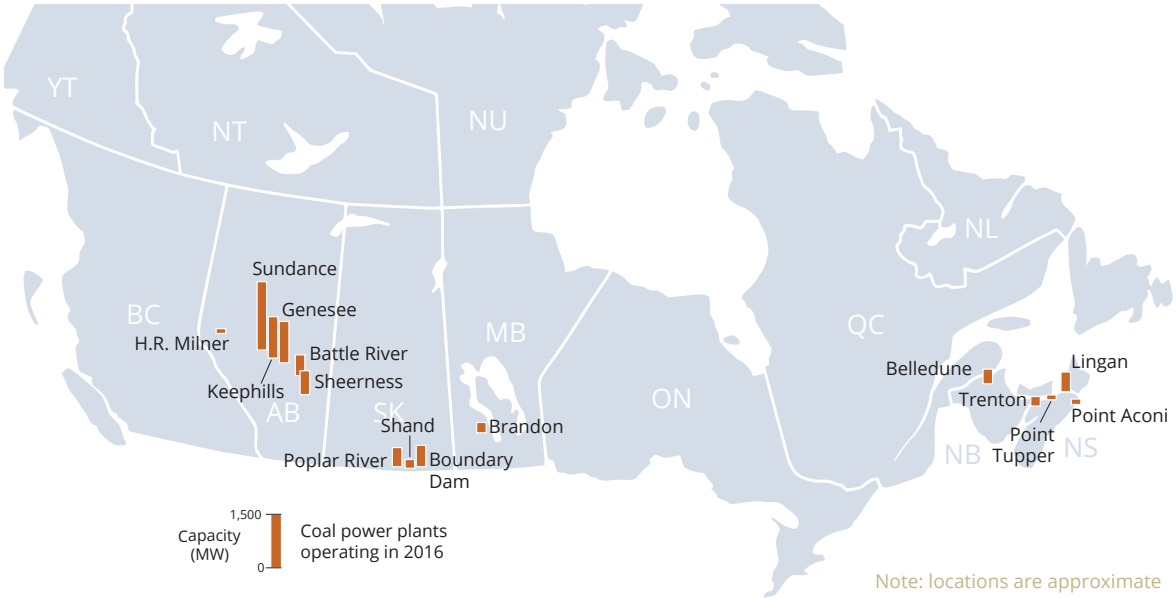

Figure 1. Coal power capacity in Canada in 2016

Note: Locations of coal power plants are approximate.

At present there are 34 coal power units[3] operating across Canada in four provinces: Alberta, Saskatchewan, New Brunswick and Nova Scotia. Canada has approximately 9,700 MW of coal power capacity with the greatest share being located in the Prairies

[2] Data from Environment and Climate Change Canada shows that coal power is associated with drastically more greenhouse gas, sulphur dioxide, nitrogen oxides, mercury and other harmful pollutant emissions per unit of generation than any other power sources used in Canada.

[3] The Brandon unit in Manitoba is an emergency only unit, so while there are 35 units in total, only 34 are actively operating.

(Figure 1 and Table 1). Although coal power generation in Canada has nearly halved between 2000 and 2014, coal is still burned to generate 11% of Canada's electricity.[4] Further, coal-fired power is still the primary source of electricity in Alberta, Saskatchewan, and Nova Scotia.[5]

According to 2014 data, Alberta and Saskatchewan hold 65 and 16% of Canada's overall coal capacity, respectively, with remaining capacity distributed between Nova Scotia (10%) and New Brunswick (5%). Brandon, the only coal-fired unit in Manitoba, is by law an emergency plant and therefore is not relied upon throughout the year.[6] For this reason, Manitoba's coal power plant is excluded from our analysis.

[4] Environment and Climate Change Canada, *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada*, 2016, Part 3, Section A13.

[5] Coal-fired power plants that burn petroleum coke – a solid by-product of the oil refining process – such as the Point Aconi plant in Nova Scotia, are included in this analysis. However plants that burn petroleum coke mixed with other fuels, such as Coleson Cove 3 in New Brunswick, are excluded from our analysis.

[6] The Manitoba Climate Change and Emissions Reductions Act states: "Despite any provision of The Manitoba Hydro Act, after December 31, 2009, Manitoba Hydro must not use coal to generate power, except to support emergency operations." In addition, Manitoba announced in September 2016 that Brandon will be mothballed in 2019. Charles Tweed, "Hydro says local coal-fired generator going offline in 2019," Brandon Sun, September 3, 2016. http://www.brandonsun.com/local/hydro-says-local-coal-fired-generator-going-offline-in-2019-392224731.html

Table 1. Coal power capacity and generation in Canada in 2014

Coal power facility	Number of units	Capacity (MW)	Generation in 2014 (GWh)
ALBERTA			
Battle River	3	520	4,087
Genesee	3	1,315	9,710
HR Milner	1	150	673
Keephills	3	1,307	9,117
Sheerness	2	760	5,169
Sundance	6	2,143	13,795
SASKATCHEWAN			
Boundary Dam, Shand, Poplar River	7	1,530	9,300
MANITOBA			
Brandon	1	110	65
NEW BRUNSWICK			
Belledune	1	458	2,560
NOVA SCOTIA			
Lingan	4	620	2,288
Point Aconi	1	171	1,240
Point Tupper	1	154	95
Trenton	2	308	1,717
CANADA, TOTAL	**35**	**9,546**	**60,677**

Sources: Alberta Environment and Parks,[7] Nova Scotia Power,[8] Environment and Climate Change Canada[9]

[7] Alberta Environment and Parks, *Annual Reports From Generators*, 2014.

[8] Nova Scotia Power, Air Emissions Reporting, 2014. http://www.nspower.ca/en/home/about-us/environmental-commitment/air-emissions-reporting/default.aspx

[9] Environment and Climate Change Canada, *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada*, 2016

3. Evaluating the pollution impacts of coal-fired power

Coal-fired electricity generation — a source of significant greenhouse gases among our energy sources — is also a leading emitter of several air contaminants and persistent toxics that are harmful to human health. Coal-fired power plants are a particularly important source of sulphur dioxide (SO_2), nitrogen oxides (NO_x), fine particulate matter ($PM_{2.5}$), mercury, and ground-level ozone. Continued use of this antiquated technology results in substantial negative impacts: burning coal produces GHG emissions that contribute to climate change, it also produces air pollution and mercury that affects the health of Canadians, all of which result in negative impacts to health and economic outcomes nation-wide.

3.1 A source of pollution that worsens health and economic outcomes

3.1.1 NO_x and SO_2 emissions

It is well understood that coal-fired plants' emissions of SO_2 and NO_x harm human health directly when present in the ambient air we breathe.[10] Short- and long-term exposure to NO_x and SO_2 have been linked to increases in respiratory ailments, diseases and premature deaths, while exposures to SO_2 have also been linked to cardiovascular ailments.[11]

A 2016 study from Health Canada draws alarming new conclusions about the direct impacts of SO_2. While short-term exposures have already been linked to respiratory morbidity in sensitive populations such as people with asthma, children, unborn children and the elderly, it appears that these populations are also more susceptible to adverse effects when exposed to SO_2 at current ambient levels. It pointed out there is no

[10] Pembina Institute, *Breathing in the benefits: How an accelerated coal phase-out can reduce health impacts and costs for Albertans* (2016). http://www.pembina.org/pub/breathing-benefits

[11] World Health Organization, *Review of evidence on health aspects of air pollution – REVIHAAP Project* (2013). http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-final-technical-report

known threshold below which no damage occurs. The study also suggests there may be a causal relationship between long-term, low-level exposure to SO_2 and adverse reproductive outcomes such as congenital heart defects and preterm delivery.[12]

Both gaseous NO_x and SO_2 also react with other elements in the atmosphere to produce $PM_{2.5}$, the air pollutant that has been most clearly and consistently linked to chronic cardiovascular and respiratory diseases, including lung cancer.[13]

3.1.2 Fine particulate matter ($PM_{2.5}$)

Coal plants emit fine particulates directly ("primary PM"), but it is "secondary PM" formed from NO_x and SO_2 that is the major culprit behind the high levels of $PM_{2.5}$ that are typically measured in airsheds of provinces that burn coal to generate power. The chemical composition of the fine particulate matter can vary based on the pollutants present, and health impacts will be different based on the specific chemicals. Secondary particles formed through reactions with NO_x and SO_2 have a higher impact to human health than primary PM that is directly emitted. As Environment Canada states: "While the primary PM emissions from the electricity sector are important, it is the secondary PM formation resulting from NO_x and SO_x emissions, which has the greatest human health impact."[14]

Long-term exposure to fine particulate matter has been clearly and consistently associated with higher rates of cardiovascular diseases such as ischemic heart disease, dysrhythmias, heart failure, and cardiac arrest.[15] More recent evidence suggests that $PM_{2.5}$ may also be associated with increases in adverse birth outcomes, development of childhood respiratory diseases, development of cognitive disorders, and increased rates of diabetes.[16] With respect to asthma specifically, a 2015 study funded by the European Union shows a strong link between exposure to air pollutants such as NO_2 and $PM_{2.5}$ and

[12] Andrew Read, *Sulphur Dioxide and Health: Summary of recent findings from Health Canada* (Pembina Institute, 2016). http://www.pembina.org/pub/sulphur-dioxide-and-health

[13] *Review of evidence on health aspects of air pollution.*

[14] RIAS, 2048.

[15] C. Arden Pope et al., "Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution: Epidemiological Evidence of General Pathophysiological Pathways of Disease," *Circulation* 109 (2004), 1.

[16] *Review of evidence on health aspects of air pollution*.

the development of asthma during childhood and adolescence.[17] Unfortunately, these air contaminants also exacerbate asthma symptoms.

3.1.3 Mercury

Coal plants are also a significant source of mercury, a persistent toxic substance that accumulates in the aquatic food chain.[18] Coal-fired power is presently responsible for 18% of the country's mercury emissions from human activities (Figure 2). In Alberta, this number is much higher – coal-fired power is responsible for 37% of provincial mercury emissions.

Prenatal and early life exposure to mercury, resulting from the consumption of mercury-contaminated fish, has been linked to adverse developmental impacts such as reductions in cognitive abilities and motor skills.[19] Researchers have attributed 3.2% of intellectual disability cases in the United States to mercury exposure and valued these excess cases at $2.0 billion per year.[20] Further, a study of the economic costs of lifelong losses in IQ and productivity resulting from prenatal mercury exposures to mercury emissions from American coal power plants reported a $1.3 billion cost to Americans annually.[21] Women of childbearing age, pregnant women, children and populations that depend on fish as a traditional food source, are at greatest risk from mercury.[22]

3.1.4 Greenhouse gas emissions

Coal power plants emit significant amount of greenhouse gas emissions – which, by contributing to climate change, will impact the health of Canadians and global citizens in the long term. The vast majority of scientists agree that climate change will substantially affect our environment and health. For example, a 2009 collaboration

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[17] Ulrike Gehring et al., "Exposure to air pollution and development of asthma and rhinoconjunctivitis throughout childhood and adolescence: a population-based birth cohort study," *The Lancet Respiratory Medicine,* 3 (2015). dx.doi.org/10.1016/S2213-2600(15)00426-9

[18] Canadian Council of Ministers of the Environment, *Canada-Wide Standards for Mercury Emissions from Coal-Fired Electric Power Generation Plants* (2006). http://www.ccme.ca/files/Resources/air/mercury/hg_epg_cws_w_annex.pdf

[19] Ibid.

[20] L. Trasande, C. Schechter, K.A. Haynes, P.J. Landrigan, "Mental retardation and prenatal methylmercury toxicity," *American Journal of Industrial Medicine,* 49(2006), 3. http://www.ncbi.nlm.nih.gov/pubmed/16470549

[21] Tresande L, Landrigan P.J. & Schecter C. (2005) Public health and economic consequences of methyl mercury to the developing brain. Environmental Health Perspectives; 113(5): 590–596.

[22] *Canada-Wide Standards for Mercury Emissions from Coal-Fired Electric Power Generation Plants.*

between The Lancet and University College London examined the potentially disastrous effects that climate change could have on health across the globe, and concluded it could potentially be the biggest global health threat of the 21st century.[23]

Coal plants continue to be a serious source of greenhouse gases in Canada. In 2014, the year that Ontario completed its phase-out, coal-fired electricity was responsible for approximately 8.4% of Canada's greenhouse gas emissions.[24]

3.2 Coal on Canada's grid: current pollution impacts from coal-fired power

3.2.1 NO_x and SO_2 emissions

In 2014, 10 of the top 17 sources of sulphur dioxides in Canada were coal plants. For nitrogen oxides, they represent 10 of the top 14.[25] In 2014, coal plants were responsible for 23% of Canada's SO_2 emissions (Figure 2). These levels were significantly higher in some provinces, such as Alberta, where coal power contributed over 40% of provincial SO_2 emissions. Other harmful pollutants released by coal-fired power generation include lead, cadmium, hexachlorobenzene, dioxins and furans, polycyclic aromatic hydrocarbons, and arsenic.

The amount of air pollution varies by coal plant but all are significantly higher emitting than the cost effective alternatives for electricity production. Out of Canada's 34 operating coal-fired units, 32 were commissioned before the 2000s and therefore were not originally equipped with the best available technology for pollution reduction.[26] Newer coal units (such as Genesee 3 and Keephills 3 in Alberta) are equipped with pollution control technology for SO_2 and NO_x that significantly reduces these pollutants. In additional to the state of technology deployed at individual facilities, the quality of coal burned at these units is also a factor affecting pollution emissions rates.

