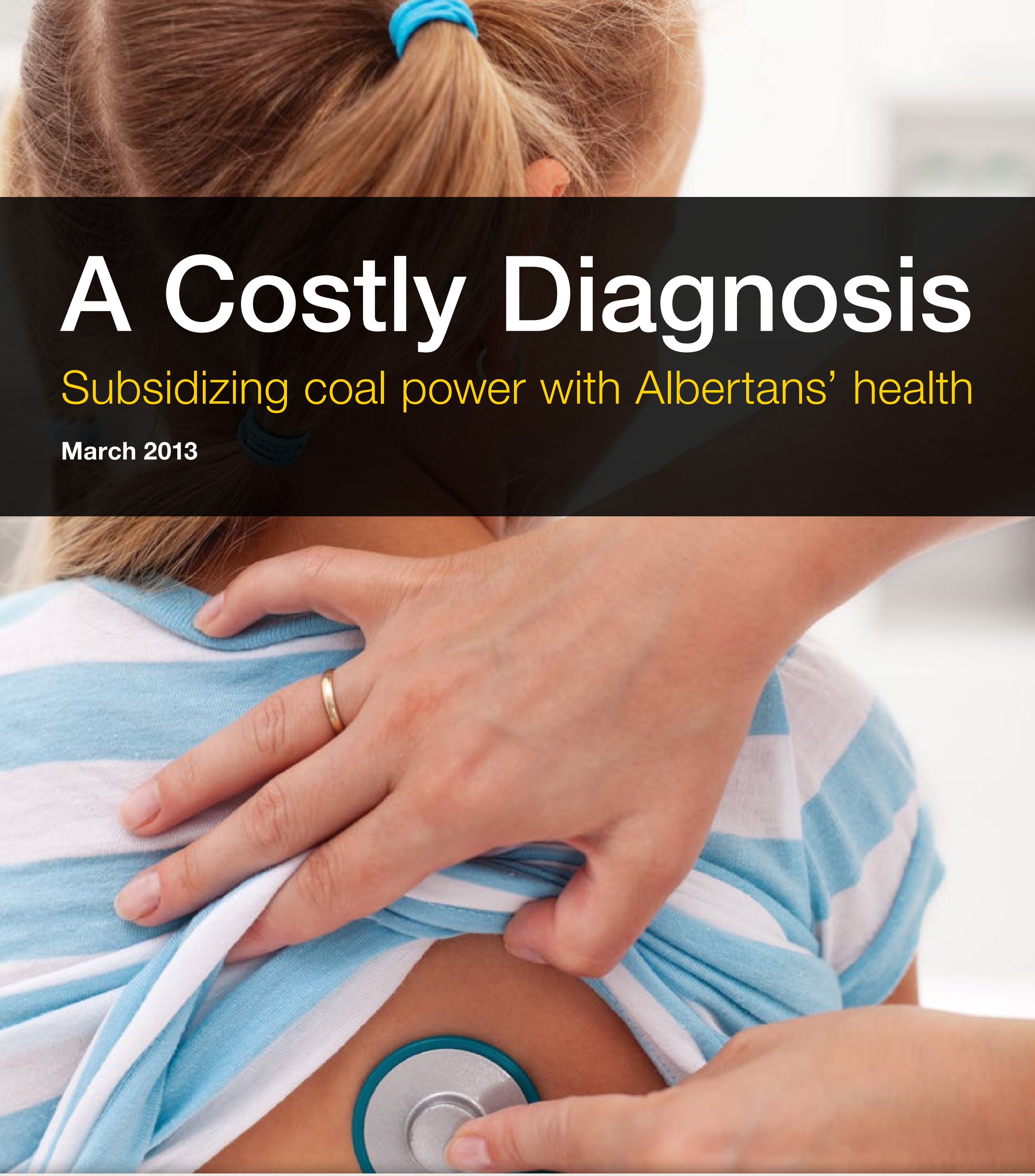

A Costly Diagnosis

Subsidizing coal power with Albertans' health

March 2013

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Kristi Anderson, Tim Weis, Ben Thibault, Farrah Khan, Beth Nanni, and Noah Farber
March 2013

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Foreword

In the year 2000, I introduced a course for undergraduate medical students called Ecosystem Health. The course was designed to help medical students understand the relationship between human health and the environment. A key component of that course was education about climate change and its impact on the environment and on human health. The course outlined how the earth had warmed considerably over the past 30 years and that this warming is not a “normal fluctuation” in earth temperatures. Carbon dioxide levels had increased markedly and the theory was and is that this “greenhouse gas” would lead to a hotter earth. My hope in the year 2000 was to convince medical students and the public at large that global warming was real. I thought that the challenge at the time to was in the convincing – convincing the majority of the population that global warming was a worry for humanity. I thought that once we understood that global warming was real and that it was a problem, I was confident that we as responsible humans would collectively act to stop it.

I was dead wrong. We are seeing more and more of the severe weather events that were predicted a decade or so ago. Global warming is now real and recognized as a problem by most, but far too little is being done to stop it. The challenge has unfortunately changed from proving the existence of global warming to doing something significant about it — making real changes in our energy use and how energy is generated. Global warming is beginning to threaten the existence of many if not all on the planet, particularly those who are poor and live a marginal existence — the very people who are powerless to do anything about global warming. Those who can make the difference, those people in power, the ones that produce the most carbon dioxide, are not acting for fear of slowing economic growth. Economic growth, and energy production and consumption, seem to trump environmental responsibility, and in turn threaten the future of human existence.

How do Canadians begin to save the world? We begin where we can win and make a big difference in reducing our carbon footprint. The abolition of coal in power generation is the one place to begin. Using coal to produce electricity is dirty in many ways. The mining, transportation and burning of coal leads to significant carbon dioxide and other greenhouse gases being released into the air. The combustion of coal pollutes the air, causing illness and death in more people than any other method of energy generation. According to figures in Scientific American, the mining, transportation and burning of coal for electricity generation is responsible for more deaths per kilowatt of electricity generated than any other source of power — a death rate 70 times that of renewable energy sources. This does not include the effects of the air pollution it generates which results in even more illness-related deaths, asthma, pneumonia and cardiovascular events.

The Province of Ontario has taken a bold leadership position by phasing out coal-generated electricity. Ontario recognizes the disease burden coal-generated electricity places on its present and future residents. It is critical for other provinces and jurisdictions to follow Ontario’s lead. Once Canada becomes coal free, we truly can influence other countries by example. Once Canada is coal free, we can leverage other countries such as the United States to do the same, given the harm their emissions from coal electricity generation has on Canadians. It is a great opportunity for Canada to lead the world by acting environmentally responsibly.

This past year, I was blessed with the birth of my first grandchild. He is loving, trusting and oblivious to the perils of climate change. We all now know that climate change is real and a real threat to human existence as we know it. Someday my grandson will know about climate change and if nothing is done about it, will probably suffer some consequence because of it. Our children and our grandchildren are coming into a world that has been spoiled by our overconsumption and reluctance to make the necessary changes to reduce carbon emissions. How can we fulfill our responsibilities to our children, our grandchildren and our great-grandchildren? By taking the first major step — phasing out our coal-generated electricity.

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List of Abbreviations

BATEA	Best Available Technology Economically Available
BLIERs	Base Level Industrial Emissions Requirements
CAAQS	Canadian Ambient Air Quality Standards
CASA	Clean Air Strategic Alliance
CCME	Canadian Council of Ministers of the Environment
CCS	Carbon capture and storage
CO_2e	Carbon dioxide equivalent
GHG	Greenhouse gas
HCB	Hexachlorobenzene
Hg	Mercury
ICAP	Illness Costs of Air Pollution
kg	Kilogram
km	Kilometre
MeHg	Methylmercury
MW	Megawatt
MWh	Megawatt-hour
NO_x	Nitrogen oxides
O_3	Ozone
PAHs	Polycyclic aromatic hydrocarbons
PM	Particulate matter
$PM_{2.5}$	Particulate matter with aerodynamic diameters below 2.5 micrometres
PM_{10}	Particulate matter with aerodynamic diameters below 10 micrometres
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
µg	Microgram
VOCs	Volatile organic compounds

Summary

Coal electricity in Alberta

Alberta burns more coal than the rest of Canada combined. Alberta generated 64 per cent of its electricity in 2012 by burning coal, higher than the average in the United States of 44 per cent. Coal causes more pollution than any other source of electricity, including greenhouse gas pollution as well as air contaminants such as sulphur dioxide and mercury that pose health risks. Globally, coal produces more greenhouse gas emissions than any other fossil fuel.

Currently there are several discussions underway that will affect the length of time that coal plants are allowed to operate in Alberta before reducing different emissions, ranging from 40 to 50 years beyond their original commissioning date. These decisions will have real impacts on air quality in Alberta. As a result it is important to have a public discussion about the emissions in Alberta resulting from coal.

Alberta has six coal plants comprising 18 individual units, which range in size from 150 MW to 495 MW for a combined capacity of over 6,200 MW. In 2011, coal plants in Alberta emitted 33 per cent of the sulphur dioxide (SO_2), 10 per cent of the nitrogen oxides (NOx), 6 per cent of the fine particulate matter ($PM_{2.5}$), and 44 per cent of the mercury (Hg) from man-made sources in Alberta. Other pollutants emitted by coal plants in Alberta include lead, cadmium, hexachlorobenzene, dioxins and furans, polycyclic aromatic hydrocarbons, and arsenic. In addition, the 43 megatonnes of greenhouse gas (GHG) emissions from coal-fired electricity plants was only slightly less than all of the GHG emissions from all of the oilsands operations combined in 2011.

Table A. Key emissions from coal plants in Alberta

Air Emission	2011 releases	% of Alberta total
Sulphur dioxide	114,500 t	33
Nitrogen oxides	71,500 t	10
Fine particulate matter	1,780 t	6
Mercury	216 kg	44
Greenhouse gases	43.2 Mt	18.5

Health risks of emissions

There is an extensive body of literature dealing with the health impacts of air pollutants. This report provides an overview of many of the known health risks associated with the emissions that result from burning coal for electricity production.

Nitrogen oxides, in addition to being acid rain precursors, react in the atmosphere to form ground-level ozone, which is linked to the exacerbation of asthma, as is exposure to sulphur dioxide. Exposure to fine particulate matter — either from direct emissions or formed as a result of sulphur dioxide emissions — is known to affect lung development in children. Short-term exposure to fine particulate matter has also been associated with increased incidence of cardiac disease. Mercury and lead are pollutants emitted by coal plants that can affect neurological development when exposure to sufficient quantities occurs during the early stages of life. A dangerously warming climate increases the medical risks of heat exhaustion and cardiovascular and respiratory diseases from more frequent and severe heat waves, while potentially allowing the introduction of new parasites and pathogens. Several substances emitted by coal plants are known, probable or possible carcinogens.

Estimating damages in Alberta

In 2008, modelling by the Canadian Medical Association published a landmark report estimating the impacts and costs of poor air quality from all sources in Canada. This same model, the Illness Cost of Air Pollution (ICAP), was used in this report to estimate the health risks and economic damages of coal-fired electricity generation in Alberta. The results are compared against Environment Canada's published benefits of limiting the lives of coal units to a maximum of 50 years, as well as health and economic damage estimates from models in the United States.

The ICAP model incorporates reported levels of pollutants in the ambient air, and correlates known health impacts to population densities and forecasts. Based on studies on the health effects of air pollution, including the chronic effects of exposure, ICAP estimates health damages in physical terms (i.e., illness rates) and economic terms (i.e., monetary damages associated with air pollution-related illnesses).

Isolating reported levels of pollution from coal plants in Alberta, and accounting for expected retirement dates, the model suggests there are 700 visits to Alberta's emergency departments and 80 hospital admissions related to respiratory and cardiovascular ailments due to short-term exposure to air pollution from coal plants in Alberta annually. Exacerbation of asthma from air pollution is estimated to be responsible for over 4,800 asthma symptom days, which are days when asthma sufferers must miss work or school due to their illness. The model estimates that long-term exposure to air pollution from coal plants is a contributing factor to the premature deaths of more than 100 Albertans each year.

The ICAP model estimates that total economic damages in Alberta associated with the health impacts of air pollution from coal plants are in the range of $300 million annually, which would translate into approximately 0.7 ¢/kWh. The ICAP results are lower than those of other estimates — for example, estimates in the United States have ranged from 3.2 to 3.6 ¢/kWh, which reflects the lower population densities in Alberta as well as some of the progress that has been made to reduce emissions. Applying the Air Pollution Emissions Experiments and Policy model, which uses multipliers per pollutant to estimate damages, to Alberta's emissions profile from coal plants generates an estimate of 2.1¢/kWh in health impact damages. Basing estimates on the regulatory impact statement of Environment Canada's *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulation* these health impact costs amount to 1.7 ¢/kWh.