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[23] UCL Lancet Commission, "Managing the Health Effects of Climate Change," *The Lancet* 373 (2009), 9676. http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(09)60935-1/fulltext

[24] Environment and Climate Change Canada, National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada, 2016.

[25] Environment and Climate Change Canada, National Pollutant Release Inventory, 2014. http://ec.gc.ca/inrp-npri/

[26] Some coal-power units were refurbished with pollution control technologies, especially in Atlantic Canada. Also, Boundary Dam 3, equipped with both pollution control and carbon capture and storage technologies, is part of the three units commissioned after 2000 as it was re-commissioned in 2014.

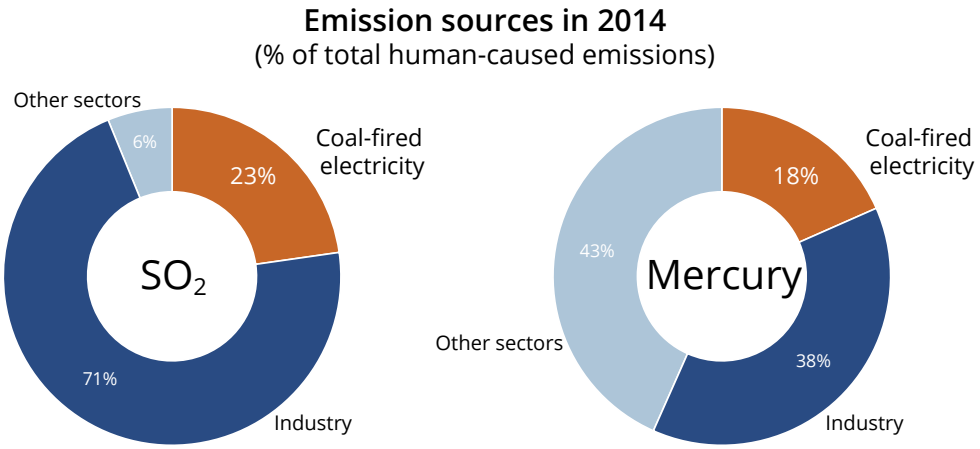

Figure 2. Contribution from coal-fired power plants to overall sulphur dioxides and mercury emissions in 2014 in Canada

Source: Government of Canada[27]

Notes: Industry includes aluminum, asphalt paving, cement and concrete, chemicals industry, mineral products, foundries, grain industries, iron and steel, iron ore mining, mining and rock quarrying, non-ferrous smelting and refining, pulp and paper, wood, upstream petroleum, downstream petroleum, petroleum product transportation and distribution, biofuel production. Other sectors include non coal-fired electric power generation, transportation, agriculture, waste, and other miscellaneous sources.

Given these factors, SO_2 and NO_x emissions per unit of power generated vary greatly across Canada, as illustrated in Figure 3 below. While the range for NO_x emissions per megawatt-hour tends to be somewhat limited, SO_2 emission intensity varies by a factor of eight between the best and worst unit. However, as Figure 3 shows, cost-effective alternatives to coal power, such as natural gas, emit substantially less NO_x, zero SO_2, and zero mercury per MWh as compared to the whole range of coal plants. And of course, by definition, renewable energy emits virtually no NO_x, SO_2 or mercury emissions at all, making it the ideal option for electricity generation from a pollution reduction perspective.

[27] Government of Canada, "Air Pollutant Emission Inventory." http://open.canada.ca/data/en/dataset/4d7f1350-c707-4a2b-8cd3-7eed1b41d415

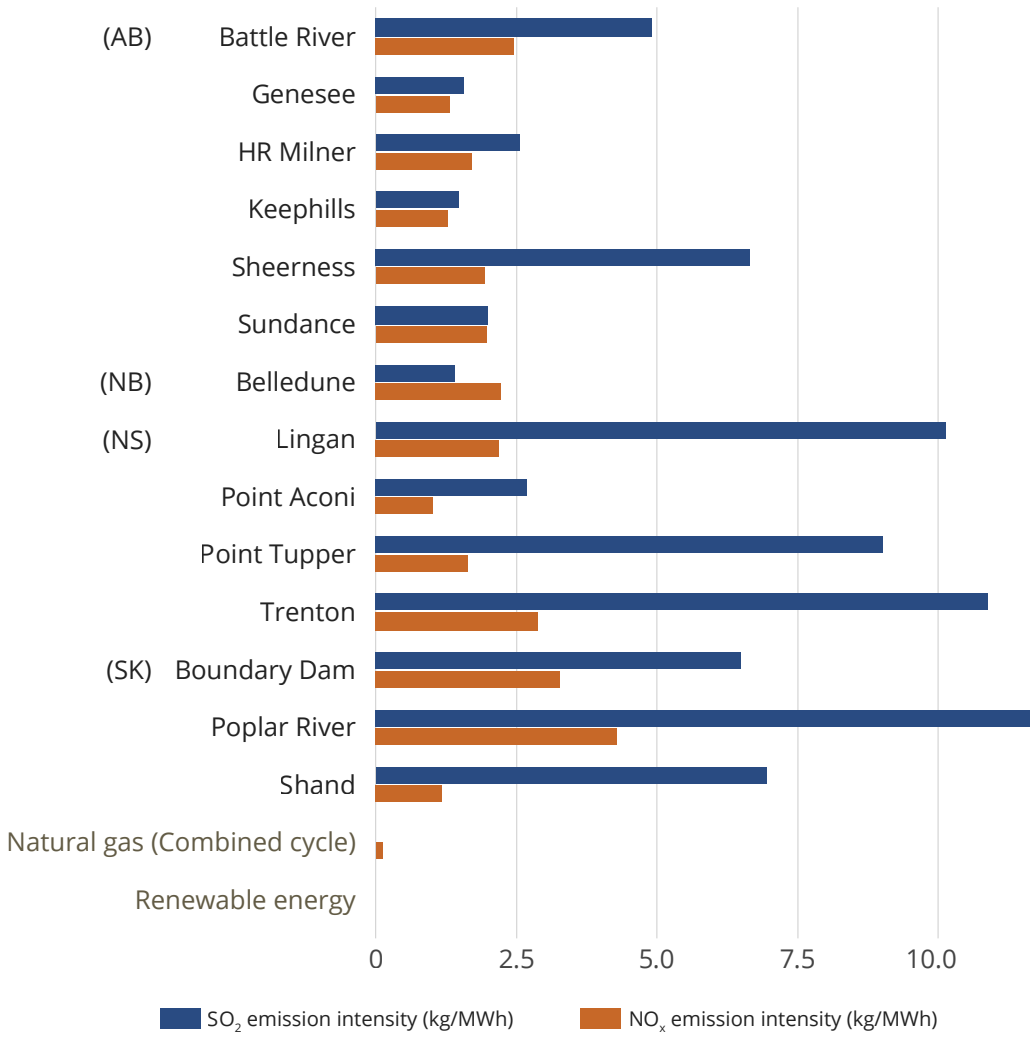

Figure 3. Emission intensity for SO_2 and NO_x per facility in 2014 compared to other technologies

Sources: Alberta Environment and Parks,[28] Nova Scotia Power,[29] Environment and Climate Change Canada[30]

Notes: Power generation from Saskatchewan's coal-fired plants is no publicly available data. It was estimated by combining the GHG emissions from each plant with the provincial, non-facility-specific GHG emission intensity factor in 2014 (1,260 kg of CO2e per MWh). Point Aconi runs primarily on petroleum coke, a fuel that is considered similar to coal by the federal regulation. When combusted, petroleum coke produces more air pollutants than coal. However, specific

[28] Alberta Environment and Parks, *Annual Reports From Generators*, 2014.

[29] Nova Scotia Power, Air Emissions Reporting, 2014. http://www.nspower.ca/en/home/about-us/environmental-commitment/air-emissions-reporting/default.aspx

[30] Environment and Climate Change Canada, National Pollutant Release Inventory, 2014

technology choices at petroleum coke facilities result in the better emissions performance overall.[31] SO_2 and NO_x emissions rates for natural gas assume both combined cycle technology and low-NOx burners.[32]

Measured air pollution correlates with the location of coal plants. As shown in Figure 4 below, SO_2 and NO_X air pollution is worse where coal generation is highest, i.e. in Alberta and Saskatchewan.

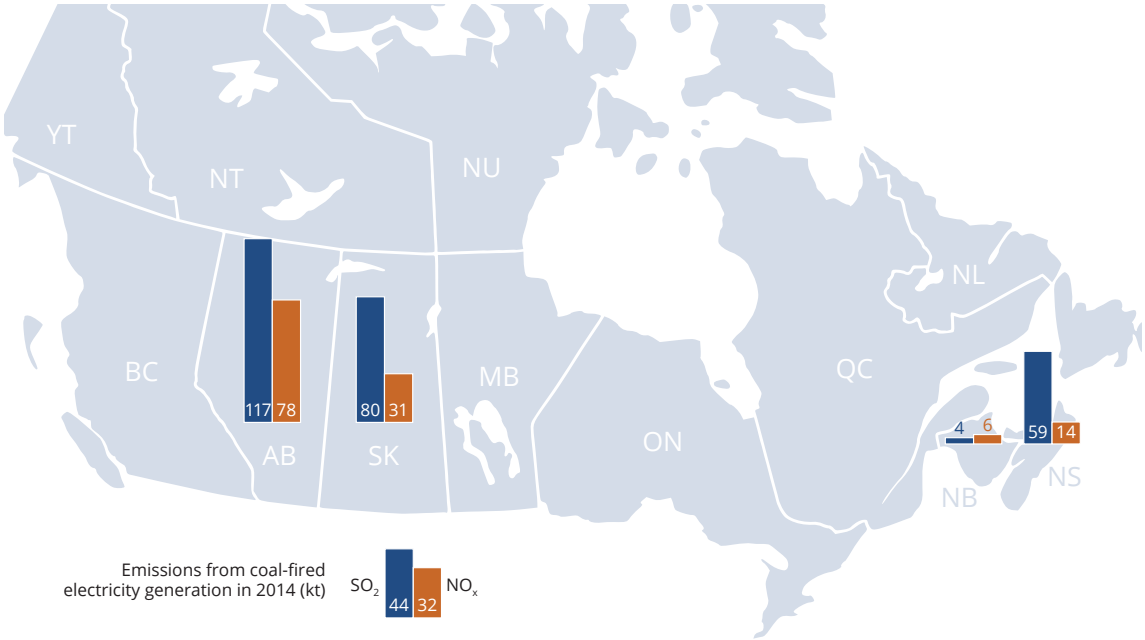

Figure 4. SO_2 and NO_x emissions from coal-fired power plants in Canada in 2014

Sources: Alberta Environment and Parks,[33] Nova Scotia Power,[34] Environment and Climate Change Canada[35]

3.2.2 A carbon-intensive form of electricity generation

In Canada, the electricity sector was responsible for 85 megatonnes (Mt) of GHG emissions in 2014 — approximately 12% of Canada's overall emissions (732 Mt). Coal-fired power represents over 72% of these electricity emissions, while only providing

[31] Nova Scotia Power indicates "Point Aconi has a 90 per cent reduction of sulphur dioxide emissions and lower nitrogen oxide emissions than typical coal boilers because of its special boiler technology." http://www.nspower.ca/en/home/about-us/how-we-make-electricity/thermal-electricity/coal-facilities.aspx

[32] Pembina Institute, *A Comparison of Combustion Technologies for Electricity Generation* (2006), 23. https://www.pembina.org/reports/Combustion_CCS_Final.pdf

[33] Alberta Environment and Parks, *Annual Reports From Generators*, 2014.

[34] Nova Scotia Power, Air Emissions Reporting, 2014. http://www.nspower.ca/en/home/about-us/environmental-commitment/air-emissions-reporting/default.aspx

[35] Environment and Climate Change Canada, National Pollutant Release Inventory, 2014

around 11% of the country's electricity.[36] Coal plants are highly concentrated in a small number of locations across the country, and half of Canada's top-10 GHG emitters are coal plants.[37] On a provincial scale, coal-fired facilities are consistently among the top GHG emitting facilities in Alberta, New Brunswick, Nova Scotia, and Saskatchewan.[38]

Burning coal for power is among the world's most carbon-intensive forms of electricity generation.[39] Despite recent progress in technology, coal-fired power emits more than double the amount of carbon pollution per unit of power generated as natural gas. Figure 5 below demonstrates that, on average, a MWh of electricity generated from coal in Canada emits 1,070 kg of CO_2e — significantly more polluting than the 'good-as-gas' standard of 420 kg per MWh established in the federal government's 2012 regulation.[40]

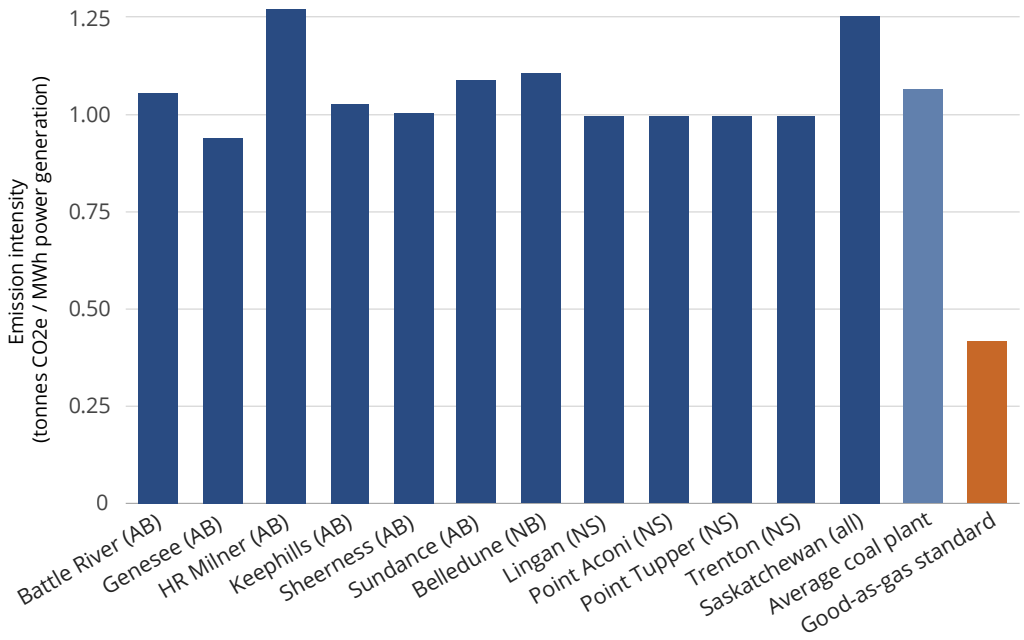

Figure 5. GHG emission intensity of coal-fired power plants in Canada in 2014

[36] Environment and Climate Change Canada, *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada*, 2016, Part 3, Table A13-1.