Given the complexities of environmental processes, these numbers should not be taken as definitive, but rather indicative of the costs of health risks that are not internalized from pollution.

In addition, Environment Canada determined the social costs of greenhouse gas emissions to lie in a range of $26-104 per tonne. The low end of this range translates into an additional 2.9 ¢/kWh. Thus, including human health risks, the total social cost of burning coal for electricity is at minimum 3.6-5.0 ¢/kWh. These costs do not include the costs associated with environmental impacts from air pollution, and are at the very low end of climate change estimates.

Table B. Summary of costs of coal-fired electricity in Alberta

	Cost (¢/kWh)
Minimum greenhouse gas social cost	2.9 – 11.6
Economic damages from health impacts from air pollution	0.7 – 2.1
Economic damages from environmental impacts from air pollution	not calculated
Total cost to society	**3.6 – 13.7**
Pool price (2012)	6.6
True cost of electricity from coal	**10.2 – 20.3**

The current electricity market does not internalize the health and environmental costs associated with its pollution from coal burning, placing renewable energy at a market disadvantage. Use of full-cost accounting for electricity from coal would foster cleaner sources of electricity as coal plants reach the end of their lives.

Conclusions

There is a growing awareness of the price that society pays for generating electricity from coal, both in terms of climate change and health impacts. Some of these costs are starting to be applied to existing plants as mercury capture requirements increase and to newer plants as stricter air NO_x and SO_2 requirements are implemented. However, air pollutants and greenhouse emissions from Alberta's sizeable existing fleet are not fully internalized.

Pricing in the additional health and environmental costs of coal puts coal on par with numerous sources of low and non-polluting sources of electricity.

New federal greenhouse gas regulations mean that an eventual phase-out of conventional coal is inevitable in Canada, although those same regulations do not require this phase-out to be complete in Alberta until 2062.

Ontario's coal fleet was once the size of Alberta's, yet it will be phased out completely by the end of 2014. Nova Scotia, which was once more dependent on coal than Alberta, has legislated targets that require 40 per cent renewable electricity by 2020, which will cut its coal dependence in half. In seeking an equivalency agreement with the federal government, Alberta should not be copying the weak aspects of the federal regulations, but should use the opportunity to show leadership by phasing out existing plants faster than the 50-year lives allowed under the federal regulations. Such leadership would not only significantly reduce greenhouse emissions but also have the co-benefit of reducing the other health-damaging pollutants and their associated costs to Albertans.

Sundance coal plant

Photo David Dodge, The Pembina Institute

1. Introduction

1.1 Coal power in Alberta: past, present and future

Unlike most Canadian provinces, Alberta generates the majority of its electricity by burning coal. Alberta's electricity system burns more coal than the rest of Canada's provinces combined.[1] In 2011, over two-thirds of the electricity traded on Alberta's electricity market was generated from coal. Not only does this make Alberta's electricity system the most greenhouse gas (GHG) intensive in Canada, it also means that the generation of electricity in Alberta results in major releases of air pollutants and toxic contaminants that have numerous known health impacts.

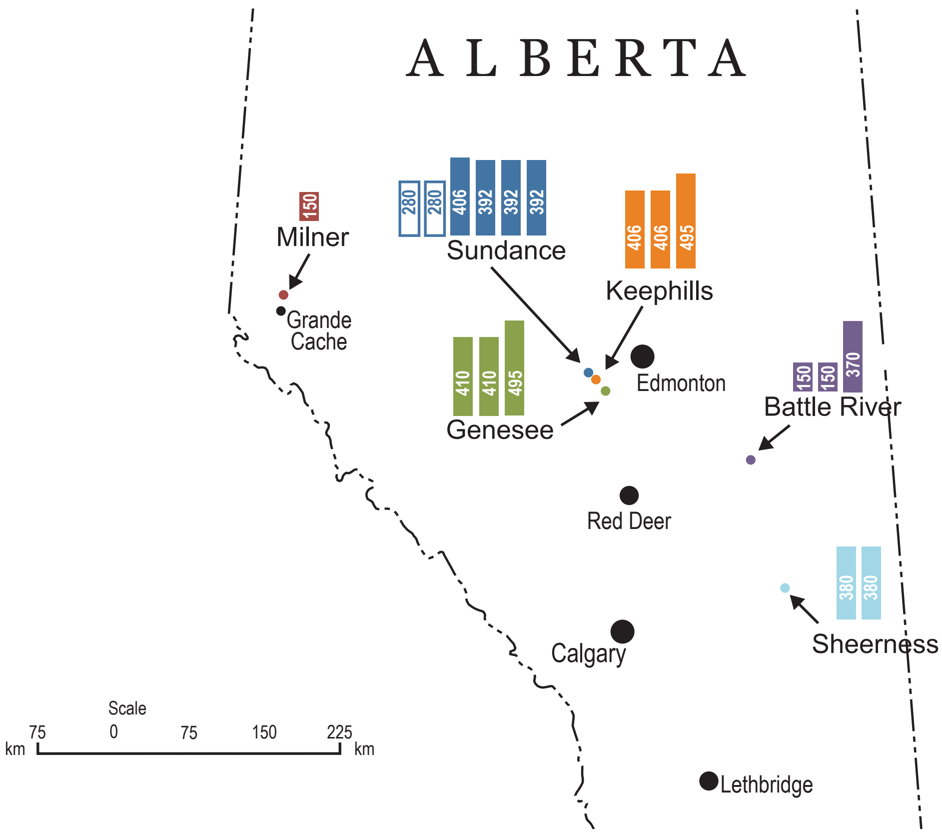

Figure 1. Coal-fired electricity generating units in Alberta (coloured bars denote unit size in MW)

Data source: Milner Power, TransAlta, Atco Power; map adapted from Natural Resources Canada[2]

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[1] Statistics Canada, "Fuel consumed for electric power generation, by electric utility thermal plants," CANSIM Table 127-0004, (2010 data). www5.statcan.gc.ca/cansim/

[2] Milner Power Inc., "HR Milner Generating Station," www.milnerpower.ca/; TransAlta, "Plants in Operation," www.transalta.com/facilities/plants-operation; ATCO Power, "Battle River Coal-Fired Generating Station," http://www.atcopower.com/Our+Facilities/North+America/Battle+River+%28AB%29/Battle_River_Coal_Fired_Generating_Station.htm; Natural Resources Canada, "Alberta," The Atlas of Canada, http://atlas.gc.ca/site/english/maps/reference/provincesterritories/alberta

Alberta's existing coal units are located in the central and south-central areas of the province (see Figure 1) and range widely in age from the two-year-old Keephills 3 unit that was commissioned in 2011, to the 44-year-old Battle River 3 unit, which has been operating since 1969. This means a broad variance in efficiency, pollution control measures, and rates of pollution emissions — and a long timeframe of dates over which these plants will be allowed continue to operate. Recently established federal GHG regulations allow most existing coal plants to continue to operate without any regulatory impact until they reach their fiftieth year of operation,[3] at which point they must either close or incorporate carbon capture and storage (CCS) technologies that would reduce their greenhouse gas emissions by over half of their current rate. CCS is presently expensive so unless there are major cost reductions, it is likely that most units in Alberta will be shut down when they reach the federal age limit, as illustrated below in Figure 2.

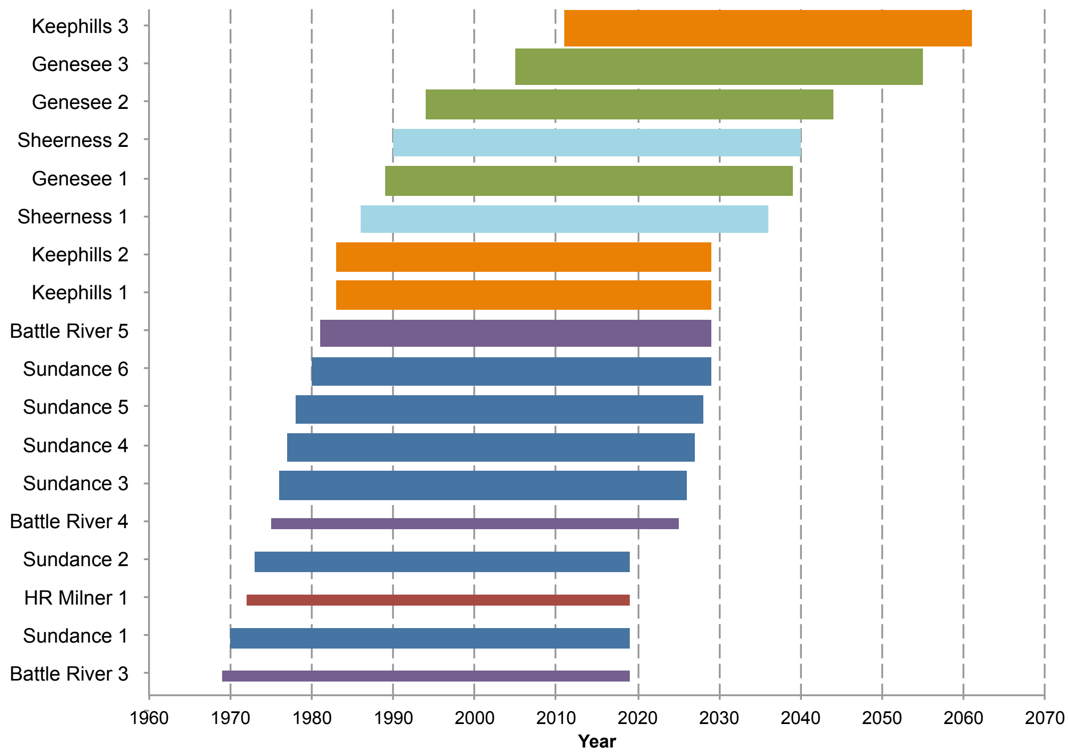

Figure 2. Allowed lifespan of existing coal power units in Alberta under federal regulations. Bar thickness is proportional to plant size.

Data source: Environment Canada[4]

Regulations which may shorten the expected lives of some of the units in Alberta are the provincial limits on sulphur oxides (SO_x) and nitrogen oxides (NO_x) that were negotiated over a decade ago by the Clean Air Strategic Alliance (CASA). Under these regulations, each unit has a specified NO_x and SO_x limit established from baseline performance from 2000–2003. Units can operate without meeting this limit until the end of their "design life", which is usually either the

[3] Units are allowed to operate until their fiftieth anniversary of commissioning unless the year 2019 or 2029 falls between their forty-fifth and fiftieth year of operation, in which case units will be required to comply with the regulation on the last day of 2019 or 2029.

[4] Calculations based on Government of Canada, *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations* SOR/2012-167. http://www.gazette.gc.ca/rp-pr/p2/2012/2012-09-12/html/sor-dors167-eng.html

expiration of their power purchase agreement or 40 years after start-up, whichever is longer. Once the unit has reached the end of its design life it must comply with a "post-design-life intensity target,"[5] either physically or using credits accumulated by it or another plant. This requirement could potentially change the viability of a coal plant, leading to it closing before it reached the federal limits, but if enough credits are available it is likely that most if not all coal units will be operated as long as they can, particularly as they are highly profitable once they are fully amortized.

In the scenario that the federal coal regulations are the dominant policy governing the time allowed for coal units to operate unabated, no existing coal units in Alberta will feel an impact of these regulations until the last day of 2019. By the end of 2025, over twelve years away, the regulations will have impacted less than one-sixth of the coal capacity in the province. Nearly two-thirds will remain immune from any greenhouse gas emissions control through 2029. While the vast majority of the coal plants in the province date from the 1970s and 1980s, there are units in operation today that will be allowed to continue to operate through the 2030s, 2040s, and even one into the 2060s. Alberta's coal power legacy, still dominant in today's electricity grid, could remain relevant through the first half of this century — unless new policies arise at the provincial or federal level.

Alberta has seen a 14 per cent increase in coal capacity from 2002 to 2012[6]. Despite a federal narrative about Canada "phasing out coal" in the short term,[7] Alberta is actually expected to experience a continued increase in coal-fired electricity in the next few years. Two units, Sundance 1 and 2, collectively known as Sundance A, have been offline since December 2010 due to an unexpected and catastrophic failure. As a result of a July 2012 arbitration decision, these units will be required to return to service, resulting in a 560 MW increase in capacity compared to 2012. The impacts of coal power in Alberta are relevant today, and will continue to be relevant for years and perhaps decades to come, and deserve appropriate attention to inform good public policy on electricity generation in the province.

1.2 Scope of report

As described in the preceding section, Alberta is poised to continue to burn millions of tonnes of coal every year for decades to come in order to generate electricity. Given the known air pollutants and toxins that are released from burning coal, this research set out to examine the risks to human health from the continued use of coal in Alberta.

This research is not an epidemiological study, but rather an attempt to collect known literature about the health impacts of coal, and relate that to the current and forecast pollutants released from burning coal for electricity generation in Alberta. Using this data, models were used to estimate the order of magnitude of human health impacts and costs. Additional work needs to be

[5] Post-design-life requirements are 0.8 t/GWh of SO_x and 0.69 t/GWh of NO_x until the unit reaches 50 years, after which any unit must comply with the best available technology economically available, which become more stringent over time.

[6] Alberta Electric System Operator, *2012 Annual Market Statistics Data File* (2012), www.aeso.ca/downloads/2012_Annual_Market_Stats_Data_File.xlsx

[7] Environment Canada, "Government of Canada to Regulate Emissions from Electricity Sector", news release, June 23, 2010. http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=E5B59675-BE60-4759-8FC3-D3513EAA841C

done to refine and better understand all of the human health impacts; this research lays a foundation on which to build.

The focus of this work is on the air pollutants resulting from coal-fired electricity generation, but there are also notable health impacts from other parts of the coal life cycle such as mining and processing. Furthermore, health impacts resulting from climate change may in fact be the most significant in the long term, albeit indirectly.

2. Coal in Alberta

While this report focuses specifically on the health impacts of air pollution from coal-fired electricity generation, it is important to situate this activity and its effects within the broader Alberta coal industry. Other stages of coal power's fuel life cycle pose health risks, notably coal mining. The majority of coal mined in Alberta is destined for electricity generation within the province; as such, coal demand for electricity generation in Alberta is the major determinant of coal mining output in the province. Therefore, the impacts of upstream coal activities — beginning with mining — are relevant for a complete understanding of coal power's consequences in the province. These upstream stages deserve their own detailed treatment, but are reviewed summarily here simply to acknowledge their relevance in a more comprehensive conversation about coal power's impacts.

2.1 Alberta's coal deposits

Alberta holds 70 per cent of Canada's coal deposits or 33.3 billion tonnes (68 per cent of which is estimated to be technically recoverable).[8] The location of the coal deposits in Alberta can be seen in Figure 3.[9] Alberta is also Canada's largest coal producer, producing 25–30 million tonnes of coal a year from 11 mines.

Coal is categorized based on carbon and moisture content, energy value and chemical composition. The four major types of coal are lignite, sub-bituminous, bituminous and anthracite, in order of decreasing carbon content (see Table 1). In Alberta, sub-bituminous and bituminous are the dominant coal types that are mined and used for electricity generation. In 2011, 37 million tonnes of coal was mined in Alberta, 23.2 million tonnes of which was sub-bituminous and 13.8 million tonnes bituminous.[10]

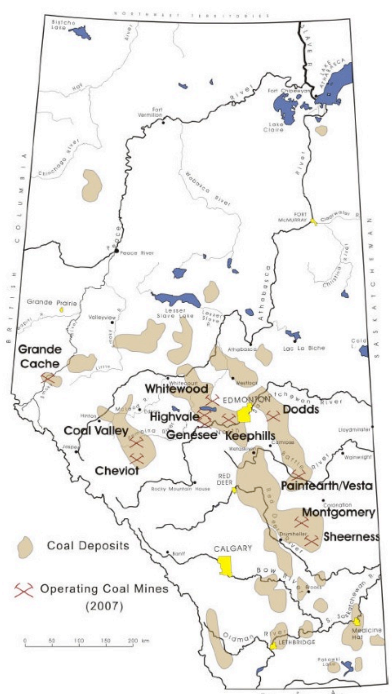

Figure 3. Coal deposits in Alberta

Source: Alberta Environment and Sustainable Resource Development[11]

Approximately 80 per cent of the coal mined in Alberta is used for electricity generation. Most of the remaining coal is shipped through British Columbia to international markets, in particular

[8] EUB, *ST98-2012Alberta's Energy Reserves 2011 and Supply/Demand Outlook 2012-2021* (2012), 18. www.ercb.ca/sts/ST98/ST98-2012.pdf

[9] Alberta Environment and Sustainable Resource Development, "Coal Mines." http://environment.alberta.ca/02251.html

[10] Alberta Energy, "Coal Statistics." www.energy.alberta.ca/coal/643.asp

[11] Alberta Environment and Sustainable Resource Development, "Coal Mines."

Asia, where it is used in the production of steel and iron. Only small amounts of Alberta's coal are exported to other provinces in Canada.[12]

Table 1. Types of coal and their characteristics

Type of coal	Characteristics			Use in Alberta
	Hardness	Carbon content (%)	Moisture content (%)	
Lignite	Soft	25-35	30-60	Not produced in Alberta
Subbituminous	Medium soft	35-45	10-45	Electricity generation
Bituminous	Medium hard	45-86	2-15	Export
Anthracite	Hard	86-97	<15	Export

Data sources: US Energy Information Administration, Alberta Energy, Indiana Center for Coal Technology Research[13]

2.2 The coal power fuel life cycle in Alberta

2.2.1 Coal mining

In the mining process, coal is either extracted through underground mining or surface mining. Coal mining in Alberta started in the late 19th century and was typically done in underground mines; currently, however, only the Grand Cache coal mine operates an underground operation, in addition to surface mining.[14] The other 10 mines in the province use either strip mining or the open pit extraction method. Six of Alberta's mines supply coal to nearby electric power generating stations using strip mining.

In strip mining, draglines and large stripping shovels are used to remove overburden and expose a relatively horizontal coal seam that is mined in distinct strips.[15] The largest coal mine in Canada is the Highvale strip mine, located 70 km west of Edmonton and covering 12,600 hectares.[16] The mine produces 12.6 million tonnes of coal per year.[17]

Surface mining poses the environmental challenge of reclaiming large tracts of land.[18] Two strip mines, the Highvale mine to the south and the Whitewood mine to the north, lie in the water catchment basin of Lake Wabamun. By 2004, these two mines had disturbed 5,593 ha of land, representing 22 per cent of the catchment basin of Lake Wabamun. Of this disturbed area, 45 per

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[12] Alberta Energy. "What is coal?" www.energy.gov.ab.ca/coal/645.asp

[13] U.S. Energy Information Administration, "Today in Energy," 2011. http://www.eia.gov/todayinenergy/detail.cfm?id=2670; Alberta Energy, *Talk About Coal: Facts on Coal*, 2010. http://www.energy.alberta.ca/coal/pdfs/FactSheet_CoalFacts.pdf; Alberta Energy, "Coal Statistics," 2013; Indiana Center for Coal Technology Research, *Coal Characteristics*, 2008. http://www.purdue.edu/discoverypark/energy/assets/pdfs/cctr/outreach/Basics8-CoalCharacteristics-Oct08.pdf

[14] Alberta Energy. "What is coal?"

[15] Ibid.

[16] TransAlta, "Highvale Mine," 2012. http://www.transalta.com/facilities/mines-operation/highvale-mine

[17] Alberta Environment and Sustainable Resource Development, "Coal Mines," 2012.

[18] National Research Council of the National Academies, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use* (2010).

cent had undergone some form of reclamation by that time but only 16 per cent of the mined area received reclamation certificates from Alberta Environment. Reclamation is typically insufficient to bring about habitat restoration. Upon decommissioning, all of the mined area has been converted to agricultural land rather than the mosaic of forests, wetlands and farms that existed on the landscape prior to mining.[19]

Criteria air contaminants, including sulphur oxides, oxides of nitrogen, volatile organic compounds, carbon monoxide, particulate matter less than 2.5 micrometres in diameter, and ammonia are released during open mining processes.

Coal mining also results in emissions of greenhouse gases. Methane gas is frequently present in coal seams, and is released as the seams are cut to extract the coal. Because methane is a greenhouse gas 23 times more potent than carbon dioxide, fugitive methane releases are of potential concern.

Overall, however, because of the enormous quantity of GHGs and criteria air pollutants emitted during combustion of coal, upstream activities, while not negligible, are a relatively small component of the coal-fired power plant life cycle, at 77 kg of carbon dioxide equivalent per MWh (CO_2e/MWh) out of a total life cycle emission factor of 1,029 kg CO_2e/MWh.[20]

2.2.2 Transport

In Alberta, most coal mines are adjacent to coal-fired power plants. These mines are known as “mine-mouth” operations because coal is removed from the earth and moved directly to a nearby power generation plant.[21]

2.2.3 Combustion

To produce electricity, coal is typically crushed and then pulverized before it is burned to boil water, creating high-pressure steam, which turns a turbine shaft. The shaft is connected to an electrical generator, which produces electricity.

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[19] D. Schindler et al., *Lake Wabamun: A Review of Scientific Studies and Environmental Impacts*, prepared for Alberta Environment (2004). Available at http://www.wwmc.ca/pdf/Lake Wabamu - A Review of Scientific Studies and Environment.pdf

[20] *Hidden Costs of Energy,* 82

[21] Coal Association of Canada, “Markets,” 2012. www.coal.ca/main-markets/

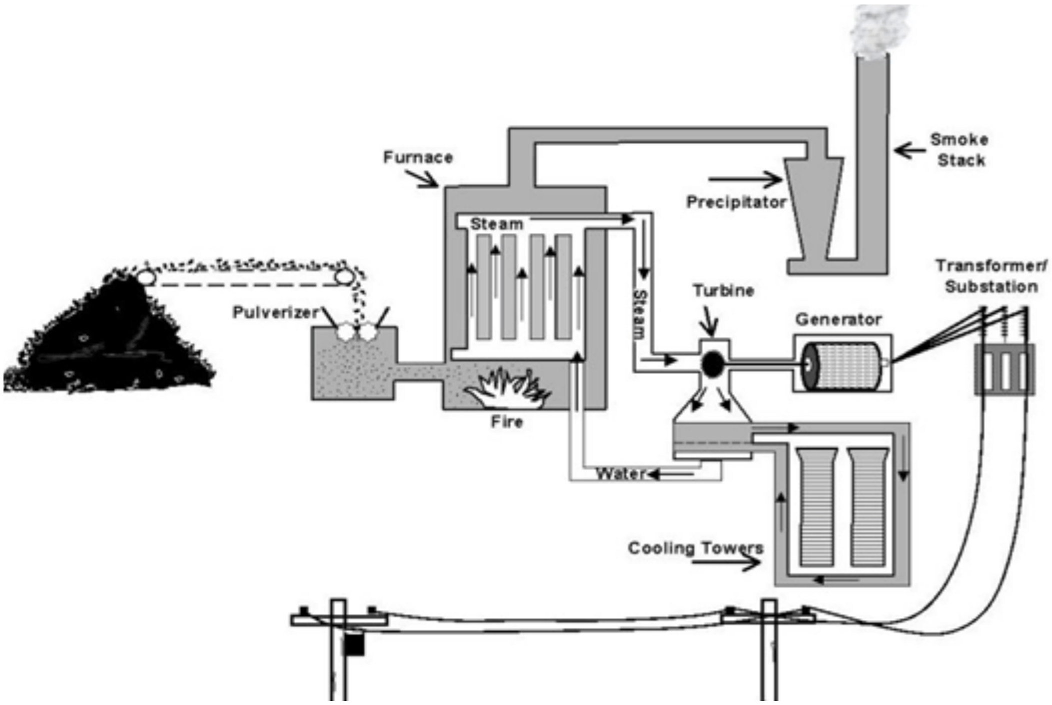

Figure 4. Conventional process for generating electricity from coal

Source: University of Kentucky[22]

Because energy content in coal is largely carbon-based, the exhaust gas is predominately carbon dioxide, but also contains steam, nitrogen oxides and sulphur dioxide as well as airborne heavy metals. Coal is formed from prehistoric plants that have been compressed under heat and pressure over millions of years. Over the millions of years that the coal formed, trace amounts of toxic heavy metals such as mercury, cadmium and lead had time to accumulate in the coal in small but significant proportions. Post-combustion technologies can be added to reduce the level of these pollutants, including carbon dioxide. Pollution reduction technologies are expensive, and are rarely voluntarily added to coal power plants unless they are required by government regulation.