[37] Environment Canada, "Reported Facility Greenhouse Gas Data: Downloadable Emissions Data." http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=8044859A-1

[38] Ibid.

[39] IPCC, *IPCC Working Group III – Mitigation of Climate Change, Annex III: Technology - specific cost and performance parameters* (2014). https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_annex-iii.pdf

[40] Environment and Climate Change Canada, "Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations (SOR/2012-167)," 2012. https://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=209

Source: Environment and Climate Change Canada

Note: Data for Saskatchewan is a provincial average since no facility data is available. Also, Saskatchewan's average is slightly improved by the launch of a carbon capture and storage module on unit 3 of Boundary Dam generation station in October 2014.

With the exception of Saskatchewan, these emission intensities are provided at the facility level and therefore don't reflect the variety of technologies existing within a given plant. As an example, Alberta's Keephills power plant comprises three coal units, two of which are subcritical units built in the 1980s, while the third is a supercritical[41] unit. Supercritical units typically attain higher efficiency rates and therefore have slightly less GHG emissions per unit of power[42].

[41] A supercritical steam generator is a type of boiler that operates at supercritical pressure (i.e pressure that is above the critical pressure at which liquid water turns into steam). Therefore, liquid water immediately becomes steam, without boiling. This technology is associated with slightly less fuel use and therefore produced fewer greenhouse gas emissions.

[42] Subcritical units are units are designed to achieve thermal efficiencies up to 38%, while supercritical units typically reach efficiencies of 42% to 43%. Therefore the same amount of coal burnt in a supercritical unit generates up to 10% more power. Source: International Energy Agency, *Technology Roadmap. High-Efficiency, Low-Emissions Coal-Fired Power Generation*, 2012.

4. Estimating the health and economic impacts of coal-fired power in Canada

In 2008, the Canadian Medical Association published *No Breathing Room: National Illness Costs of Air Pollution*, a report that employed the Illness Cost of Air Pollution (ICAP) model to estimate the health impacts associated with air pollution in Canada and to further estimate the value of these impacts borne by society.[43] While this report — and the model that supports it — included the impact of pollution generated by coal-fired power facilities, it did not provide specific estimates of the health and economic impact of coal-fired power across Canada.

The health impacts stemming from coal-fired power were first estimated in 2012, when Environment Canada finalized its regulations to impose carbon dioxide limits on new and existing coal-fired generation facilities. The regulations, enacted under the federal *Canadian Environmental Protection Act, 1999,* required coal-fired power plants to meet an emissions performance standard — set to a rate equivalent to combined cycle natural gas plant — by the time they reached 50 years in age, or face closure.[44]

When developing its regulation, Environment Canada published a cost-benefit analysis, known as a Regulatory Impact Analysis Statement (RIAS).[45] This RIAS is, to date, the most complete report published detailing the health and economic impacts from coal-fired electricity generation in Canada.

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[43] Canadian Medical Association, *No Breathing Room: National Illness Costs of Air Pollution* (2008). Available at http://www.healthyenvironmentforkids.ca/sites/healthyenvironmentforkids.ca/files/No_Breathing_Room.pdf

[44] The new regulation states that, in general, a unit reaches its end-of-life when it turns 50 years of age. There are, however, exceptions: units commissioned before 1975 will reach their end-of-useful-life on December 31st, 2019 or on December 31st of the 50th year that follows their commissioning date, whichever comes first; units commissioned after 1974 but before 1986 will reach their end-of-useful-life on December 31st, 2029 or on December 31st of the 50th year that follows their commissioning date, whichever comes first; and units commissioned in or after 1986 will reach their end-of-useful-life on December 31st of the 50th year that follows their commissioning date. See: "Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulations (SOR/2012-167)."

[45] Environment Canada, Regulatory Impact Analysis Statement (RIAS), *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations* (2012). Available in Canada Gazette Part II, Vol. 146, No. 19. http://publications.gc.ca/collections/collection_2012/gazette/SP2-2-146-19.pdf

The RIAS modelled the health and economic impact of the Government of Canada's 2012 regulation on emissions for coal-fired power relative to a business-as-usual (BAU) scenario in which coal-fired power plants are not required to control GHG emissions[46] when they reach their end of life. In the BAU scenario, plants can operate an additional 25 additional years after their end-of-life under the federal regulations. The costs and benefits to the federal regulation were estimated over a 20-year time frame, from 2015-2035, using a health benefit model similar to the ICAP model.

The following section presents the original results from the federal government's RIAS. See Table 16 for more detail on our proposed national coal phase-out schedule.

4.1 Unpacking the federal health benefit approach

The health benefits modelling used in Environment Canada's RIAS for its 2012 federal coal regulations took a three-step approach:

1. It started with Environment Canada's Environment Energy and Economy Model of Canada (E3MC) to estimate electricity demand to be met by various generation technologies, including coal-fired power plants. From this, it predicts the generation and emissions from each coal-fired unit.

2. It then employed the Unified Regional Air-quality Modelling System (AURAMS) to predict how the emission changes associated with reduced coal generation would affect local ambient air quality employing three-dimensional state-of-the-art modelling.[47]

3. It used the ambient air quality outputs to estimate the incremental health and environmental benefits using the Air Quality Benefits Assessment Tool (AQBAT). AQBAT is an internationally respected computer simulation program developed by Health Canada to estimate the human health costs and/or benefits associated with changes in ambient air quality that arise from changes in air contaminant emissions.

[46] Both scenarios are modelled to meet existing federal and provincial regulations on pollutant emissions. "All known/existing provincial and federal air regulations have been incorporated into the BAU scenario of the cost-benefit analysis. Therefore, all the CAC reductions and associated health and environmental benefits presented are incremental and attributable to the Regulations." RIAS, 2083.

[47] RIAS, section 7.2.4. This AURAMS model incorporates information on the emissions changes with "information on wind speed and direction, temperatures, humidity levels, and existing pollution levels, in order to predict how these emissions changes would impact local air quality."

Figure 6 below shows the conceptual flow of this three-step model.

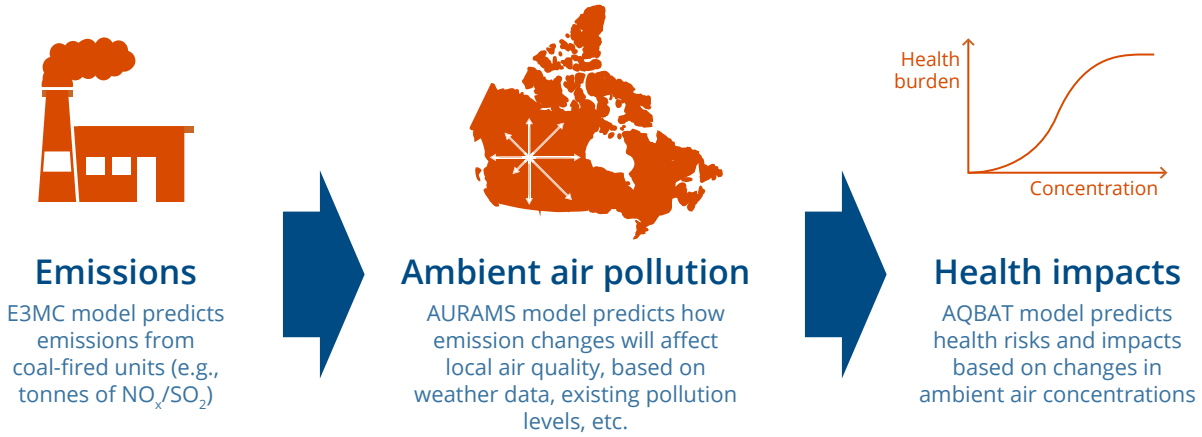

Figure 6. RIAS methodology: from emissions to health burden and cost for society

It should be noted that in the RIAS, Environment Canada states that the methodology "provides conservative estimates for health and environmental benefits" because emissions reductions will actually increase over time.[48]

4.2 Benefits secured from Canada's existing coal regulation – Results from the RIAS

4.2.1 Air pollution-related health benefits

The RIAS found that the new 50 year regulation resulted in a 298,000 GWh reduction in coal-fired electricity generation in Canada and an avoidance of 900 premature deaths and 800 emergency room visits and hospitalizations between 2015 and 2035 (Table 2 below). The breakdown of cumulative benefits per province shows that nearly 90% of the cumulative avoided health impacts between 2015 and 2035 will take place in Alberta and in Saskatchewan.

[48] RIAS, section 7.4.2.

Table 2. Cumulative avoided health impacts from air pollution for selected outcomes, 2015 – 2035

		Premature deaths	Emergency room visits and hospital-izations	Asthma episodes	Days of breathing difficulty and reduced activity	Present value of total avoided health outcomes (2015$M)[49]		
						Ozone related costs	$PM_{2.5}$ related costs	Total
Canada		900	800	120,000	2,700,000	$1,202	$3,169	$4,590
AB	*Coal-based electricity grid*	590	520	80,000	1,900,000	$743	$2,076	$2,950
SK		140	110	15,000	360,000	$175	$481	$688
NB		3	3	450	6,400	$8	$8	$14
NS		11	9	1,200	19,000	$25	$26	$54
MB	*Coal-free electricity grid*	80	68	9,000	240,000	$96	$317	$415
ON		57	49	7,000	170,000	$82	$208	$284
QC		18	18	2,700	47,000	$38	$55	$92
PEI		2	2	280	4,600	$4	$5	$10
NFLD		10	9	1,200	21,000	$21	$28	$50

Source: Environment Canada[50]

Notes: Aggregate numbers for Canada have been rounded by Environment Canada. Also, while Manitoba has one coal-fired power plant, it is assumed to be a coal-free province as its plant is for emergency service only and excluded from the RIAS analysis.

These findings highlight that those provinces adjacent to provinces that burn coal for electricity are polluted by their neighbors' use of coal, and therefore benefit when those provinces reduce coal emissions. As the previous section explains, the second step in the RIAS modelling consists of estimating how pollutant emissions move across provincial airsheds in Canada, and the third step models health impact based on population density. The methodology explains why the RIAS predicts that coal power reductions in Alberta, Saskatchewan, New Brunswick, and Nova Scotia will have

[49] The "value of (avoided) health outcomes" (or "socio-economic value") represents the cumulative value of the risks associated with different health outcomes due to air pollutants emitted by coal-fired generation. This includes the benefit of avoided medical costs, the benefit of increased worker productivity, the benefit of avoiding pain and suffering, and the social benefit of reducing the risk of premature death. The exact ratio of how much of the benefits are due to avoided medical costs, versus how much are because of worker productivity or any of the other costs, varies based on which pollutants, which health end points, and which regions of the country are under analysis.

[50] RIAS, Table 18.

significant health impacts in coal-free provinces such as Newfoundland, Prince Edward Island, Québec, Ontario, and Manitoba.

For the same reason the RIAS does not estimate any health benefits in British Columbia or the Canadian territories, recognizing that not only do these jurisdictions have no coal power generation, but that coal pollution does not contaminate their airsheds due to wind patterns.[51]

Figure 7 illustrates the modelling conducted in the RIAS at the federal level. The shaded area between the solid line (i.e., BAU) and the dotted line (i.e., the implementation of the 2012 federal coal regulations) represents the coal-generation reduction used by Environment Canada to calculate cumulative avoided health impacts (summarized at right in the diagram). As the RIAS notes, "all the CAC [Criteria Air Contaminants] reductions and associated health and environmental benefits presented are incremental and attributable to the Regulations", acknowledging the direct relationship between burning coal and health impacts.[52]

[51] RIAS section 7.4.2 reads: "The Regulations are not expected to have any noticeable incremental change in concentrations of air pollution in British Columbia, the Northwest Territories, Yukon or Nunavut."

[52] RIAS section 10.