Coal provided over two-thirds of electricity generation in Alberta in 2011, amounting to 39,190 GWh of electricity — more than all other provinces combined. Saskatchewan, Ontario, Nova Scotia and New Brunswick also burn coal to generate electricity, but in 2011, all of these provinces together generated 33,411 GWh of coal-fired electricity.[23] A decade ago, Ontario was second to Alberta in the quantity of coal it used for electricity generation, but Ontario has successfully phased out almost 90 per cent of its coal-fired electricity generation, with the remainder to be completely eliminated by the end of 2014.

While coal-fired electricity makes up the majority of electricity sold on Alberta's market, the generating stations are concentrated in four locations across the province, as shown in Figure 1. The vast majority of the coal burning in Alberta occurs approximately 70 km west of Edmonton,

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[22] University of Kentucky, "Uses of Coal." http://www.uky.edu/KGS/coal/uses_of_coal.htm

[23] Statistics Canada, "Electricity generated from fuels, by electric utility thermal plants," CANSIM Table 127-0006. www5.statcan.gc.ca/cansim/

where 10 units comprising close to 4,700 MW (out of the province's 6,286 MW of coal-fired power generation) operate.[24] The 10 units consume approximately 19.3 million tonnes of coal per year. Two units totaling 760 MW of generation operate in the Sheerness power plant located approximately 200 km northeast of Calgary, and 670 MW of generation operate in the Battle River power plant, less than 125 km east of Red Deer. A single, relatively small 150 MW unit operates near Grande Cache.

Coal-fired generating facilities in Alberta use various technologies to burn coal. The two most modern units in Alberta (Genesee 3 and Keephills 3) use supercritical boilers operating at high temperature and pressure and employ a high-efficiency steam turbine. Together, these technologies result in close to 18 per cent less coal use per megawatt-hour of electrical energy than conventional processes[25], reducing the intensities of all emissions (amount of pollution emission per unit of electricity generated).[26] The boiler technologies and types of coal used in some of Alberta's coal-fired power plants are listed in Table 2. The other units in the province use subcritical boilers to produce the steam to generate electricity from burning coal.

Table 2. Coal type and technology used by coal-fired power stations in Alberta

Facility	Technology	Fuel	Mine	Annual coal consumption (million tonnes)
Battle River 3, 4 & 5	Boiler	Subbituminous	Paintearth and Vesta	2.9
Genesee 1 & 2[27]	Boiler	Subbituminous	Genesee	5.5
Genessee 3	Supercritical boiler	Subbituminous	Genesee	
Keephills 1 & 2[28]	Boiler	Subbituminous	Highvale	(see Sundance)
Keephills 3	Supercritical boiler	Subbituminous	Highvale	1.8
Milner	Boiler	Coal washings	Coal Valley	Up to 0.5
Sheerness	Boiler	Subbituminous	Montgomery and Sheerness	3.8
Sundance	Boiler	Subbituminous	Highvale	12 (includes Keephills 1 & 2)
Total				**26.5**

Data source: Industcards[29], or as indicated

Another technology for generating electricity from coal is integrated gasification combined cycle (IGCC). An IGCC power plant uses a partial combustion process that converts coal into "syngas" (synthetic gas), a mixture of carbon monoxide and hydrogen, which is then used to fire

[24] Alberta Energy, "Electricity Statistics," 2012. www.energy.alberta.ca/Electricity/682.asp

[25] National Energy Board, *Coal-Fired Power Generation – An Overview*, Energy Brief, September 2008, 1. http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/lctrcty/clfrdpwrgnrtn2008/clfrdpwrgnrtnnrgybrf-eng.pdf

[26] TransAlta, "Genesee 3," 2011. http://www.transalta.com/facilities/plants-operation/genesee-3

[27] Capital Power, "Genesee Mine," 2011. www.capitalpower.com/community/consultationengagement/geneseemine/Pages/default.aspx

[28] TransAlta, "Highvale Mine," 2012. www.transalta.com/facilities/mines-operation/highvale-mine

[29] Industcards, "Power Plants Around the World: Coal-fired Plants in Canada," 2012. www.industcards.com/st-coal-canada.htm

the combustion turbine in a combined-cycle power plant (see Figure 5), similar to a natural gas plant. Plants operating with this technology are more efficient in their power production, have lower greenhouse gas emissions, and can scrub pollutants like sulphur and heavy metals from the fuel before it is burned. This technology also lends itself to deployment of carbon capture and storage.[30] There are currently no IGCC plants in Canada but there are three operating in the United States.[31]

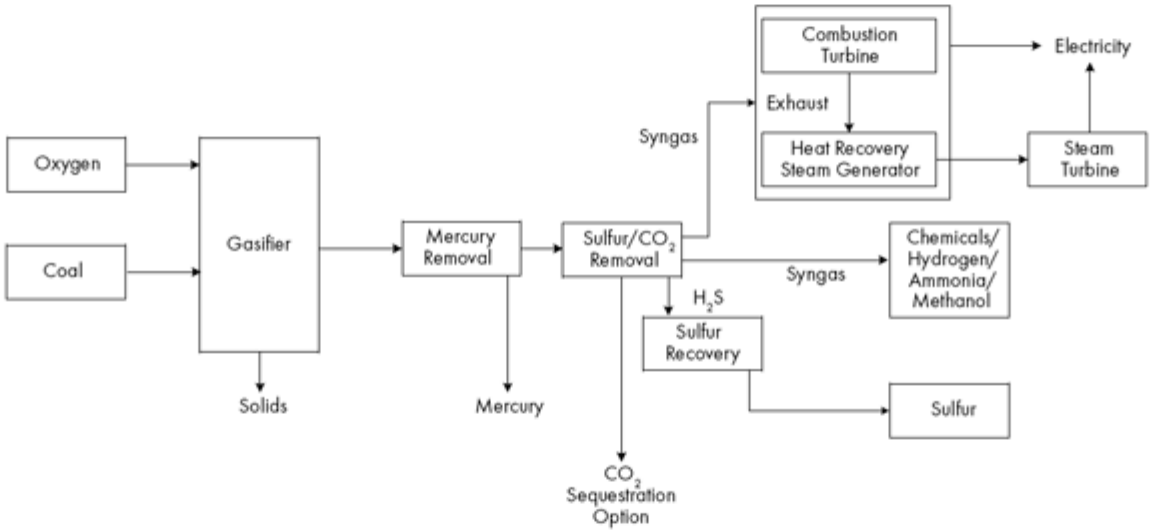

Figure 5. Schematic of integrated coal gasification combined cycle process
Source: National Energy Board[32]

Another method of generating electricity from coal is the fluidized bed power plant. This is a technology that mixes limestone with the burning coal to absorb sulphur and, by reducing combustion temperature, reduces the formation of NO_x. The fluidized bed operates at a lower temperature than a supercritical coal-fired plant so it uses slightly more fuel for the same level of electric output. There is one fluidized bed power plant in Canada, located in Point Aconi, Nova Scotia.[33]

Combustion of coal has numerous impacts on the surrounding environment. Acid deposition resulting from the emission of NO_x and SO_2 causes acidification of soils, streams and lakes.[34] Though much of Alberta has alkaline soils that can temper the effects of acidic precipitation, there are areas that have limited buffering capacity and are therefore sensitive to acid deposition.

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[30] Ibid.

[31] National Energy Board, *Emerging Technologies in Electricity Generation – An Energy Market Assessment*, 2006. http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/lctrcty/mrgngtchnlglctcty2006/mrgngtchnlglctcty2006-eng.pdf

[32] Ibid.

[33] National Energy Board, *Coal-Fired Power Generation: A Perspective,* Energy Briefing Note, July 2008. http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/lctrcty/clfrdpwrgnrtn2008/clfrdpwrgnrtn-eng.html#s3

[34] J. Newman, E. Zillioux, C. Newman, C. Denny, P. Colverson, K. Hill, W. Warren-Hicks, and S. Marynowski. *Comparison of Reported Effects and Risks to Vertebrate Wildlife from Six Electricity Generation Types in the New York / New England Region* (New York State Energy Research and Development Authority, 2009). http://www.nyserda.ny.gov/Publications/Research-and-Development-Technical-Reports/Environmental-Reports/EMEP-Publications/~/media/Files/Publications/Research/Environmental/EMEP/Report%2009-02%20Wildlife%20report%20-%20web.ashx

Coal-fired electricity generation results in the deposition of mercury, which is converted in aquatic environments to the biologically available and toxic substance methylmercury. Methylmercury persists in nature as it is not easily broken down; as a result it bioaccumulates as it moves up the food chain, negatively affecting fish and the birds and wildlife that feed on fish.[35] Mercury deposition to Wabamun Lake's sediments has increased several-fold over background levels, largely due to the emissions from the local coal-fired generating stations.[36] A more complete discussion of pollution from combustion of coal is found in Section 3.

2.2.4 Post-combustion solid wastes

In addition to exhaust gases, a number of solid wastes byproducts remain following combustion that can have significant impacts on health and the environment. These include coal ash and coal ash slurry, which need to be stored and disposed of,[37] but can still remain as threats to regional water supplies.[38]

[35] Ibid.

[36] Schindler, et al., *Lake Wabamun: A Review of Scientific Studies and Environmental Impacts*.

[37] Alberta Environment and Sustainable Resource Development, *Coal Ash: Acceptable Industry Practices* (2012). www.environment.gov.ab.ca/info/library/7638.pdf

[38] Alan H. Lockwood, Kristen Welker-Hood, Molly Ranch, Barbara Gottlieb, *Coal's Assault on Human Health* (Physicians for Social Responsibility, 2009), 11. http://www.psr.org/assets/pdfs/psr-coal-fullreport.pdf

3. Air pollution from coal-fired electricity generation and associated health risks

The major pollutants that result from burning coal are oxides of nitrogen (NO_x), sulphur dioxide (SO_2), mercury, and particulate matter (PM). Coal combustion also results in emissions of arsenic, cadmium, lead, polycyclic aromatic hydrocarbons (PAH), dioxins and furans. Additionally, nitrogen dioxide reacts in the atmosphere to create another health hazard — ground-level ozone, a major component of smog. Finally, coal facilities are some of the largest greenhouse gas-emitting facilities in the province, while coal is the largest greenhouse gas problem globally. Greenhouse gases contribute to global climate change, which poses significant long-term risks to the health of Albertans and global citizens more broadly.

New pollution control technology when required by government regulation can reduce the amount of pollution emitted by coal units, but many units, particularly older one, still emit significant amounts of pollution. For example, in Alberta, the provincial government has standards for SO_2 and NO_x emissions for new facilities (i.e. a generating unit that is commissioned on or after January 1, 2006), but almost all existing facilities still emit those pollutants at levels well above the standard, as shown in Figure 6, Figure 7 and Figure 9, based on information reported to the National Pollutant Release Inventory.

These atmospheric emissions can have acute as well as chronic health consequences as a result of inhaling the pollutants directly, or being exposed to them as they accumulate in the environment, as they are transferred along the food chain or as they impact the health of our ecosystems.

Air pollution from burning coal affects numerous systems in the body — respiratory, cardiovascular, and the central nervous system. These impacts on human health result in loss of work days, increased hospital visits, chronic respiratory illnesses, and premature mortality, locally and regionally. All of these take a measurable toll on society in terms of the well-being of the population, and the financial costs to the health care system.

This section describes the types of pollutants produced by coal-fired electricity generation in Alberta, and outlines the major health impacts of these pollutants. Section 4 examines the impacts on specific populations, while Section 5 attempts to quantify the human health and financial costs.

3.1 Emissions management in Alberta

In Alberta, the Clean Air Strategic Alliance (CASA) has played a key role in working to reduce emission levels of pollutants. This multi-stakeholder partnership is composed of representatives from industry, government and non-government organizations.[39] At the request of the Government of Alberta, CASA established a multistakeholder Electricity Project Team to negotiate an emissions management framework for the Alberta electricity sector. This team's report and recommendations, produced in 2003, was adopted by the CASA Board and subsequently adopted by the Government of Alberta into various regulations, standards and policies. Later, at the request of the Government of Alberta, CASA formed an Electricity Framework Review Project Team (EFR) to conduct the first mandatory five-year review of the framework. This team presented its final report in 2010; the report included 10 consensus recommendations and one non-consensus recommendation.[40] While adopted by the CASA Board, these consensus recommendations are yet to be formally implemented by the Government of Alberta (although they are being informally used by government staff to deal with new project applications).

A fundamental component of the framework is that capital stock turnover will be based on a "design life" concept with an underlying assumption that coal units are fully amortized after 40 years of operation. After a coal plant has operated for 40 years, it will be required to be retired or retrofitted to meet the new facility limits in place at that time. In recognition that a number of units were operating under Power Purchase Agreements (PPAs) that in several cases exceed the 40-year lifespan, the formal design life for coal units is defined as the "date of expiry of the PPA term or 40 years from the date of commissioning, whichever is greater".[41]

To offer flexibility to industry in complying with the requirement when a unit reaches its design life deadline, an emission trading mechanism was established for NO_x and SO_2. In lieu of reducing emissions directly at a particular unit, facility operators could employ emissions credits accrued from other units, whether their own or purchased from other coal facilities that have volutarily reduced emissions of these two pollutants below required levels, in advance of their fortieth year of operation.[42] The framework incorporates standards that are based on using best available technology economically achievable (BATEA). Because technology continually advances, these standards are to continue to be reviewed every five years.

Contained within the framework is a "hot spots" protocol that is intended to provide health protection in regions where exceedances of air quality objectives occur that could be caused by air emissions from thermal electrical generation facilities. It provides a mechanism to deal with specific area air quality concerns.[43]

An electricity working group of CASA continues to monitor emissions management; it issued a report in 2012 on progress made on emissions management in Alberta.[44] The report states that the electricity management framework has reduced NO_x emissions by 45,027 tonnes and SO_2

[39] Clean Air Strategic Alliance, "About CASA." http://www.casahome.org/HomePageLinks/AboutCASA.aspx

[40] Clean Air Strategic Alliance, "Electrical Framework Review." http://www.casahome.org/PastProjectsandAwards/ElectricityFrameworkReview2008.aspx

[41] Clean Air Strategic Alliance, *An Emissions Management Framework for the Alberta Electricity Sector: Report to Stakeholders* (2003), 5. http://www.environment.gov.ab.ca/info/library/5976.pdf

[42] Alberta Environment and Resource Development, "Managing Air Emissions in the Electricity Sector," 2013. http://environment.alberta.ca/02504.html

[43] Alberta Environment, *Guide for Responding to Potential "Hot Spots" Resulting From Air Emissions from the Thermal Electric Power Generation Sector* (2005). http://environment.alberta.ca/documents/EPT_Hotspots.pdf

[44] Clean Air Strategic Alliance, *Electricity Working Group Report* (2012).

emissions by 25,058 tonnes between the beginning of 2006 and the end of 2011.[45] Significant reductions in mercury have also been achieved as plants have implemented plans to capture 70 per cent of the mercury in coal.

On a federal level, the Canadian Council of Ministers of the Environment (CCME) have been working to develop an Air Quality Management System to better protect the health of Canadians. This system consists of new proposed Canadian Ambient Air Quality Standards (CAAQS) for fine particulate matter and ozone, presented below. These standards are more stringent than the Canada-wide standards that were previously used. In addition, air zones and airsheds are part of the management system, as are an Air Zone Management Framework and Base Level Industrial Emissions Requirements (BLIERs).[46]

BLIERs are emissions requirements for new and existing major industrial sectors as well as some types of equipment.[47] For coal-fired units in the electricity sector, the focus was on developing BLIERS for NO_x and SO_2 emissions. Agreement was reached by the parties in BLIERS standards for new coal units, but there is no agreement on whether BLIERS standards should be applied to existing coal units.[48] CASA compared the proposal to establish BLIERS for existing units with the current framework in Alberta and advocated for maintaining the existing regulatory system in Alberta, warning that "implementing BLIERs at existing coal-fired facilities will have the effect of negating much of the existing emissions management framework while resulting in no net (and probably negative) environmental gain or benefits."[49] This report and recommendation by CASA was presented to the CCME by Alberta's Environment Minister. The question of whether BLIERS should be established for existing coal units remains unresolved. Further discussion on this issue is anticipated between the federal government and Alberta in the near future.

3.2 Nitrogen oxides

3.2.1 As a pollutant

Nitrogen oxides (NO_x) consist of nitric oxide (NO) and nitrogen dioxide (NO_2). NO is a colourless, odourless gas, while NO_2 is a reddish-brown gas with a pungent and irritating odour. Nitric oxide is highly reactive, oxidizing rapidly in the atmosphere to form NO_2.[50] Nitrogen oxides play a key role in the formation of ground-level ozone and are a major contributor to the

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[45] Ibid.

[46] Canadian Council of Ministers of the Environment, *Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone* (2012). http://www.ccme.ca/assets/pdf/pn_1483_gdad_eng.pdf

[47] Canadian Council of Ministers of the Environment, "Air Quality Management System," 2012. http://www.ccme.ca/ourwork/air.html?category_id=146

[48] Environment Canada, *Performance Report on Environment Canada's 2011-2012 Departmental Sustainable Development Strategy*, 2012. http://www.ec.gc.ca/default.asp?lang=En&n=3E88484B-1&offset=5&toc=show

[49] CASA, *Electricity Working Group Report*.

[50] David Yap, Neville Reid, Gary De Brou and Robert Bloxam, *Transboundary Air Pollution in Ontario* (Ontario Ministry of the Environment, 2005). http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079137.pdf

formation of fine particulate matter.[51] Nitrogen dioxide is a precursor to ground-level ozone, which can exacerbate asthma attacks.[52] NO_x emissions also contribute to acid deposition and excessive nutrient input to soils and aquatic systems.

In accord with the CASA Framework recommendations, the emission standard for NO_x was revised in 2006 from the older rate of 1.25 t/GWh[53] to a new one, based on BATEA, of 0.69 t/GWh. Later, in 2010, the CASA EFR recommended that the intensity limit be further reduced to 0.47 t/GWh by the beginning of 2011. The current formal Alberta government air emission standards still reflect the 2006 standard of 0.69 t/GWh for NO_x, as shown in Figure 6. When dealing with facility applications, however, government staff members are referencing the de facto standard of 0.47 t/GWh as this is what would be required for a new facility based on CASA's EFR recommendations. To remove any confusion regarding this matter, the Government of Alberta needs to formalize this latest standard.

Coal plants emitted 78,335 tonnes of NO_x into Alberta's atmosphere in 2010 and in 2011, 71,507 tonnes, accounting for 10 per cent of Alberta's emissions of NO_x.[54,55]

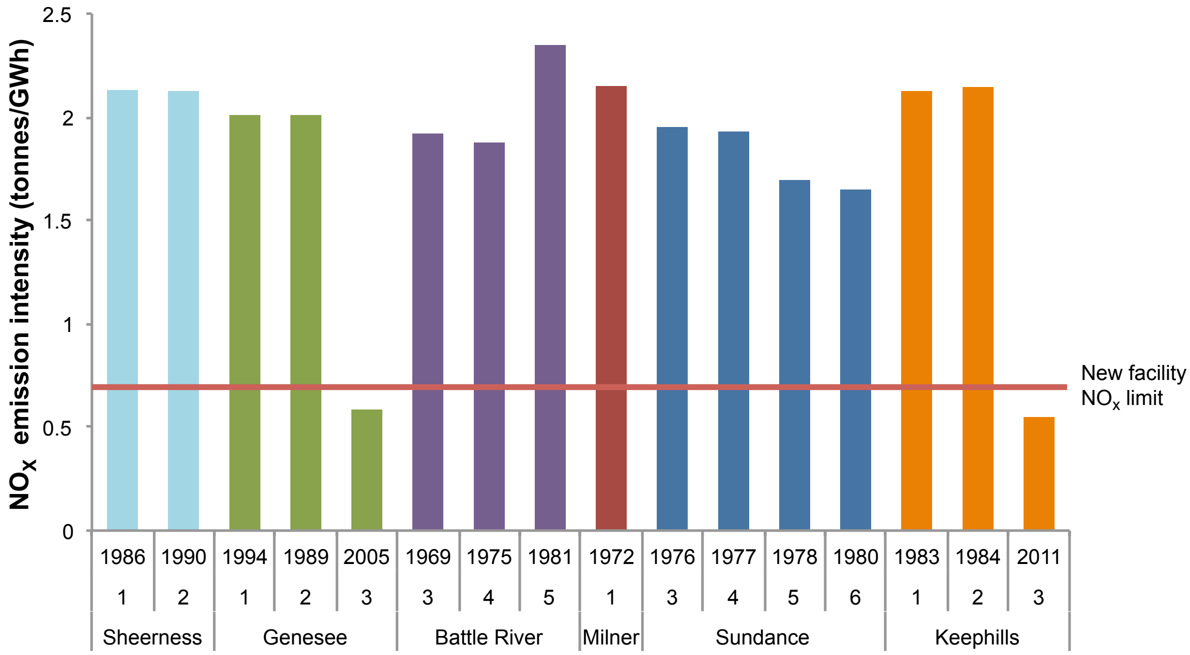

Figure 6. Nitrogen oxide (NO_x) emission intensities of Alberta's coal power units in 2011 relative to the regulated intensity standard

Includes year of commissioning for each unit.

Data source: Alberta Environment and Sustainable Resource Development[56]

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[51] Ibid.

[52] U.S. Environmental Protection Agency, "Sulphur dioxide [and] Health," *Six Common Air Pollutants.* http://www.epa.gov/air/sulfurdioxide/health.html

[53] Standards are often quoted in units of kg/MWh, which is the same as using units of t/GWh.

[54] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants," *National Pollutant Release Inventory,* 2012. http://www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=0EC58C98-

[55] Environment Canada, "2011 National, Provincial and Territorial Emission Summaries for Key Air Pollutants," *National Pollutant Release Inventory,* 2013. http://www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=0EC58C98-

3.2.2 Known health risks

Nitrogen dioxide has a greater effect on people with pre-existing respiratory problems. NO_2 is a lung irritant and can increase the chance of respiratory illness by lowering resistance to infection. People afflicted with asthma and bronchitis are generally more sensitive.[57] Exposure to very high levels of NO_x makes breathing difficult, especially for people who already suffer from asthma or bronchitis.[58]

3.3 Sulphur dioxide

3.3.1 As a pollutant

Sulphur dioxide (SO_2) is a colourless gas that smells like burnt matches. Sulphur dioxide is oxidized in the atmosphere to form sulphuric acid aerosols or sulphates, which are one of the main components of airborne fine particulate matter.[59]

Alberta's 24-hour mean ambient air quality objective for SO_2 was reduced from 150 $\mu g/m^3$ to 125 $\mu g/m^3$ in 2011.[60] In 2005, the World Health Organization revised its 24-hour mean ambient air quality guideline for SO_2 from 125 micrograms per cubic metre ($\mu g/m^3$) to 20 $\mu g/m^3$ because health effects are known to be associated with much lower levels of SO_2 than previously believed.[61]

In accord with the CASA Framework recommendations, the emission standard for SO_2 was revised in 2006 from the old, outdated rate of 1.8 t/GWh to 0.8 t/GWh based on BATEA. Later, in 2010, CASA recommended that the intensity limit be further reduced to 0.65 t/GWh or 90 per cent capture, whichever is less stringent, by the beginning of 2011. The current formal Alberta government air emission standards still reflect the 2006 standard of 0.8 t/GWh as shown in Figure 7. While 0.65 t/GWh has become the de facto standard for new applications as this is what would be required for a new facility based on CASA's EFR recommendations, to remove any confusion regarding this matter, the Government of Alberta should formalize this latest standard.

Coal plants in Alberta emitted 119,666 tonnes of SO_2 in 2010 and 114,511 tonnes of SO_2 in 2011, accounting for 33 per cent of Alberta's emissions of SO_2 to the air.[62,63]

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[56] Alberta Environment and Sustainable Resource Development, *Emissions Trading Registry: Summary of Annual Reports from Operators, 2006-2011*. Available at http://www.environment.alberta.ca/apps/etr/Documents.aspx

[57] Ibid.

[58] Health Canada, "Let's Talk About Health and Air Quality," *Environmental and Workplace Health,* 2006. http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/effe/talk-a_propos-eng.php

[59] Ontario Ministry of the Environment, *Air Quality in Ontario: 2009 Report* (2011), 11. http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_081228.pdf

[60] Alberta Environment and Sustainable Resource Development, *Alberta Ambient Air Quality Objectives and Guidelines Summary* (2013). http://environment.gov.ab.ca/info/library/5726.pdf

[61] World Health Organization, Air quality and health, Fact Sheet No. 313, 2011. http://www.who.int/mediacentre/factsheets/fs313/en/index.html

[62] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[63] Ibid.