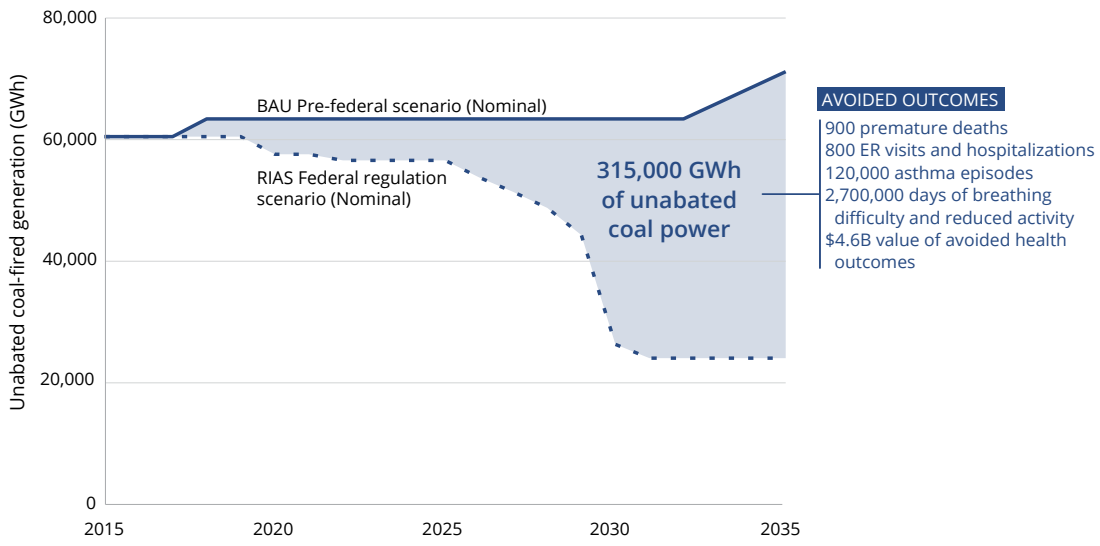

Figure 7. Health benefits associated with coal-generation reduction in Canada between 2015 and 2035

Data source: Environment Canada[53]

Note: Although the RIAS suggests cumulative reduction in coal-fired generation is 298,000 GWh between 2015 and 2035, this figure contains a significant amount of power generated using CCS technologies, that is coal power virtually associated with no GHG and pollutants emissions. The reduction in coal power generation displayed in the graphic was calculated from the reduction in GHG emissions – more details on this explained in Section 5.2.

The health benefits estimated in the RIAS are due predominantly — but not entirely — to the lower ambient levels of $PM_{2.5}$ and ozone that result from the reduced coal-fired electricity generation. These respectively account for 70% and 26% of the total present value of avoided health costs in Canada from reducing coal-fired electricity (Table 2).

4.2.2 Mercury related health benefits

The RIAS also estimates the health impacts prevented due to avoided mercury releases, which affect humans through deposition followed by bioaccumulation through the food chain. Over the 2015-2035 RIAS study timeframe, the modelled coal power reduction was estimated to result in 6,686 kg less mercury released, predominantly in Alberta, Saskatchewan, and Nova Scotia (see Table 3). Environment Canada indicates this cumulative reduction is associated with a present value of $26 million in health benefits in Canada, using a conservative estimate of the cost of health impact per kg of

[53] Health benefits data from RIAS. Numbers for electricity generation are approximated for illustration purposes as Environment Canada did not publish sufficient information about its model. Methodology is detailed in Appendix A.

mercury.[54] However, Environment Canada notes that these costs are limited to the neurodevelopmental impacts of mercury, whereas emerging scientific evidence at that time suggested that mercury may also be connected to heart disease and premature death, an impact that could potentially magnify the cost of mercury by 50 times.[55] Environment Canada chose not to include this much larger number in their analysis because of uncertainties, but noted that this clearly makes their analysis conservative. We estimate that including this would place mercury's impacts more in the range of $1,311 million, raising the total costs of coal power summarized in Table 2 by nearly a third.[56]

Table 3. Cumulative reduction in mercury emissions and associated present value

	Cumulative reduction in mercury emissions, 2015–2035 (kg)	Present value of mercury-related health impacts reductions (2015 $M)	
		Environment Canada	Current literature
Total, Canada	**-6,686**	**26**	**1,311**
SK	-2,571	10	492
AB	-3,607	14	710
NS	-524	2	109

Source: Environment Canada[57] and Pembina Institute calculations

Note: Canada's figures are rounded by Environment Canada in the RIAS data

[54] RIAS, section 7.4.2.

[55] G. Rice and J. K. Hammitt, Economic Valuation of Human Health Benefits of Controlling Mercury Emissions from U.S. Coal-Fired Power Plants (Northeast States for Coordinated Air Use Management, 2005).

[56] Ibid.

[57] RIAS, Table 19.

5. Modelling the benefits of a national phase-out by 2030

The cost-benefit analysis conducted by Environment Canada to estimate avoided health impacts from the reduction of coal-fired power is currently the most detailed analysis on this subject available in Canada. Though the RIAS provides important information on the existing regulation to limit emissions from coal-fired power, its timeline misses out on an opportunity to more quickly reduce greenhouse gas emissions and air pollution across the country. It therefore forgoes significant additional health, environment and economic benefits.

In order for Canada to reduce emissions consistent with its 2030 climate target, greater policy action is required. More specifically, Canada must work to reduce the GHG emission intensity of its grid, so that clean electricity can become the predominant fuel source for transportation, industry and the built environment.

To that end, the Pembina Institute has recommended that the federal government require a zero-emitting electricity supply by 2050, with a schedule for decreasing proportion of emitting sources of electricity between now and 2050. Further, we recommend the federal government join provincial trends and commit to an accelerated phase-out schedule for Canada's coal-fired electricity. More specifically, the government should incrementally claw-back the end-of-life of coal plants in a measured fashion down to 40 years, with no later than a 2030 end-date for unabated coal power. The schedule must account for regional electricity supply.

In order to assess the additional health, climate and economic benefits from an accelerated phase-out of coal-fired power, the Institute used the federal government's RIAS determine the avoided health impact per 1,000 GWh of unabated coal-power generation. This "benefit factor" is then extrapolated to project the national and regional health benefits gained by phasing out coal-fired power across Canada by 2030. Further, a regional approach was employed to account for health benefits associated with the reduction in pollution occurring in neighbouring non-coal provinces. To that

end, avoided health impacts from a national accelerated coal phase-out are presented regionally — as discussed in more detail below.[58]

5.1 Applying a regional approach

As previously noted, the RIAS estimates significant health benefits in provinces not or no longer equipped with coal-fired generation capacity. This is explained by the transboundary nature of air pollution released from tall stacks. The modelling conducted by Environment Canada demonstrates that coal pollution contaminates the airsheds and residents of other provinces. However, Environment Canada's analysis does not specify the level and the origin of contamination coming from another province for a given jurisdiction. This was resolved by grouping provinces in three regions, along with the following assumptions:

- **In the prairies** a reduction in coal-fired generation in Alberta and Saskatchewan benefits both provinces, as well as Manitoba.[59]
- **In central Canada,** Québec and Ontario benefit from emission reductions in both the Prairies and Atlantic Canada because of changing wind directions despite the fact that no emission reduction takes place in this region.
- **In Atlantic Canada,** reductions from Nova Scotia and New Brunswick's coal-fired power have health benefits for all Atlantic Canada provinces.

Table 4 summarizes the health impacts indicated in the RIAS aggregated at the regional level.

[58] Due to a lack of detailed data in certain provinces, such as Saskatchewan, data from multiple sources was often used. For example, Alberta provides data for individual coal units; Nova Scotia provides facility level data (i.e. covering multiple units); and Saskatchewan only provides reporting at the provincial level through the National Inventory Report.
[59] While Manitoba is equipped with one coal-fired plant, it was excluded from the analysis, as it is by law an emergency-only plant.

Table 4. Cumulative avoided air-pollution related health impact between 2015 and 2035 for selected health outcomes, aggregated at regional levels

	Canada	Prairies	Central Canada	Atlantic Canada
Premature deaths avoided	900	810	75	23
ER visits and hospitalization avoided	800	698	67	20
Asthma episodes avoided	120,000	104,000	9,700	2,680
Days of breathing difficulty and reduced activity avoided	2,700,000	2,500,000	217,000	44,600
Value of avoided health outcomes (2015 $M)	$4,590	$4,054	$376	$114

Source: Environment Canada[60] and Pembina Institute calculations

Note: Canada's figures are rounded by Environment Canada in the RIAS data

5.2 Determining coal health impact factors across Canada

While the RIAS models a 298,000 GWh coal power reduction between 2015 and 2035, this number does not accurately reflect the change in air pollution from burning coal as its regulation scenario from 2012 assumes more units are equipped with Carbon Capture and Storage (CCS) technology than are actually in operation today. In the RIAS scenario, coal-fired power plants equipped with CCS contribute to the aggregate 298,000 GWh of coal-fired generation reduction — however, the CCS-equipped units generate electricity with virtually no emissions.[61] Therefore, this RIAS scenario's aggregate reduction in coal-fired generation over this period cannot be used to accurately estimate health benefits – since a portion of the emissions reduced never would have generated air pollution to later cause health impacts.

[60] RIAS, Table 18.

[61] Existing commercial projects illustrate that CCS technology does not eliminate all air pollution from facilities at which it is employed, though these emissions are an order of magnitude lower than non-CCS projects. As an example, Boundary Dam 3, the only commercial CCS project operating in Canada, claims it only captures up to 90% of GHG emissions of the coal-fired unit. For more information, see: http://www.saskpower.com/our-power-future/innovating-today-to-power-tomorrow/capturing-carbon-and-the-worlds-attention/. CCS was assumed to operate ideally for the purposes of this report's calculations to ensure analysis was conservative.

To rectify this, unabated coal-fired generation was back-calculated using the reduction in carbon pollution from coal power estimated from the RIAS combined with a provincial emission factor based on historical emissions.[62]

Table 5 shows the estimated unabated coal-fired generation in each of the regions between 2015 and 2035 — i.e., coal-fired generation without installed CCS allowed under the federal regulation over this time period.

Table 5. Cumulative reduction in GHG emissions and in generation from unabated coal power between 2015 and 2035

	Cumulative GHG emissions reduction (Mt CO_2e)	Estimated unabated coal-fired generation reduction (GWh)
Canada	**325**	315,434
Prairies	307	296,495
Atlantic Canada	18	18,939
Central Canada	0	0

Source: Environment Canada[63] and Pembina Institute calculations (see Appendix A for methodology notes)

Interpolating avoided health impacts (Table 4) per 1,000 GWh of unabated coal power (Table 5) generates incremental health factors for each unit of coal-fired generation on a regional basis. These regional impact factors show that, on average, a unit of coal-fired generation does not impact Canadians' health the same way in every region (Table 6). Burning coal in the Prairies has more than twice the impact of coal power in Atlantic Canada, while the combined impact of pollution from neighbouring coal provinces has a limited, yet tangible, impact in central Canada.

[62] Emission factors are calculated as the average of the GHG emission intensity of coal power for a given province between 2012 and 2014, based on Environment and Climate Change Canada data (see Appendix A.1.2 for methodology).

[63] RIAS, Table 18.

Table 6. Avoided air pollution-related health impacts per 1,000 GWh of coal-fired generation per region

	Prairies	Central Canada	Atlantic Canada
Premature deaths avoided	2.7	0.2	1.2
ER visits and hospitalization	2.4	0.2	1.1
Asthma episodes	351	31	142
Days of breathing difficulty and reduced activity	8,432	688	2,355
Value of avoided health outcomes (2015 $M)	$13.7	$1.2	$6.0

Note: Health impact factors for Central Canada are calculated from coal-fired generation reduction from both Prairies and Atlantic Canada.

When extrapolated to the amount of electricity generated in each of the regions, these health impact factors estimate that, in 2014, coal power contributed to 163 premature deaths and overall health outcomes valued at approximately $816 million in Canada (Figure 8).

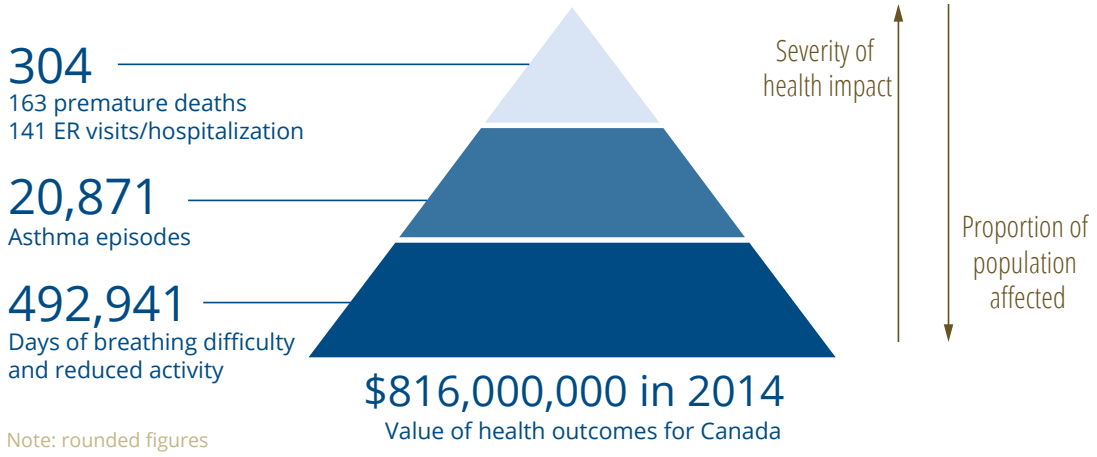

Figure 8. Impact on Canadians' health from coal-fired electricity in 2014

These health impacts can be broken down into regional impacts, as summarized in Table 7. Unsurprisingly, the Prairies bear most of the health impacts, reflecting the region's heavy reliance on coal. The high population of Québec and Ontario (nearly 62% of Canada's population[64]) means that even with the low impact factor for the region (Table 6) there is still a fairly large absolute impact on health in these two provinces as a large number of people are exposed to the pollution from coal plants in other provinces.