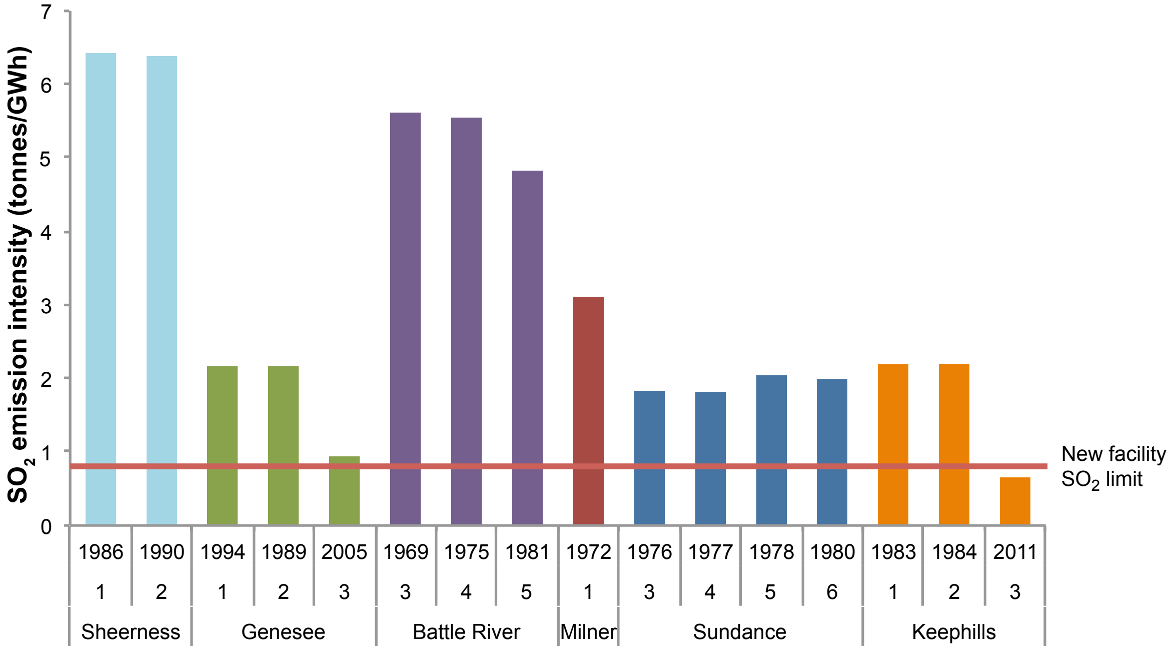

Figure 7. Sulphur dioxide (SO_2) emission intensities of Alberta's coal power units in 2011 relative to the regulated intensity standard

Includes year of commissioning for each unit.

Data source: Alberta Environment and Sustainable Resource Development[64]

3.3.2 Known health risks

SO_2 has been shown to negatively affect human embryo development. A greater and longer exposure to SO_2 emissions during the initial two months of pregnancy is associated with a significantly shorter gestation and lower body mass of newborns. At relatively high levels of exposure, SO_2 is a known cause of bronchoconstriction and worsened asthma symptoms as it can react with other substances in the air to create particulate matter.[65] There is some evidence that exposure to elevated SO_2 levels may increase hospital admissions and premature deaths.[66]

3.4 Mercury

3.4.1 As a pollutant

Mercury (Hg) is a toxic, persistent, bioaccumulative substance.[67] Mercury exists in the atmosphere primarily in the gas phase, as atomic (elemental) Hg_o vapour. In this form, it is generally resistant to reactions with other air contaminants. Elemental mercury is highly mobile

[64] Alberta Environment and Sustainable Resource Development, *Emissions Trading Registry: Summary of Annual Reports from Operators, 2006-2011*.

[65] U.S. EPA, "Sulfur dioxide [and] Health."

[66] Health Canada, "Let's Talk About Health and Air Quality."

[67] Canadian Council of Ministers of the Environment, *Canada-Wide Standards for Mercury Emissions from Coal-Fired Electric Power Generation Plants* (2006). www.ccme.ca/assets/pdf/hg_epg_cws_w_annex.pdf

in the environment due to its relatively high vapour pressure and long global atmospheric lifetime (estimated from several months to one year). Mercury can also be emitted as (or chemically transformed to) the more reactive form of ionic mercury, which reacts to form mercury chloride or mercury oxide (Hg^{2+}) and can be deposited over short distances by precipitation or dry deposition.[68] Coal power plants emit both elemental and ionic mercury. From the mid-eighteenth century until the present, mercury concentrations in the biosphere have increased; for example, the mercury concentration in the atmospheric compartment is estimated to have increased by a factor of three over this period of time.[69]

The Canadian Council of Ministers of the Environment developed Canada-wide standards for mercury emissions from coal-fired electric power plants in 2010. Provincial caps on mercury emissions from existing coal-fired electricity generating plants represented a 60 per cent national capture of mercury from coal burned, or 70 per cent including recognition for early action. Standards were also set for capture rates or emission limits for new plants, based on best available control technology.[70]

The framework recommendations made by CASA and adopted by the Government of Alberta are similar to those of the CCME. By March 31, 2007, coal-fired plants were required to submit proposals to Alberta Environment on how they would capture at least 70 per cent of the mercury in the coal they burn. Technology to reduce mercury emissions to this level had to be in place by the end of 2010 at the latest. Plants were then required to submit proposals to Alberta Environment for capturing 80 per cent of their mercury emissions by the end of 2012.[71] The CASA EFR recommended that the Government of Alberta further require coal facilities to have systems in place to capture 80 per cent of mercury by the beginning of 2013 but these recommendations have yet to be formally implemented.

Alberta's mercury emissions from coal-fired generating plants totaled 481 kg in 2008 (a 43 per cent decrease from 2007 levels) and 579 kg in 2009 (an increase of 17 per cent). Alberta's targeted cap for the industry for 2010 was 590 kg[72], which is equivalent to 70 per cent of mercury emissions being captured.[73] The actual emission level in 2010 from the coal plants was 643 kg, exceeding the cap by nine per cent.[74] Major reductions were made in 2011 (including, but not limited to, the unexpected shutdown of Sundance 1 and 2), reducing the amount emitted to 216 kg. This still represents 44 per cent of mercury emissions from man-made sources in

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68 Ibid.

69 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). www.nescaum.org/documents/rpt050315mercuryhealth.pdf/

70 Environment Canada, "Managing and Reducing Mercury: Canada-Wide Standard," *Pollution and Waste,* 2010. http://www.ec.gc.ca/mercure-mercury/default.asp?lang=En&n=C6953AC5-1

71 Alberta Environment, *Mercury and Power Plants: Facts at Your Fingertips* (2005). http://environment.alberta.ca/documents/mercuryEmissionsFactsheet2005.pdf

72 Canadian Council of Ministers of the Environment, *Canada-Wide Standard for Mercury Emissions from Coal-Fired Electric Power Generation Plants: 2009 Progress Report* (2011). http://www.ccme.ca/assets/pdf/cws_mercury_coalfired_2009rpt_e.pdf

73 Alberta Environment, *Mercury and Power Plants*.

74 Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

Alberta.[75] Figure 8 shows the emissions of mercury for each unit of electricity generation from coal facilities in Alberta in 2011.

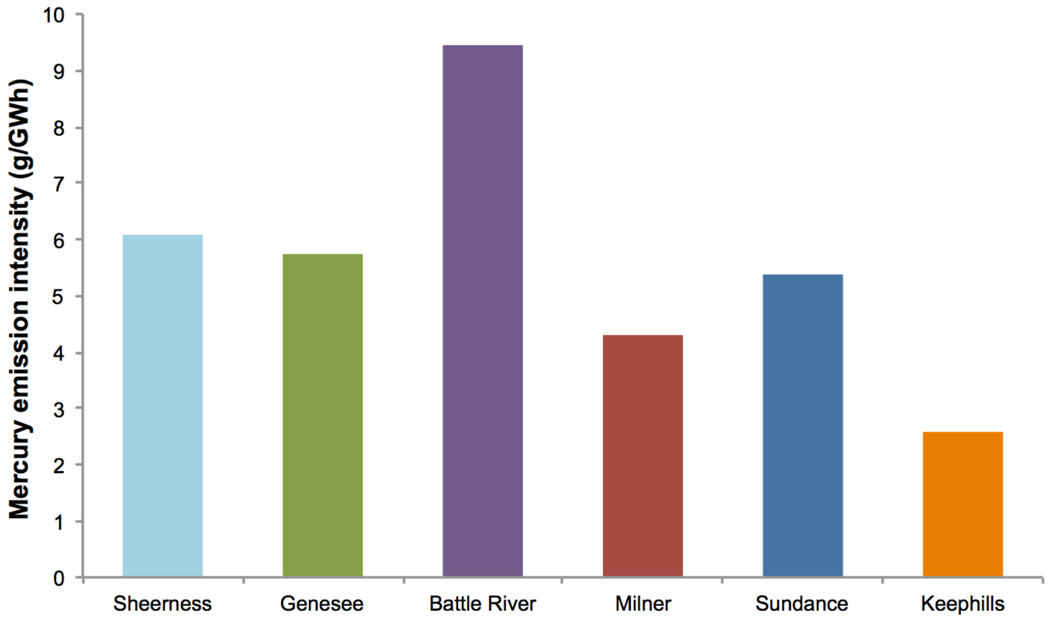

Figure 8. Mercury emissions intensities of coal-fired facilities in Alberta in 2011

Data source: Alberta Environment and Sustainable Resource Development, Environment Canada[76]

3.4.2 Known health risks

Methylmercury accumulates in fish and other species, damaging the central nervous system of these animals and causing reproductive failure; this has been observed in loons and river otters. Mercury can be taken up first by the lowest forms of life, algae, which in turn are consumed by smaller fish, and then by larger fish, which are consumed by people who eat fish.[77] Human exposure to mercury is primarily by eating contaminated fish.[78]

The body of scientific evidence that has evaluated the relationship between intrauterine methylmercury exposures and childhood neurodevelopmental delays has been thoroughly reviewed by the National Academy of Sciences.[79] Women of childbearing age, pregnant women, children, and populations who depend on fish as a traditional food source are most at risk.[80]

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[75] Environment Canada, "National Pollutant Release Inventory Online Data Search," http://www.ec.gc.ca/pdb/websol/querysite/results_e.cfm

[76] Alberta Environment and Sustainable Resource Development, *Emissions Trading Registry: Summary of Annual Reports from Operators, 2006-2011*.

Environment Canada, "National Pollutant Release Inventory Online Data Search." http://www.ec.gc.ca/pdb/websol/querysite/query_e.cfm

[77] Yap, et al., *Transboundary Air Pollution in Ontario.*

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

[79] Rice and Hammitt, *Economic Valuation of Human Health Benefits of Controlling Mercury Emissions from U.S. Coal-Fired Power Plants.*

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

Babies born to mothers exposed to methylmercury emissions are born with mercury-related losses of cognitive function. It is estimated that 3.2 per cent of mental retardation cases in the United States are attributable to methylmercury exposure and that the cost of these excess cases of mental retardation is $2.0 billion annually.[81] Based on these results, researchers have concluded that toxic injury to the fetal brain caused by mercury emitted from coal-fired power plants exacts a significant human and economic toll on children.[82]

Three studies grouped maternal exposure to methylmercury based on measured levels in the hair and evaluated the intelligence quotients (IQ) of the children born to the mothers in each group. An analysis that integrated the results of these studies produced an estimate of the reduction in IQ with each increment in mercury exposure. There was an average loss of 0.18 IQ points for each part per million of mercury measured in maternal hair.[83] Other studies have shown an even higher loss ranging from 0.6 to 1.4 IQ points lost per ppm of mercury in maternal hair.[84]

Mercury has been shown to negatively affect neurobehavioural endpoints (such as motor skills) in children that cannot be measured by an IQ test. Therefore, the monetized impacts of mercury based on IQ measurements are significant underestimates.[85]

The U.S. National Research Council has identified the possibility of additional health effects of mercury even at low levels of exposure, including immune and cardiovascular effects as well as neurological effects emerging later in life.[86] Epidemiological studies have reported an association between methylmercury exposures in males and increased risks of myocardial infarction and premature mortality.[87]

3.5 Particulate matter

3.5.1 As a pollutant

Solid particles and liquid droplets present in the air are referred to as particulate matter.[88] Particles are grouped into categories based on their size (aerodynamic diameter): coarse or inhalable particulate matter (PM_{10}) refers to particles less than 10 micrometres in size; fine or respirable particulate matter ($PM_{2.5}$) is less than 2.5 micrometres in size; and ultrafine particulate matter ($PM_{0.1}$) is smaller than 0.1 micrometres in aerodynamic diameter.