[64] Statistic Canada Census 2011.

Table 7. Coal-fired generation and air pollution-related health impacts in Canada in 2014

	Canada	Prairies	Central Canada	Atlantic Canada
Coal-fired generation in 2014 (1,000 GWh)	57.8	52.2	0	5.6
Premature deaths avoided	163	143	14	7
ER visits and hospitalization	141	123	12	6
Asthma episodes	20,871	18,310	1,776	785
Days of breathing difficulty and reduced activity	492,941	440,143	39,729	13,070
Value of avoided health outcomes (2015 $M)	$816	$714	$69	$33

6. A triple win: health, climate and diplomatic benefits

When the federal government weakened its proposed coal regulations back in 2012 in response to lobbying from some coal generators, it allowed coal plants to continue unabated longer than first proposed,[65] and left climate and health benefits on the table. With the upcoming pan-Canadian climate plan, and continued reductions in the cost of alternative generating technologies, Canada has an opportunity to grasp additional health and climate benefits across the country by accelerating the transition away from coal-fired electricity. A national commitment to phase-out coal fired-power would be in line with leading provincial and international trends.

Having interpolated regional health impact factors per 1,000 GWh of coal generation from Environment Canada's own analysis of its coal-fired GHG regulations, this analysis now extrapolates these factors to produce an estimate of the benefits of an accelerated coal phase-out by 2030 in Canada.[66]

To outline phase-out benefits, we updated the two scenarios modelled in the RIAS to better align with the actual state of coal-fired generation in Canada in 2016 (See Appendix A.2.1 for more details around scenario modelling methodology). The updated 2012 federal regulation scenario becomes the baseline against which the benefits to a 2030 national coal phase-out are determined. These two scenarios are referred to as 'updated' (as opposed to 'nominal') in the rest of this report. Figure 9 shows the updated RIAS scenarios.

[65] Mike De Souza, "Feds pressured by coal industry to weaken regulations, records reveal," *Postmedia News*, April 22, 2012.

[66] Detailed methodology of the modelling can be found in Appendix A.

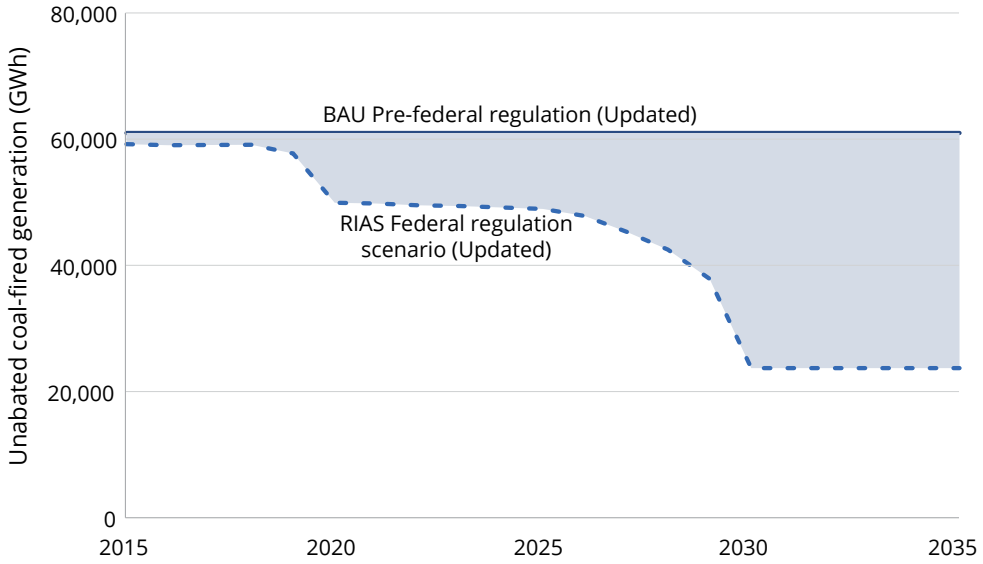

Figure 9. Updated RIAS scenarios used for comparison

Note: Reduction in unabated coal power generation is higher between the updated scenarios as opposed to between the nominal scenarios from the RIAS (Figure 7), which translates into greater benefits (captured in Figure 10). The larger difference in unabated generation results from the combination of reduction in coal-fired generation using CCS (current state of the industry cannot confirm the level of adoption that is assumed in the RIAS) and significantly lower coal power generation in the updated federal regulation scenario in Nova Scotia due to the implementation of the Equivalency Agreement. Details about the modelling are available in Appendix A.

6.1 Health impacts of an accelerated phase-out of coal-fired power

To determine the additional health savings of an accelerated phase-out of coal fired generation we extrapolate from the Environment Canada RIAS by applying the per-1,000-GWh health impact factors to the avoided coal-fired generation were the regulations to require a national accelerated phase-out by 2030. From this we estimate the incremental health savings associated with the phase-out by 2030. The methodology and assumptions in this analysis are listed in Appendix A.

Figure 10 below illustrates the accelerated decrease in coal emissions and lists the health and economic benefits — including avoided premature deaths, ER visits, hospital admissions and other costs to the health care system — to an accelerated phase-out of coal-fired power in Canada. The health benefits from reductions in air pollution alone would double if the Canadian government capped the life of plants at forty years, and did not allow any to operate beyond 2030 without achieving a 'good-as-gas' emissions performance requirement. Indeed, the improvements in air quality that would results

from a national coal phase-out by 2030 would avoid an additional 1,008 premature deaths, 871 ER visits, and produce additional health benefits valued at nearly $5 billion (including health costs and reduced losses in productivity) between 2015 and 2035.

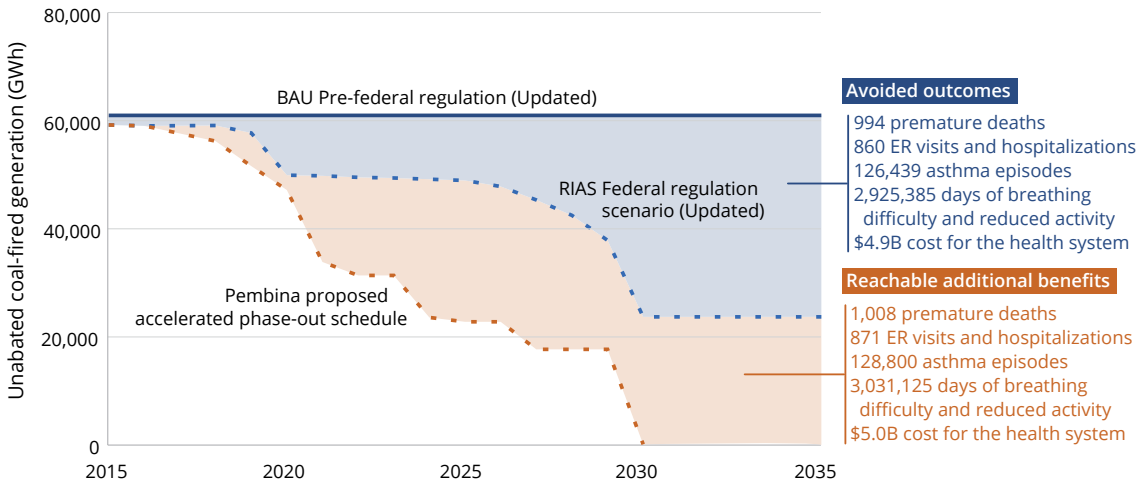

Figure 10. Health and economic benefits associated with air quality improvements from a Canada-wide coal-phase out by 2030

Note: Detailed methodology pertaining to the modelling of each of the scenarios can be found in Appendix A.

Below, Table 8 breaks down the additional benefits of a national coal phase-out by 2030 per region. Unsurprisingly, the greatest share of the benefits can be found in the prairies, where most of Canada's coal power generation lies. However, there remains substantial value to an accelerated national phase-out across central and Atlantic Canada.

Table 8. Additional cumulative air pollution related health impacts avoided with a Canada-wide coal phase-out by 2030

	Canada	Prairies	Central Canada	Atlantic Canada
Premature deaths avoided	1,008	868	86	54
ER visits and hospitalization	871	748	77	47
Asthma episodes	128,800	111,387	11,130	6,282
Days of breathing difficulty and reduced activity	3,031,125	2,677,573	249,001	104,551
Value of avoided health outcomes (2015 $M)	5,040	4,342	431	266

6.2 Climate impacts of an accelerated phase-out of coal-fired power

The schedule the Pembina Institute proposes to retire coal-fired plants would also come with significant GHG emissions reductions that would contribute to Canada's 2030 emissions reduction targets. Indeed, should all of Canada's coal-dependant provinces replace their coal generation with two-thirds renewable energy and one-third natural gas (as proposed in Alberta), carbon pollution from Canada's electricity sector would decrease from 85 Mt in 2014 to 34 Mt in 2030 — a decline of 51 Mt in just over 15 years.

Figure 11 below illustrates how the Pembina Institute's proposed phase-out schedule will reduce emissions in the electricity sector between 2015 and 2035. The current regulatory pathway estimates the GHG emissions from the electricity sector with implementation of the 2012 federal emissions rules for coal-fired power. This scenario is based on the updated RIAS federal regulation scenario, which assumes all phased-out coal power is replaced with new, best-in-class natural gas generation. As mentioned above, the accelerated phase-out pathway assumes all of Canada's coal-fired power generation is replaced by two-thirds renewable energy and one-third natural gas-fired electricity. However, if national and sub-national policy support were in place to facilitate even greater rates of renewable energy deployment, even greater climate benefits could be obtained.

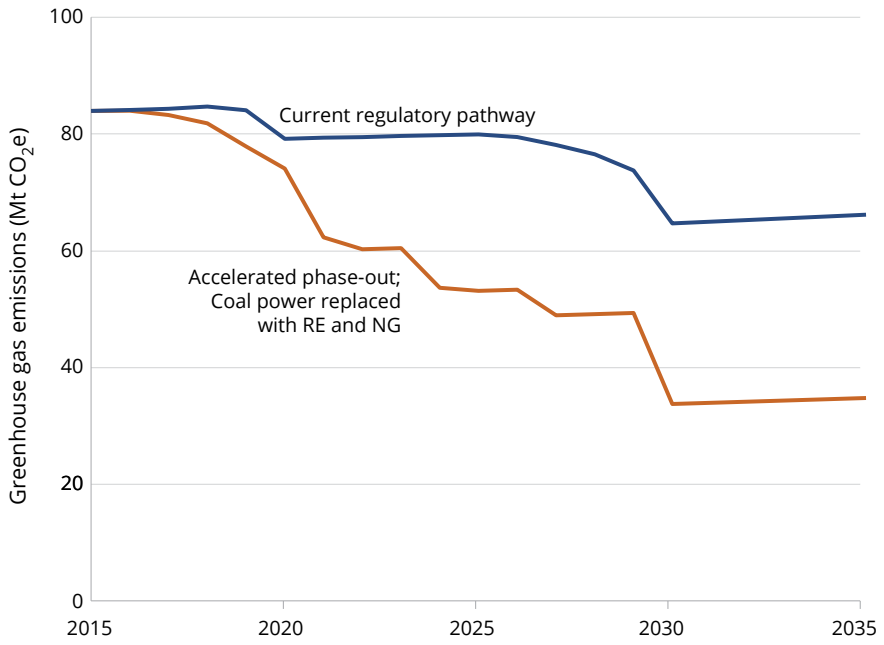

Figure 11. Greenhouse gas reductions in the electricity sector for an accelerated phase-out of coal-fired power to 2030

Both scenarios assume a yearly 0.6% growth in electricity generation between 2015 and 2035, as employed by the National Energy Board in its *Energy Futures* publication.[67] We assume this growth in generation is equally distributed among all existing electricity generation technologies. Further, we assume the existing fossil fuel generation fleet keeps operating at 2014 GHG emissions intensity, without units being retired or refurbished over the period.[68] Both the business-as-usual and the accelerated phase-out scenario assume new gas-fired generation built to replace coal power is best-in-class technology.

Under these conditions, we find that Canada's electricity system would emit 34 Mt of emissions in 2030 — 31 Mt lower than under current regulatory pathway and approximately 73% below 2005 levels from the sector (124 Mt). Cumulatively, an accelerated phase-out to 2030 would avoid 418 Mt of greenhouse gas emissions between today and 2035.

[67] National Energy Board, *Canada's Energy Future 2016: Update - Energy Supply and Demand Projections to 2040*, (2016). http://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016updt/index-eng.html

[68] In 2014, Canada's gas-fired fleet generated electricity at a rate of 605 kg of CO_2e per MWh, an intensity significantly higher than the U.S. performance standard of 350 kg of CO_2e per MWh for natural gas combined cycle plants. U.S. EPA, *Clean Power Plan – Technical Summary for States*. https://www3.epa.gov/airquality/cpptoolbox/technical-summary-for-states.pdf

6.2.1 Supporting Canada's long-term climate ambitions

Canada is in a unique moment in the development of its climate and energy policies. For the first time ever, national and sub-national governments have come together to design a pan-Canadian plan to meet or exceed the country's 2030 emissions target. Further, at COP22 in Marrakech, Morocco, the federal government released a long-term low greenhouse gas strategy for Canada – effectively launching a new, iterative process in Canada to achieve deep emissions reductions economy-wide by 2050.

Taken together, the pan-Canadian climate plan and the mid-century strategy will be two helpful tools to centre policymaking and planning on the objective of decarbonizing Canada's economy. However, with its long history of target-setting and unfortunately matched history of climate inaction, it is essential now that federal, provincial, and territorial governments implement ambitious new climate policies that will allow the country to get back on track for these ambitious climate commitments.

In order to achieve the climate change goals outlined in the Paris Agreement, experts at the Deep Decarbonization Pathway Project have articulated "three pillars" for decarbonization: maximizing the energy efficiency in buildings, transportation and industry; minimizing the GHG emission intensity of electricity produced; and switching from fossil fuels to clean electricity for energy end-use.[69] When taken together, these three pillars would allow countries around the world to cut their carbon pollution and begin to transform domestic and local economies to reap the long-term benefits of the low-carbon economy. However, in order for the process of electrification to result in maximum emissions reductions benefits for Canada, its electricity should be derived from an increasing supply or low or zero-carbon sources. Because of this, an accelerated phase-out of coal-fired power by 2030 is a critical piece of the Canada's climate action puzzle.

6.3 International impetus to act: knock-on benefits to a national coal-phase out in Canada

While coal-fired electricity continued to grow in Canada until recently, many OECD jurisdictions have been actively moving away from coal for the last a decade. A critical driver for the international trend is the imperative to restrain climate change with the

[69] Sustainable Development Solutions Network and Institute for Sustainable Development and International Relations, *Pathways To Deep Decarbonization: 2014 Report*. http://unsdsn.org/wp-content/uploads/2014/09/DDPP_Digit.pdf

internationally agreed-to commitment of 2ºC and target of 1.5ºC. Given that coal-fired electricity is one of the world's most carbon-intensive electricity sources, it is an obvious target for immediate phase-out in order to achieve the commitments outlined in the Paris Agreement.

In the U.S. context, the Clean Power Plan and stringent pollution control requirements, combined with the ailing economics of coal-fired power relative to alternatives, is resulting in accelerated coal plant retirements. And, even in the event of changes to those requirements under a new administration, this trend is likely to continue due to state level action.

Looking more broadly to global trends, a number of jurisdictions announced their intention to phase out coal-fired power in the coming years prior to the Paris climate talks in December 2015. Those commitments were New York by 2020; the U.K., the Netherlands, Denmark, and Austria by 2025; Oregon and Alberta by 2030. These commitments have triggered coal phase-out conversations in a number of other jurisdictions, including Italy and Germany. More recently, France announced during COP22 in Marrakech its intention to phase out coal electricity by 2023.

Canada is well placed to lead these international trends. Ontario completed a coal phase-out in 2014, realizing both health and climate benefits in doing so. More recently, Alberta has committed to phase out pollution from coal-fired power and to secure 5,000 MW of new clean electricity. Were Canada to announce a national commitment to phase out its coal-fired power by 2030, the country would be on track to demonstrate important global leadership on this foundational element of climate action.

7. Conclusion

As the world ratifies the Paris Agreement and works to reconcile existing climate plans with the long-term need to decouple greenhouse gas emissions from economic growth, the pace of coal plant closures has begun to define climate leadership. In order for countries like Canada to live up to ambition of the Paris Agreement, they must work to reduce their reliance on fossil fuels, and power their economies through clean energy. Because of this, an accelerated phase-out of coal-fired power is a critical piece of Canada's climate action puzzle. Limiting the role of coal-fired power and promoting clean alternatives on Canada's grid will ensure the process of electrification results in maximum emissions reductions for the country, and would support the country's long-term climate ambitions.

But equally, a national commitment to phase-out coal no later than 2030 will secure other benefits for Canadians. A national phase-out of coal-fired power by 2030 would avoid 1,008 premature deaths, 871 emergency room visits, and save nearly $5 billion in health outcomes (including health costs) between 2015 and 2035. These health benefits should be consider as a bottom-line that would be surpassed should Canada implement an even earlier phase-out.

Policy action to reduce reliance on coal-fired power in the near term secures important health and climate benefits, sends clear investment signals for replacement generation, and establishes a foundational building block for long-term climate action.

To implement this commitment, the federal government should incrementally claw-back the end-of-life of coal plants in a measured fashion down to 40 years, with no later than a 2030 end-date for unabated coal power. The accelerated phase-out is simply a strengthening of the existing Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations issued under the *Canadian Environmental Protection Act* (CEPA). Importantly, the CEPA regime allows for equivalency agreements with provinces that can meet the same GHG reductions through other policy approaches – meaning that a federal commitment of this nature would stay true to the principle of flexibility outlined in the Vancouver Declaration. This can allow for greater flexibility in jurisdictions that have unique circumstances, such as Nova Scotia with its relatively small system, heavy extant reliance on coal power and absence of existing natural gas infrastructure.

With the development of the pan-Canadian climate plan, the prime minister and premiers have an opportunity to lock-in important policy that will reduce carbon pollution, and provide health and economic co-benefits to Canadians. No public policy better exemplifies this “win-win” for the climate and for the health of Canadians more than an accelerated phase-out of coal-fired power. We urge federal and provincial policymakers to match leading provincial and international trends and commit to an accelerated coal-phase out by 2030 so the country can reap these important health and environmental benefits.

Appendix A. Methodology

Calculations throughout this report are based on the Government of Canada's Regulatory Impact Analysis Statement (RIAS) for its 2012 regulation, Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations.[70]

In this analysis, Environment Canada associates specific health and economic benefits across Canada with a given change in coal generation between 2015 and 2035. Our analysis builds on this correlation between reduction in coal generation and health benefits, a principle that is clearly stated in the RIAS by Environment Canada: "all the CAC reductions and associated health and environmental benefits presented are incremental and attributable to the Regulations."[71]

The coal generation reduction comes from modelling two scenarios, business-as-usual and the new regulations. For details on these scenarios see section A.2.

Due to the limitations of the available data, the capacity factors of individual coal fired generation units are unclear. For this reason, as well as the fact that all units differ in their emissions intensities and their impacts on population (due to proximity to population densities), this analysis made the simplification of treating every GWh of coal power, no matter where it comes from, the same. Section A.3 articulates additional caveats relative to the methodology as well as some of the drivers that make our analysis conservative despite this assumption.

A.1 General modelling interpolation and extrapolation approach

A.1.1 Regional approach

The RIAS indicates that reducing coal power generation in coal-equipped provinces also generates health benefits in provinces not, or no longer, equipped with coal-fired

[70] Environment Canada, Regulatory Impact Analysis Statement (RIAS), *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations* (2012). Available in Canada Gazette Part II, Vol. 146, No. 19. http://publications.gc.ca/collections/collection_2012/gazette/SP2-2-146-19.pdf
[71] RIAS, 2083.

generation. These health benefits are because Environment Canada's modelling includes the impact of coal pollution contaminating other provinces' airsheds.

However, the analysis published by Environment Canada does not specify the level or the origin of the pollution coming from other provinces for a given jurisdiction. This was resolved by grouping provinces into three regions, along with the following assumptions:

- **In the prairies** a reduction in coal-fired generation in Alberta and Saskatchewan benefit those two provinces, as well as Manitoba.[72]
- **In Atlantic Canada** reductions from Nova Scotia and New Brunswick's coal-fired power have health impacts on all Atlantic Canada provinces.
- **In central Canada,** Québec and Ontario benefit from reductions in both the Prairies and Atlantic Canada, despite no new emission reductions taking place in this region.

A.1.2 Unabated coal-fired generation

Given that the health impacts result from a reduction of the emissions associated with coal-fired generation — and not from coal-fired generation itself — one important step was to estimate the actual reduction in unabated coal-fired generation. Unabated generation refers to coal power generated without CCS. To be conservative, implementation of CCS was assumed to completely remove all GHG and pollution emissions.

For each of the provinces, cumulative GHG emissions reduction from coal power was calculated by removing the deemed emissions from natural gas units[73] from the overall GHG emissions reduction indicated in the RIAS.[74] Unabated coal power generation was then estimated from the GHG emissions reductions, using an average GHG emissions factor for coal electricity. These average GHG emissions factors were calculated from government data for the years 2012 to 2014 and align with industry standards (Table 9).

[72] While Manitoba is equipped with one coal-fired plant, it was excluded from the analysis, as it is by law an emergency only plant.

[73] RIAS, Table 10. An emission factor of 420 kg of CO_2e per MWh was used to estimate GHG from gas-fired generation. This factor corresponds to the 'good-as-gas' performance indicated in the 2012 federal regulation and is quite conservative for future natural gas generation. Jurisdictions such as the U.S. assume performance of 350 kg of CO_2e per MWh for new natural gas combined cycle plants. Source: U.S. EPA, *Clean Power Plan – Technical Summary for States*. https://www3.epa.gov/airquality/cpptoolbox/technical-summary-for-states.pdf

[74] RIAS, Table 15.

Table 9. Average GHG emissions factors used to calculate unabated coal-fired generation

	Average GHG emissions factors between 2012 and 2014 (t CO_2e per MWh)
Alberta	1.02
Saskatchewan	1.14
New Brunswick	1.19
Nova Scotia	0.95

Sources: Environment and Climate Change Canada[75]

Cumulative unabated coal-fired generation was calculated to be 315,434 GWh between 2015 and 2035, a slight increase from the 298,000 GWh indicated in the RIAS as the difference between the two modelled scenarios.[76]

A.1.3 Health and economic impact per unit of unabated generation

Health and economic impacts from coal-burning per 1,000 GWh of generation were determined by dividing the impacts listed in the RIAS[77] by the difference in generation between the two scenarios, the business-as-usual and the regulatory change for each of the regions.

This approach assumes linearity between the incremental change in air contaminant release and the incremental change in health impact.

A.1.4 Additional health benefits associated with a national coal phase out

An accelerated phase-out of coal units between 2015 and 2030 will have an impact on the health of Canadians and the country's economy. This impact was calculated by combining the reduction in coal-fired generation from the accelerated phase-out with the calculated impact factors.

[75] Environment and Climate Change Canada, *National Inventory Report 1990-2014: Greenhouse Gas Sources and Sinks in Canada*, 2016; and Environment and Climate Change Canada, Greenhouse Gas Emissions Reporting Program, 2016

[76] RIAS, Table 10.

[77] RIAS, Table 18.

The reduction in coal-fired generation is calculated by using the Pembina Institute's proposed phase-out schedule, and comparing that against a revised version of the RIAS scenarios. The revised RIAS takes into account the most recent developments in unit closures, restarts and new development.

A.1.5 Inflation of avoided health costs

Values of avoided health outcomes are estimated by Environment Canada in the RIAS in 2010$. They were converted into 2015$ using the Bank of Canada's inflation calculator.[78]

A.2 Scenarios and generation differentials

A.2.1 Modelled scenarios

Five scenarios were modelled for our analysis, with different retirement years for each of the coal-fired units:

Business-as-usual Pre-federal regulation (Nominal): This scenario is the business-as-usual (BAU) scenario outlined in the RIAS. The document specifically expects six units to be built in Alberta and one unit to be rebuilt in Saskatchewan, some of these being equipped with CCS technology.[79] The RIAS also indicates that "for other units, it is assumed they do not automatically retire at the end of their useful life, but instead are refurbished [...] and continue generating electricity as the lowest cost option for another 25 years."[80] While we indicate a retirement year for each coal unit under this scenario, no modelling was conducted in this analysis so that all numbers cited for this scenario come from the RIAS.

RIAS Federal regulation scenario (Nominal): The RIAS mentions that "under the regulatory scenario modelled, coal units retire (close) at the end of their useful life or continue operating if they employ CCS."[81] It also indicates a year for each of the units retiring under this scenario.[82] It is assumed that all non-CCS coal units envisaged in the

[78] Bank of Canada, Inflation Calculator. http://www.bankofcanada.ca/rates/related/inflation-calculator/

[79] RIAS, section 7.1.5.

[80] RIAS, section 7.1.5.

[81] Ibid., section 7.1.6.

[82] Ibid., Table 6.

BAU are excluded in this scenario as the RIAS states that "the Regulations prevent some planned coal units from being built."[83] While we indicate a retirement year for each coal unit under this scenario, no modelling was conducted in this analysis so that all numbers cited for this scenario come from the RIAS.

Business-as-usual Pre-federal regulation (Updated): This scenario is a modified, more realistic version of the nominal pre-federal regulation scenario as envisaged in the RIAS. Details about the changes are indicated in section A.2.3.

RIAS Federal regulation scenario (Updated): Similarly, this scenario is a modified, more realistic version of the nominal post-federal regulation scenario as envisaged in the RIAS, from the vantage of 2015. It was necessary to produce this scenario to reflect the reality of the BAU as seen from 2016, to assess the implications of the national phase-out policy options. Details about the changes are indicated in section A.2.3.