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81 L. Trasande, C. Schechter, K.A. Haynes, P.J. Landrigan, "Applying Cost Analyses to Drive Policy that Protects Children," *Annals of the New York Academy of Sciences*, 1076 (2006): 911.

82 Ibid.

83 U.S. Environmental Protection Agency, *Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards*, EPA-452/R-11-011 (2011). http://www.epa.gov/ttn/ecas/regdata/RIAs/matsriafinal.pdf

84 Rice and Hammitt, *Economic Valuation of Human Health Benefits of Controlling Mercury Emissions from U.S. Coal-Fired Power Plants.*

85 Ibid.

86 National Research Council of the National Academies, *Toxicological Effects of Methylmercury* (2000).

87 Rice and Hammitt, *Economic Valuation of Human Health Benefits of Controlling Mercury Emissions from U.S. Coal-Fired Power Plants.*

88 Alberta Environment, *Alberta Environment Summary Report on 2004 NPRI Air Emissions* (2006). http://environment.alberta.ca/0970.html

Fine particulate matter can include acid aerosols, metal fumes, organic chemicals, pollen and smoke. Particles can be emitted directly from combustion sources (referred to as "primary PM"), as in the case of elemental carbon, or can be formed when emissions of sulfur dioxide and nitrogen oxides react with ammonia ("secondary PM").[89]

In 2003, the Clean Air Strategic Alliance released a particulate matter and ozone management framework, which recommended strategies to achieve the Canada-wide standards for particulate matter and ozone in Alberta that were introduced by the CCME in 2000.[90] Alberta's current ambient air quality objective for $PM_{2.5}$ is 30 μg/m^3 over a 24-hour time frame based on the standards.[91] However, a planning trigger is invoked at 20 μg/m^3 over a 24-hour time frame that results in the preparation of a management plan.[92] This provides a more stringent action level that ensures that these standards are not levels that can be "polluted up to".[93]

The CCME has proposed CAAQS for fine particulate matter, which are stricter than the Canada-wide standards. The proposed 24-hour mean CAAQS for $PM_{2.5}$ is 28 μg/m^3 in 2015 and 27 μg/m^3 in 2020. On an annual basis, the proposed CAAQS are 10.0 μg/m^3 in 2015 and 8.8 μg/m^3 in 2020.[94]

Coal-fired power plants in Alberta emit a notable amount of fine particulate matter, but a relatively small portion of all emission sources in Alberta. Approximately six per cent of $PM_{2.5}$ from all man-made sources in the province comes from coal plants. Newer units emit significantly less $PM_{2.5}$ than older ones. Retirement of these older units will mean that coal plants will be responsible for a declining portion of overall emission sources. Particulate matter is also formed indirectly, and SO_2 is a major precursor for secondary formation; coal plants are responsible for 33 per cent of SO_2 emissions in Alberta[95]. Although secondary formation of $PM_{2.5}$ is a smaller contributor than direct emission, it has the greatest impact on human health.[96]

The Alberta government set the facility limit for primary PM that can be emitted by new facilities at 0.095 t/GWh, shown in Figure 9. The CASA EFR recommended in 2010 that this standard be tightened to 6.4 ng/J of heat input (~0.066 kg/MWh).

Alberta's coal plants emitted 2,009 tonnes of $PM_{2.5}$ in 2010 and 1,782 tonnes in 2011, accounting for six per cent of $PM_{2.5}$ emissions from man-made sources in Alberta. In 2010, coal-fired generating stations emitted 4,445 tonnes of PM_{10} and 6,800 tonnes of total particulate matter. In

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[89] Abt Associates, *Power Plant Emissions: Particulate Matter-Related Health Damages and the Benefits of Alternative Emission Reduction Scenarios*, prepared for Clean Air Task Force (2004). http://www.abtassociates.com/reports/Final_Power_Plant_Emissions_June_2004.pdf

[90] Clean Air Strategic Alliance, *Particulate Matter and Ozone Management Framework* (2003). http://www.casahome.org/Projects/ProjectsAdminController.aspx?Command=Core_Download&EntryId=636

[91] Alberta Environment and Sustainable Resource Development, *Alberta Ambient Air Quality Objectives and Guidelines Summary*.

[92] Alberta Environment and Sustainable Resource Development, *Particulate Matter And Ozone Management Fact Sheet (2009 - 2011)* (2013). http://environment.gov.ab.ca/info/library/8770.pdf

[93] Ibid.

[94] CCME, *Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone.*

[95] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[96] *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*, Table 18.

2011, coal plants emitted 3,872 tonnes of PM_{10} and 6,045 tonnes of total particulate matter (the sum of fractions larger and smaller than 10 micrometres in aerodynamic diameter).[97,98]

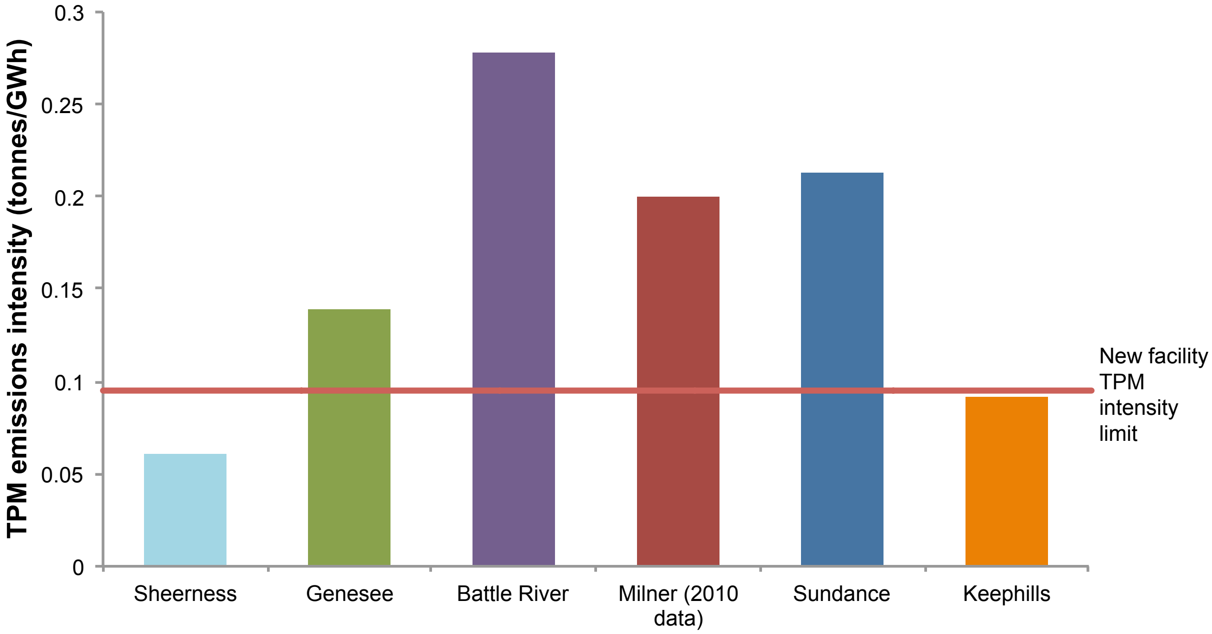

Figure 9. Total particulate matter emission intensities of Alberta's coal power units in 2011 relative to the regulated intensity standard

Data source: Environment Canada[99]

3.5.2 Known health risks

Health impacts of exposure to particulates depend on the composition of the particles, which may vary with season.[100] The coarse fraction of PM_{10} can deposit widely within the lung but it is more likely to deposit in the upper portions. Both $PM_{2.5}$ and $PM_{0.1}$ penetrate deep into the lungs and elicit a range of physiological responses and can even enter into the bloodstream.[101] Exposure to ambient particulate matter is associated with dose-dependent increases in morbidity and mortality.[102]

Particulate matter has been associated with hospitalizations and increased respiratory and cardiovascular mortality. It has also been associated with asthma exacerbation, inflammation and

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[97] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[98] Environment Canada, "2011 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[99] Environment Canada, National Pollution Release Inventory – 2010 NPRI Reviewed Facility, http://www.ec.gc.ca/pdb/websol/querysite/query_e.cfm

[100] Health Canada, *Human Health in a Changing Climate: A Canadian assessment of vulnerabilities and adaptive capacity*, Jacinthe Séguin, editor (2008), 120. Available at http://www.2degreesc.com/Files/CCandHealth.pdf

[101] Ibid.

[102] M.I. Gilmour et. al., "Comparative toxicity of size-fractionated airborne particulate matter obtained from different cities in the United States," *Inhalation Toxicology*, 19 No. s1 (2007), 7.

changes in heart rate variability.[103,104,105] Exposure to particulate matter has also been associated with increased incidence of respiratory diseases including chronic obstructive pulmonary disease, cancer and pneumonia. Short-term exposure to fine particulate matter has also been associated with increased incidence of cardiac disease including cardiovascular disease and ischaemic heart disease; it also places people at higher risk of heart failure.[106,107] Long-term exposure to fine particulate matter increases the risk of mortality from cardiovascular illness.[108]

Children, the elderly and people with pre-existing medical conditions are more vulnerable to the health impacts of particulate matter.[109] For example, diabetics suffer from reduction in vascular function due to exposure to $PM_{2.5}$ associated with coal-burning power plants.[110] A significant direct effect of $PM_{2.5}$ on lung function was found in asthmatic children resulting from exposure to particulate matter and an effect through interaction between particulate matter and meteorological conditions.[111]

Both short-term (from days to a few weeks) and long-term (multi-year) exposure to $PM_{2.5}$ are associated with adverse health effects.[112] A slight increase in the fine particulate matter level has been associated with an increase in both lung cancer and cardiopulmonary mortality health risks.[113]

3.6 Lead

3.6.1 As a pollutant

Lead has been used extensively for the past 2,000 years; most recently it was used as a gasoline additive before being phased out in Canada in the 1980s. As a result, lead has become widely distributed at low levels throughout the environment.[114]

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[103] S.T. Ebelt, W.E. Wilson and M. Brauer, “Exposure to ambient and nonambient components of particulate matter: A comparison of health effects,” *Epidemiology* 16 (2005), 396.

[104] H. Gong, Jr. et al., “Controlled exposures of healthy and asthmatic volunteers to concentrated ambient fine particles in Los Angeles,” *Inhalation Toxicology* 15 (2003), 305.

[105] R. McConnell et al., “Air pollution and bronchitic symptoms in southern California children with asthma,” *Environmental Health Perspectives* 107 (1999), 757.

[106] L.D. Pengelly and J. Sommerfreund, *Air Pollution-Related Burden of Illness in Toronto: 2004 Update*, prepared for City of Toronto (2004). http://www.toronto.ca/health/hphe/pdf/air_and_health_burden_technical.pdf

[107] F. Dominici et al., “Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases,” *Journal of the American Medical Association* 295 (2006), 1127.

[108] D.W. Dockery et al., “An association between air pollution and mortality in six U.S. cities,” *New England Journal of Medicine* 329 (1993), 1753.

[109] Health Canada, *Human Health in a Changing Climate*.

[110] M.S. O'Neill et. al., “Diabetes enhances vulnerability to particulate air pollution-associated impairment in vascular reactivity and endothelial function,” *Circulation* 111 (2005), 2913.

[111] R. Peled et. al., “Fine particles and meteorological conditions are associated with lung function in children with asthma living near two power plants,” *Public Health* 119 (2005), 418.

[112] *Air Quality in Ontario: 2009 Report,* 6.

[113] C. Arden Pope III et al., “Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution,” *Journal of the American Medical Association* 287 (2002) 1132.

[114] N.N. Greenwood and A. Earnshaw, *Chemistry of the Elements* (Oxford: Pergamon Press, 1984).