Pembina Institute proposed national coal-phase out schedule: In this scenario, most units are retired after 40 years of service or at the end of 2029, whichever comes first. This scenario uses the retirement schedule proposed by the Pembina Institute in its submission to the federal government's online consultation for the Pan-Canadian Framework on Clean Growth and Climate Change[84], with minor changes to adjust the schedule to the latest developments of the coal industry.[85]

A.2.2 Definitions and modelling principles

Retirement years. Power plants are assumed to retire on December 31 of the indicated retirement year. The RIAS, however, specifically notes that 'Coal-fired units do not operate in the retirement year.' This explains why years in this table differ from the source.

Commission years. Similarly, power plant units are assumed to start production on January 1 of the commission year indicated in the table.

Capacity factors. While RIAS mentions their model uses variable capacity factors to balance generation and demand, a capacity factor of 75% was uniformly used in our

[83] Ibid., section 7.3.6.

[84] Pembina Institute, *Building a Pan-Canadian Climate Plan: Policy options to meet or exceed Canada's 2030 emissions target* (2016). https://www.pembina.org/pub/building-a-pan-canadian-climate-plan

[85] Pembina Institute, *Early coal phase-out does not require compensation* (2015), 4. https://www.pembina.org/pub/early-coal-phase-out-does-not-require-compensation

model to estimate electricity generation from all units between 2015 and 2035 for all scenarios and all provinces – with the exception of Nova Scotia, which has a specific treatment due to the Equivalency Agreement (see details in section A.2.3.5). This is the capacity factor referenced for coal in 2012 in the RIAS.[86] On the one hand, this capacity factor is conservative as capacity factors could increase over time, as coal generators often expect to operate at higher capacity factors than the low levels seen in recent years, especially in Alberta and Nova Scotia. As such, the total amount of coal generation assumed by the units is low across all scenarios, making the difference in energy between scenarios conservative. On the other hand, shutting down units could lead to higher utilization of remaining units, which would lessen the coal energy differential between scenarios.

Treatment of units equipped with CCS technology. Saskatchewan is the only province that has moved forward with CCS technology and has a plan to convert more plants in the coming years. While there are still GHG and pollution emissions associated with CCS, these are drastically lower than those coming from an unequipped unit, therefore all units equipped with CCS are removed from our analysis.

A.2.3 Assumed retirement schedules for the five scenarios in each of the provinces

A.2.3.1 Alberta

The present analysis builds on the modelling conducted for Alberta in the report *Breathing in the Benefits* (2016) and includes marginal updates in the assumptions. Table 10 outlines the retirement years of Alberta's coal-fired units under each of the scenarios considered in this report.

Table 10. Alberta's coal-fired unit details and assumed retirement year under five scenarios

Coal-fired unit	Capacity (MW)	Commissioned year	Retirement year under following scenarios					CEPA economic life	New economic life
			BAU Pre-federal regulation (Nominal)	RIAS Federal regulation scenario (Nominal)	BAU Pre-federal regulation (Updated)	RIAS Federal regulation scenario (Updated)	Pembina proposed accelerated phase-out schedule		
Battle River 3	149	1969	2044	2019	2044	2019	2017	50	48

[86] RIAS, Table 1.

Sundance 1	288	1970	2011	2011	2044	2019	2018	49	48
Milner 1	144	1972	2044	2019	2044	2019	2016	47	44
Sundance 2	288	1973	2011	2011	2044	2019	2018	46	45
Battle River 4	155	1975	2050	2025	2050	2025	2017	50	42
Sundance 3	368	1976	2051	2026	2051	2026	2020	50	44
Sundance 4	406	1977	2052	2027	2052	2027	2020	50	43
Sundance 5	406	1978	2053	2028	2053	2028	2020	50	42
Sundance 6	401	1980	2054	2029	2054	2029	2020	49	40
Battle River 5	385	1981	2054	2029	2054	2029	2021	48	40
Keephills 1	395	1983	2054	2029	2054	2029	2023	46	40
Keephills 2	395	1983	2054	2029	2054	2029	2023	46	40
Sheerness 1	400	1986	2061	2036	2061	2036	2026	50	40
Genesee 2	400	1989	2064	2039	2064	2039	2029	50	40
Sheerness 2	390	1990	2065	2040	2065	2040	2026	50	36
Genesee 1	400	1994	2069	2044	2069	2044	2029	50	35
Genesee 3	466	2005	2080	2055	2080	2055	2029	50	24
Keephills 3	463	2011	2086	2061	2086	2061	2029	50	18
Swan Hills	319	2015	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Milner 2	450	2018	2068	N/A	N/A	N/A	N/A	N/A	N/A
Endogenous Advanced Coal 1	400	2033	2083	N/A	N/A	N/A	N/A	N/A	N/A
Endogenous Advanced Coal 2	400	2034	2084	N/A	N/A	N/A	N/A	N/A	N/A
Endogenous Advanced Coal 3	400	2035	2085	N/A	N/A	N/A	N/A	N/A	N/A

Notes

BAU Pre-federal regulation (Nominal). The RIAS specifically expects six units to be built under this scenario: Keephills 3 (2011), Milner 2 (2018), Swan Hills (equipped with CCS technology – 2015) as well as three Endogenous Advanced Coal units (2033, 2034, and 2035).[87] Sundance 1 and 2 were deemed as permanently shut down at the time the assessment was conducted and therefore not included in this scenario.

RIAS Federal regulation scenario (Nominal). In this scenario, Swan Hills is the only unit that comes online, however it is excluded from our analysis as it operates with CCS

[87] RIAS, section 7.1.5.

technology. Sundance 1 and 2 were deemed as permanently shut down at the time the assessment was conducted and therefore not included in this scenario.

BAU Pre-federal regulation (Updated). In this scenario, Sundance 1 and 2 are back online[88] and keep operating until 25 years after the end of their economic life. Also, other than Keephills 3, which was commissioned in 2011, all new units planned in the original BAU are excluded in this scenario.

RIAS Federal regulation scenario (Updated). In this scenario, Sundance 1 and 2 are back online[89] and operate, similarly to other coal-fired units, until the end of their economic life.

Pembina Institute proposed accelerated phase-out schedule. In this scenario, most units are retired after 40 years of service or at the end of 2029, whichever comes first. Milner 1, a unit that was temporary closed at the beginning of 2016 and resumed operations in the summer, is scheduled to permanently retire at the end of 2016.[90]

A.2.3.2 Saskatchewan

Table 11 outlines the retirement years of Saskatchewan's coal-fired units under each of the scenarios considered in this report.

Table 11. Saskatchewan's coal-fired unit details and assumed retirement year under five scenarios

Coal-fired unit	Capacity (MW)	Commissioned year	Retirement year under following scenarios					CEPA economic life	New economic life
			BAU Pre-federal regulation (Nominal)	RIAS Federal regulation scenario (Nominal)	BAU Pre-federal regulation (Updated)	RIAS Federal regulation scenario (Updated)	Pembina proposed accelerated phase-out schedule		
Boundary Dam 3	160	2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Boundary Dam 4	139	1970	2044	2025	2044	2019	2019	49	49
Boundary Dam 5	139	1973	2044	2025	2044	2019	2019	46	46
Boundary Dam 6	284	1978	2053	2028	2053	2028	2019	50	41

[88] Both units were returned to production in December 2013.

[89] Both units were returned to production in December 2013.

[90] Milner 1's current power contract ends on December 31, 2016 and current electricity markets make it likely the unit will stop operations after this date. Source: http://www.marketwired.com/press-release/maxim-power-corp-announces-2016-second-quarter-financial-and-operating-results-tsx-mxg-2149806.htm

Poplar River 1	291	1983	2054	2029	2054	2029	2023	46	40
Poplar River 2	291	1980	2054	2029	2054	2029	2020	49	40
Shand 1	276	1992	2067	2042	2067	2042	2029	50	37

Notes

BAU Pre-federal regulation (Nominal). Boundary Dam 3 was equipped with CCS technology in 2014 and is therefore excluded from the analysis.

RIAS Federal regulation scenario (Nominal). Boundary Dam 3, 4, 5, and 6 are equipped with CCS technology in 2014, 2025, 2025, and 2028 respectively and therefore are excluded from the analysis at these dates as they continue to operate abated. Boundary Dam 4 and 5 will reach their end-of-life under the new federal regulations before 2025, and are allowed to keep operating until 2025 under the CCS deferral flexibility. This measure allows new and existing coal-fired units to be equipped with CCS technology to apply for a temporary deferral until 2025 before they have to meet the performance standard.[91]

BAU Pre-federal regulation (Updated). In this scenario, Boundary Dam 3 only operates with CCS technology. The poor economics of CCS combined with the operating experience from Boundary Dam 3 make it unlikely that Boundary Dam 4, 5, and 6 would be equipped with CCS technology in the near future. As a consequence, in this scenario, these three units keep operating unabated past 2035.

RIAS Federal regulation scenario (Updated). This scenario also assumes Boundary Dam 4, 5, and 6 are not equipped with CCS technology, and therefore retire at the end of their useful life following the federal regulation.

Pembina proposed accelerated phase-out schedule. In this scenario, other than unit 3, Boundary Dam units are shut down in 2019. Poplar River's two units are shut down after 40 years of useful life. Shand, Saskatchewan's newest plant, is retired in 2029 after 37 years of operation.

[91] RIAS, 2005: "New and old units will be able to apply for a temporary deferral until January 1, 2025, from the application of the performance standard if they incorporate technology for CCS. Units that are granted this deferral must meet a number of regulated implementation/construction milestones and submit implementation reports on progress made with respect to these milestones".

A.2.3.3 Manitoba

As stated in the *Manitoba Climate Change and Emissions Reductions Act,* Manitoba's only coal-fired power plant is used as an emergency plant.[92] For this reason the plant was excluded from the RIAS and therefore from our analysis.

A.2.3.4 New Brunswick

Table 12 outlines the retirement years of New Brunswick's coal-fired units under each of the scenarios considered in this report.

Table 12. New Brunswick's coal-fired unit details and assumed retirement year under five scenarios

Coal-fired unit	Capacity (MW)	Commissioned year	Retirement year under following scenarios					CEPA economic life	New economic life
			BAU Pre-federal regulation (Nominal)	RIAS Federal regulation scenario (Nominal)	BAU Pre-federal regulation (Updated)	RIAS Federal regulation scenario (Updated)	Pembina proposed accelerated phase-out schedule		
Belledune 1	458	1993	2068	2043	2068	2043	2029	50	36
Coleson Cove 3	350	1976	2054	2030	N/A	N/A	N/A	53	N/A

Notes

Coleson Cove 3. As previously noted in this report, Coleson Cove 3 burns a mix of petroleum coke and heavy fuel oil. While this unit technically falls under the coal regulation and was included in the RIAS, it was excluded from our analysis for conservativeness. For this reason no retirement year is indicated in the updated scenarios. The refurbishment completed in 2005 extended the unit's lifetime under the federal regulation until 2030.

A.2.3.5 Nova Scotia

Nova Scotia's coal-fired plants are treated differently in this analysis. The Equivalency Agreement the province negotiated with the federal government allows Nova Scotia to keep its coal units operating after they have reached the end of their useful life, in

[92] Manitoba Climate Change and Emissions Reductions Act, 2013, section 16. http://web2.gov.mb.ca/laws/statutes/ccsm/_pdf.php?cap=c135

exchange for equivalent or greater GHG emissions reduction achieved.[93] The amended regulations require a 55% reduction in electricity-sector GHGs from 10 Mt in 2007 to 4.5 Mt in 2030, and include a schedule that outlines a hard GHG cap for multi-year compliance periods between 2015 and 2030.[94]

Because of the specifics of this policy, Nova Scotia coal power generation was modelled using a methodology that differs from other provinces.

Table 13 outlines the retirement years of Nova Scotia's coal-fired units under each of the scenarios considered in this report. The notes below the table detail the specific approach we took under each scenario.

Table 13. Nova Scotia's coal-fired unit details and assumed retirement year under five scenarios

Coal-fired unit	Capacity (MW)	Commissioned year	Retirement year under following scenarios					CEPA economic life	New economic life
			BAU Pre-federal regulation (Nominal)	RIAS Federal regulation scenario (Nominal)	BAU Pre-federal regulation (Updated)	RIAS Federal regulation scenario (Updated)	Pembina proposed accelerated phase-out schedule		
Trenton 5	154	1969	2044	2029	2044	2035	2018	50	49
Point Tupper 1	154	1973	2044	2029	2044	2039	2019	46	46
Lingan 1	155	1979	2054	2019	2054	2039	2020	50	41
Lingan 2	155	1980	2055	2019	2055	2018	2020	49	40
Lingan 3	155	1983	2058	2029	2058	2039	2023	46	40
Lingan 4	155	1984	2059	2029	2059	2039	2024	45	40
Trenton 6	154	1991	2066	2041	2066	2039	2029	50	38
Point Aconi 1	171	1994	2069	2044	2069	2039	2029	50	35

Notes

Point Aconi. Point Aconi generating station is technically burning petroleum coke. This unit is included in this analysis as the federal regulation considers petroleum coke to be similar to coal.

[93] An Agreement on the Equivalency of Federal and Nova Scotia Regulations for the Control of Greenhouse Gas Emissions from Electricity Producers in Nova Scotia. http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=1ADECEDE-1

[94] Nova Scotia Environment, *Amendments to Greenhouse Gas & Air Quality Emissions Regulations*, 2013. https://www.novascotia.ca/nse/climate-change/docs/Greenhouse-Gas-Amendments-2013.pdf

BAU Pre-federal regulation (Nominal). No modification was made to this scenario.

RIAS Federal regulation scenario (Nominal). No modification was made to this scenario.

BAU Pre-federal regulation (Updated). No modification was made to this scenario.

RIAS Federal regulation scenario (Updated). In this scenario, data for coal power generation between 2015 and 2020 is provided on a per-unit basis by Nova Scotia Power's 10 Year System Outlook.[95] Coal power generation for years between 2021 and 2035 was modelled as a whole, not at the unit level, so that coal-fired generation contributes 55% of the annual GHG emissions limit. This scenario still assumes coal-fired units retire, following a schedule aligned with the Maximum retirement strategy from the Integrated Resource Plan.[96] Under this strategy, Lingan 2 is the only coal unit to retire before 2035 (see Table 14).

Pembina proposed accelerated phase-out schedule. In this scenario, Nova Scotia's Equivalency Agreement ends in 2030 and all coal-fired power plants are retired by then. Data for coal power generation between 2015 and 2020 is provided on a per-unit basis by Nova Scotia Power's 10 Year System Outlook.[97] Coal power generation for years between 2021 and 2035 assumes a capacity factor of 60% and follows the retirement schedule proposed by the Minimum retirement strategy from the Integrated Resource Plan (Table 14).[98] This retirement schedule was amended to make all coal units retire before 2030. As a consequence, Trenton 5's and Point Aconi 1's retirement year was accelerated from 2039 to 2029. In this scenario, deemed coal GHG emissions between 2021 and 2030 represent less than 46% of the annual GHG limit, making this scenario feasible.

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[95] Generation is calculated using the forecast capacity factors provided for each of the units in the document (Figures 6 and 7). Nova Scotia Utility and Review Board, *Nova Scotia Power 10 Year System Outlook, 2016 Report*. http://oasis.nspower.ca/site/media/oasis/20160630%20NSPI%20to%20UARB%2010%20Year%20System%20Outlook%20Report.pdf

[96] Nova Scotia Utility and Review Board, *2014 Integrated Resource Plan: NS Power Final Report* (2014). http://www.nspower.ca/site/media/Parent/20141015%202014%20IRP%20Final%20Report.pdf

[97] Generation is calculated using the forecast capacity factors provided for each of the units in the document (Figures 6 and 7). Nova Scotia Utility and Review Board, *Nova Scotia Power 10 Year System Outlook* (2016). http://oasis.nspower.ca/site/media/oasis/20160630%20NSPI%20to%20UARB%2010%20Year%20System%20Outlook%20Report.pdf

[98] *2014 Integrated Resource Plan*.

Table 14. Nova Scotia's coal unit retirement years according to the Maximum and Minimum retirement strategy outlined in NS Power Integrated Resource Plan

NS coal units	Maximum retirement strategy	Minimum retirement strategy
Lingan 1	2039	2019
Lingan 2	2018	2018
Lingan 3	2039	2023
Lingan 4	2039	2024
Point Tupper 1	2039	2027
Trenton 5	2035	2020
Trenton 6	2039	2029
Point Aconi 1	2039	2029

Source: NS Power[99]

Note: The Maximum retirement strategy assumes coal power plants retire after 60 years of useful life. The Minimum retirement strategy assumes coal power plants retire after 40 years of useful life. 2039 is used as a generic retirement year for units indicated as retiring "beyond planning horizon".

Sensitivity. A sensitivity test was conducted on the specific modelling of Nova Scotia coal power as well as associated emissions and health benefits. While the level of coal generation has a small impact on health benefits across Atlantic Canada, this makes little difference when looking at the benefits at national level. This is due to the combination of a relatively low impact factor per unit of generation in Atlantic Canada (Table 6) and that the majority of the retiring coal generation is located in the Prairies.

A.2.3.6 Other provinces and territories

All other provinces and territories did not operate coal-fired power plants in 2016.

While a coal phase-out by 2030 was announced by Québec in 2016 as part of Québec's *2030 Energy Policy*,[100] this phase-out actually refers to the use of thermal coal in the mining and cement industry — Québec has no coal-fired power plants.

[99] *2014 Integrated Resource Plan*, Appendix J.

[100] Québec, *Politique énergétique: Cibles*. 2016. http://politiqueenergetique.gouv.qc.ca/politique-energetique/cibles/

A.3 Caveats and other considerations

The principle behind extrapolating the RIAS benefits to calculate impact is straightforward and clearly stated by Environment Canada: "all the CAC reductions and associated health and environmental benefits presented are incremental and attributable to the Regulations".[101] Nevertheless, a number of caveats must be acknowledged due to the limited information on the assumptions and model used by Environment Canada.

The correlation between air contaminants and health impact may not be as linear as this analysis suggests: some air contaminants need to reach a threshold to inflict specific health outcomes. That being said, there is no safe threshold for the main ambient air contaminants that Environment Canada modelled, ozone and $PM_{2.5}$,[102] so non-linear threshold effects are expected to be minimal for this analysis. The straight line extrapolation adopted in this analysis also lacks the sophistication of the combined AURAMS/AQBAT modelling approach used by Environment Canada.

This analysis does not fully account for the differences in location and performance of coal units across Canada. Some coal units are closer to major population centres. At the same time, as noted earlier, control technologies and quality of coal used make some of the coal-fired plants emit significantly more or less SO_2 and NO_x than other units. For these reasons, it is a simplification to treat every GWh of coal power the same within a given region.

It must also be noted this analysis includes benefits from Alberta coal phase-out. This was announced in November 2015 as part of the province's Climate Leadership Plan, but has not been legislated yet.

Despite these caveats, there are a number of factors that make this analysis conservative and likely to understate the benefits.

The federal government's RIAS analysis includes benefits from retiring both older "dirty" coal plants as well as new "cleaner" coal plants.[103] Our analysis therefore

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[101] RIAS, section 10.

[102] Environment Canada, *Canadian Smog Science Assessment - Highlights and Key Messages* (2012). https://www.ec.gc.ca/Publications/AD024B6B-A18B-408D-ACA2-59B1B4E04863%5CCanadianSmogScienceAssessmentHighlightsAndKeyMessages.pdf

[103] The RIAS BAU scenario includes the construction of five new coal power plants in Alberta between 2015 and 2035. Under the 2012 federal regulation, these facilities would have been avoided or would have been

calculated health impact factors that are applicable to a blend of new and older plants. Our proposed accelerated coal phase-out would be taking almost exclusively older plants offline. Thus the benefits determined through our analysis are more conservative.

There are further reasons to believe that the analysis here is conservative:

- As previously noted, the RIAS analysis itself is conservative, particularly the use of low-range estimates of mercury impacts on health.
- Coal power generation using CCS was removed from our analysis based on the assumption that no GHG and pollutants emissions are associated with units using this technology. This assumption is conservative as not all emissions are captured in a CCS-equipped unit. For example, at Boundary Dam 3, GHG emissions are actually reduced by "up to 90%".[104]
- Updated and phase-out scenarios exclude Coleson Cove 3, a New Brunswick unit that uses a mix of heavy fuel oil and petroleum coke to generate power. While this unit technically falls under the coal regulation, and is expected to be quite emissions intensive, it has been left out of the analysis due to a lack of data.

equipped with CCS technologies. For example, the 450 MW Milner expansion, which would have had to be built with NO_x and SO_2 controls as required under Alberta's CASA regulations, was avoided because of the federal regulation.

[104] SaskPower, "Capturing Carbon and the World's Attention." http://www.saskpower.com/our-power-future/innovating-today-to-power-tomorrow/capturing-carbon-and-the-worlds-attention/

Appendix B. Air Quality Benefits Assessment Tool (AQBAT)

Health Canada uses the Air Quality Benefits Assessment Tool (AQBAT) to estimate the benefit of improvements in air quality. Within this model, air quality improvements are defined based on the ambient levels of several key pollutants, especially $PM_{2.5}$ and ground level ozone (O_3). The model also includes 18 different health risks, ranging from the risk of experiencing asthma symptoms to the risk of premature death. A list of all the pollutants and all the health risks included in AQBAT is provided in Table 15.

Each of the pollutants modelled by AQBAT is linked with one or more of the health risks. A reduction in pollutant levels reduces the health risks for Canadians exposed to that pollutant. For each change in a health risk, the model then assigns an economic value drawn from the available medical and economic literature. These values differ for each type of health risk. For some health risks, the economic values are associated almost entirely with avoided pain and suffering. For other risks, the economic values are driven by avoided medical costs or increased productivity. For the reductions in the risk of premature death, the economic values are based on estimates of the social benefit of reducing the risk of premature death.

Once the model has determined how much risks will be lowered, and what the economic value of reduced risks are, the model aggregates risk reductions and economic values over the affected population, to determine the number of avoided illnesses, and the net economic benefit, for a particular census division. This process is replicated in 288 Canadian census divisions, based on estimated air pollution levels in each census division.

Provincial and national estimates are then calculated simply by adding up the health impacts and economic benefits by census division.

Table 15. Health risks linked to air pollution that are measured by AQBAT

Health endpoint	At risk population	Linked to these pollutants
Acute mortality	All	CO, NO_2, O_3, SO_2
Acute respiratory symptom days	All adults and non-asthmatic children 5-19	O_3, $PM_{2.5}$
Adult chronic bronchitis	25+	$PM_{2.5}$
Asthma symptom days	Asthmatic (14.3%) children 5-19	O_3, $PM_{2.5}$
Cardiac hospital admissions	All	$PM_{2.5}$
Cardiac emergency room visit	All	$PM_{2.5}$
Child acute bronchitis episodes	Children 5-19	$PM_{2.5}$
Chronic exposure cerebrovascular mortality	25+	$PM_{2.5}$
Chronic exposure COPD mortality	25+	$PM_{2.5}$
Chronic exposure ischemic heart disease mortality	25+	$PM_{2.5}$
Chronic exposure lung cancer mortality	25+	$PM_{2.5}$
Chronic exposure respiratory mortality	30+	O_3
Chronic exposure respiratory mortality	All	O_3
Elderly cardiac hospital admission	65+	CO
Minor restricted activity days	Non-asthmatic children 5-19	O_3
Respiratory emergency room visit	All	O_3, $PM_{2.5}$
Respiratory hospital admissions	All	O_3, $PM_{2.5}$
Restricted activity days	All adults and non-asthmatic children 5-19	$PM_{2.5}$

Source: Correspondence with Health Canada

Appendix C. Proposed schedule for a national phase-out of coal-fired power

Table 16 below contains a retirement schedule for each coal-fired unit in Canada. This schedule was previously outlined and submitted to the federal government's online consultation for the Pan-Canadian Framework on Clean Growth and Climate Change, and was employed in this analysis.[105] This schedule was updated to reflect the reality of coal power industry as of Fall 2016 (see Appendix A.2.3).

Table 16. Pembina Institute proposed coal-fired plants retirement schedule

Unit name	Capacity (MW)	Year commissioned	End of economic life	Allowed life (CEPA regs.)	Proposed end-of-life	Proposed life
ALBERTA						
Battle River 3	149	1969	2019	50	2017	48
Sundance 1	288	1970	2019	49	2018	48
Milner 1	144	1972	2019	47	2016	44
Sundance 2	288	1973	2019	46	2018	45
Battle River 4	155	1975	2025	50	2017	42
Sundance 3	368	1976	2026	50	2020	44
Sundance 4	406	1977	2027	50	2020	43
Sundance 5	406	1978	2028	50	2020	42
Sundance 6	401	1980	2029	49	2020	40
Battle River 5	385	1981	2029	48	2021	40
Keephills 1	395	1983	2029	46	2023	40
Keephills 2	395	1983	2029	46	2023	40
Sheerness 1	400	1986	2036	50	2026	40

[105] Pembina Institute, *Building a Pan-Canadian Climate Plan: Policy options to meet or exceed Canada's 2030 emissions target* (2016). https://www.pembina.org/pub/building-a-pan-canadian-climate-plan

Genesee 2	400	1989	2039	50	2029	40
Sheerness 2	390	1990	2040	50	2026	36
Genesee 1	400	1994	2044	50	2029	35
Genesee 3	466	2005	2055	50	2029	24
Keephills 3	463	2011	2061	50	2029	18
MANITOBA						
Brandon	105	1958	2019	61	2019	61
NEW BRUNSWICK						
Belledune 1	458	1993	2043	50	2029	36
NOVA SCOTIA						
Trenton 5	154	1969	2019	50	2018	49
Point Tupper 1	154	1973	2019	46	2019	46
Lingan 1	155	1979	2029	50	2020	41
Lingan 2	155	1980	2029	49	2020	40
Lingan 3	155	1983	2029	46	2023	40
Lingan 4	155	1984	2029	45	2024	40
Trenton 6	154	1991	2041	50	2029	38
Point Aconi 1	171	1994	2044	50	2029	35
SASKATCHEWAN						
Boundary Dam 4	139	1970	2019	49	2019	49
Boundary Dam 5	139	1973	2019	46	2019	46
Boundary Dam 6	284	1978	2028	50	2019	41
Poplar River 2	291	1980	2029	49	2020	40
Poplar River 1	291	1983	2029	46	2023	40
Shand 1	276	1992	2042	50	2029	37
Boundary Dam 3[106]	160	2014	2064	50	N/A	N/A

[106] Boundary Dam 3 has CCS installed, and therefore it is assumed to have a negligible impact in this analysis.