Although control technologies to reduce emissions of other pollutants provide some co-benefit of reducing lead emissions, in 2010, coal-fired generating stations in Alberta emitted 1,022.4 kg of lead into the atmosphere, which was eight per cent of the lead emitted in the province in 2010.[115] In 2011, the amount emitted to the air by coal plants nearly doubled to 2,002 kg, accounting for 15 per cent of the lead emitted from all sources in the province.[116]

3.6.2 Known health risks

Lead can be absorbed by the body through inhalation, ingestion, dermal contact (mainly as a result of occupational exposure)[117] or transfer via the placenta.[118] In adults, approximately 10 per cent of ingested lead is absorbed into the body[119] whereas the gastrointestinal absorption rate in children has been estimated as 30 per cent for lead in soil and dust.[120] Young children absorb from 40 to 53 per cent of lead ingested from food.[121,122]

Lead is a cumulative general poison, with fetuses, infants, children up to six years of age and pregnant women being most susceptible to adverse health effects. Signs of chronic lead toxicity (long term, low dose) include tiredness, sleeplessness, irritability, headaches, joint pain and gastrointestinal symptoms.[123]

Lead affects various systems of the body. Both the central and peripheral nervous systems are principal targets for lead toxicity.[124] Reproductive dysfunction has been observed in men and women occupationally exposed to lead.[125] A link has also been suggested for lower, environmentally encountered levels. Exposure of pregnant women to lead also increases the risk of pre-term delivery,[126] as well as minor birth malformations.[127]

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[115] Environment Canada, “2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants.”

[116] Environment Canada, “2011 National, Provincial and Territorial Emission Summaries for Key Air Pollutants.”

[117] M.R. Moore, P.A. Meredith, W.S. Watson, D.J. Sumner, M.K. Taylor and A. Goldberg, “The percutaneous absorption of lead-203 in humans from cosmetic preparations containing lead acetate, as assessed by whole-body counting and other techniques,” *Food and Cosmetics Toxicology*, 18 (1980), 399.

[118] N.F.Angell and J.P. Lavery, “The relationship of blood lead levels to obstetric outcome,” *American Journal of Obstetrics and Gynecology*, 142 (1982), 40.

[119] U.S. Environmental Protection Agency, *Air quality criteria for lead,* EPA-600/8-83/028F (1986).

[120] U.S. Environmental Protection Agency, *The environmental lead problem: an assessment of lead in drinking water from a multi-media perspective*, EPA-570/9-79-003 (1979).

[121] F.W. Alexander, “The uptake of lead by children in differing environments,” *Environmental Health Perspectives* 7 (1974), 155.

[122] E.E. Ziegler, B.B. Edwards, R.L. Jensen, K.R. Mahaffey and S.J.Fomon, “Absorption and retention of lead by infants,” *Pediatric Research*, 12 (1978) 29.

[123] H. Hänninen, P. Mantere, S. Hernberg, A.M. Seppäläinen and B. Kock, “Subjective symptoms in low-level exposure to lead,” *Neurotoxicology* 1 (1979), 333.

[124] Health Canada, *Final Human Health State of the Science Report on Lead* (2013), 50. http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/pubs/contaminants/dhhssrl-rpecscepsh/dhhssrl-rpecscepsh-eng.pdf

[125] Ibid, 55.

[126] A.J. McMichael, G.V. Vimpani, E.F. Robertson, P.A. Baghurst and P.D. Clark, “The Port Pirie cohort study: maternal blood lead and pregnancy outcome,” *Journal of Epidemiology and Community Health* 40 (1986), 18.

[127] H. Needleman, M. Rabinowitz, A. Leviton, S. Linn and S. Schoenbaum, “Relationship between prenatal lead exposure and congenital anomalies,” *Journal of the American Medical Association* 251 (1984), 2956.

In children, lead exposure has been linked to anemia, stunted growth and disruption of bone maintenance.[128] Exposure of children to lead from air pollution may be associated with lower IQ and lower ability to maintain attention.[129]

3.7 Cadmium

3.7.1 As a pollutant

Cadmium is a toxic heavy metal. Atmospheric cadmium compounds (e.g., cadmium oxide) exist predominantly in a particulate form. Fine particulates are more easily incorporated into body tissues than larger fractions. Cadmium compounds have relatively short residence times in the troposphere (up to 10 km above the surface) of one to four weeks and are removed from air by precipitation and dry deposition.[130] Cadmium does not break down in the environment, but its mobility, bioavailability, and residence times in different environmental media may be affected by physical and chemical processes.

Although control technologies to reduce emissions of other pollutants provide some co-benefit of reducing cadmium emissions, coal-fired generating stations in Alberta emitted 80.6 kg of cadmium into the atmosphere in 2010, constituting 10 per cent of Alberta's cadmium emissions.[131] In 2011, air emissions of cadmium from Alberta's coal plants rose to 509 kg, making up 56 per cent of emissions of cadmium from all sources.[132]

3.7.2 Known health risks

Renal tubular dysfunction (a form of kidney disease) has been observed in populations exposed to cadmium in the general environment.[133,134] There is evidence that environmental exposure may result in a progressive worsening of cadmium-induced renal dysfunction, even after exposure has ceased.[135,136] Exposure to cadmium in the environment may be associated with decreased neuropsychological development and with various forms of cancer, but further studies are required to confirm that the health effects observed are linked to cadmium exposure and not other toxic contaminants also found in the environment.[137]

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[128] Health Canada, *Final Human Health State of the Science Report on Lead,* 3.

[129] A. Hatzakis et al. "Psychometric Intelligence and Attentional Performance Deficits in Lead-Exposed Children," in *Heavy metals in the environment,* vol. 1, S.E. Lindberg and T.C. Hutchinson, eds. (Athens: Athens University Medical School, 1987), 204.

[130] Government of Canada, *Priority Substances List Assessment Report: Cadmium and its Compounds,* 8. http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contaminants/psl1-lsp1/cadmium_comp/cadmium_comp-eng.pdf

[131] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[132] Environment Canada, "2011 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[133] J.P. Buchet et al., "Renal Effects of Cadmium Body Burden of the General Population," *Lancet* 336 (1990), 699.

[134] R. Lauwerys and P. De Wals, "Environmental Pollution by Cadmium and Mortality from Renal Diseases." *Lancet*, 1 (1981) 383.

[135] T. Kido et al, "Progress of Renal Dysfunction in Inhabitants Environmentally Exposed to Cadmium," *Archives of Environmental Health* 43 (1988), 213.

[136] T. Kido et al, "Long-term Observation of Serum Creatinine and Arterial Blood pH in Persons with Cadmium-induced Renal Dysfunction," *Archives of Environmental Health* 45 (1990), 35.

[137] *Priority Substances List Assessment Report: Cadmium and its Compounds.*

3.8 Dioxins and furans

3.8.1 As a pollutant

There are 210 different dioxins and furans. These substances vary widely in toxicity.[138] Dioxins and furans are persistent and bioaccumulative, working their way up the food chain and remaining stored in body fat.[139] Ninety per cent of people's overall exposure to dioxins is estimated to be from the diet. Meat, milk products and fish have higher levels of dioxins and furans than fruit, vegetables and grains.[140] Coal-fired electricity generating stations emitted 1.59 g of dioxins and furans in Alberta in 2010, representing 24 per cent of all man-made sources in the province, and 1.30 g in 2011, which was 34 per cent of all man-made sources.[141,142]

3.8.2 Known health risks

Exposure to dioxins and furans has been associated with a wide range of adverse health effects in laboratory animals and humans. The risk of health effects depends on many factors. The way a person is exposed (e.g., through food, air, water, etc.), how much a person is exposed to, and when (e.g., whether it is a large amount on one occasion, or daily exposure to small amounts) all affect the impact on an exposed person's health. An individual's susceptibility, including one's general state of health and whether the person is also exposed to other substances that may be associated with health effects, will also affect the degree to which one's health is impacted.[143]

Health Canada has identified several effects associated with human exposure to dioxins. These are skin disorders, such as chloracne, liver problems, and impairment of the immune system, the endocrine system and reproductive functions, effects on the developing nervous system and other developmental events, and certain types of cancers.[144]

3.9 Hexachlorobenzene

3.9.1 As a pollutant

At ambient temperature, hexachlorobenzene (HCB) is a white crystalline solid. It is virtually insoluble in water but is soluble in ether, benzene, chloroform and hot ethanol. Hexachlorobenzene is widely distributed throughout the Canadian environment because it is mobile and resistant to degradation. Organisms generally accumulate HCB from water and from food. HCB is substantially magnified as it moves up the food chain.[145]

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[138] Health Canada, "Dioxins and Furans," *It's Your Health*. http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/dioxin-eng.php

[139] Ibid.

[140] Ibid.

[141] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[142] Environment Canada, "2011 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[143] Health Canada, "Dioxins and Furans."

[144] Ibid.

[145] Government of Canada, *Priority Substances List Assessment Report: Hexachlorobenzene,* 23. http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contaminants/psl1-lsp1/hexachlorobenzene/hexachlorobenzene-eng.pdf

Coal plants in Alberta emitted 1,680 g of HCB in 2010 and 1,481g in 2011, accounting for 57 per cent of the HCB emitted to the air from all sources in Alberta that year.[146,147]

3.9.2 Known health risks

Hexachlorobenzene is a probable human carcinogen and considered to be a non-threshold toxicant, which is "a substance for which there is believed to be some chance of adverse health effect at any level of exposure".[148] People living near industrial sources may be exposed to higher levels of HCB than the general population. In a study of exposures to HCB, it was shown that among the general population in Canada, babies from newborn to six months of age are exposed to levels of HCB one hundred times higher than an adult (in nanograms of HCB per kilogram of body weight per day) from the mother's breast milk.[149]

HCB is known to be highly toxic to aquatic organisms, and is also a persistent pollutant that biomagnifies up the food chain.[150] It is one of the twelve Persistent Organic Pollutants globally prohibited under the Stockholm Convention for which the United Nations is calling for "urgent global actions to reduce and eliminate releases."[151]

3.10 Arsenic

3.10.1 As a pollutant

Arsenic is a metallic element found in the Earth's crust. Organic arsenic (arsenic combined with carbon compounds) may be found in fish and is considered safe. Inorganic arsenic (not combined with carbon) is not.[152] Industrial activity including coal-fired electricity generation can contaminate water with inorganic arsenic.

Five of the seven coal plants that were operating in Alberta in 2010 reported arsenic air emissions and releases to water; they reported releasing 222.3 kg of arsenic that year.[153] Air emissions from these plants rose in 2011 to a total of 254 kg, while another 63 kg were released into water.[154] All facilities reported disposals of arsenic. Disposal of arsenic in tailings and mine waste from Alberta's coal plants amounted to 39,345 kg in 2011. A study conducted over the

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[146] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[147] Environment Canada, "2011 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[148] *Priority Substances List Assessment Report: Hexachlorobenzene,* v.

[149] Ibid, 26.

[150] Ibid, 23.

[151] United Nations Environment Programme – Chemicals, "Persistent Organic Pollutants." http://www.chem.unep.ch/pops/

[152] Canadian Cancer Society, "Arsenic in drinking water." http://www.cancer.ca/Alberta-NWT/Prevention/Harmful%20substances%20and%20environmental%20risks/Arsenic%20in%20drinking%20water.aspx?sc_lang=en

[153] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[154] National Pollutant Release Inventory, Arsenic (and its compounds), 2012. http://www.ec.gc.ca/pdb/websol/querysite/query_e.cfm

period 1994 to 1997 in the Wabamun Lake area revealed total deposition of arsenic during this period of 2.03 g per hectare.[155]

3.10.2 Known health risks

Arsenic is a toxic substance that is known to cause skin, lung, bladder, liver, kidney, and prostate cancers.[156] Long-term low levels of exposure can lead to abnormal heart rhythm, decreased red and white blood cells production, and damage to blood vessels and nerve functions.[157]

3.11 Polycyclic aromatic hydrocarbons

3.11.1 As a pollutant

Polycyclic aromatic hydrocarbons (PAHs) are a large class of organic compounds that contain carbon and hydrogen and consist of two or more fused aromatic rings.[158] They are formed during combustion of carbon-containing materials, including coal. PAHs have been accumulating in the sediment of lakes near coal-fired generating stations in Alberta. One study measured annual influx of PAHs to Wabamun Lake of 730 to 1,100 micrograms per metre per year, while PAHs at nearby Lac Ste. Anne (20 km north) were building up at a rate of 190 to 420 micrograms per metre per year. A little farther away, PAH influx to Pigeon Lake (70 km south) was 140 to 240 micrograms per metre per year.[159] The concentration of PAHs measured in sediments in Wabamun Lake were measured in 2001 at 2,756 ng/g dry weight, which is nearly three times higher than found in the sediments in the lake with the highest concentrations of PAHs near the oil sands.[160]

3.11.2 Known health risks

PAHs can be absorbed by the lungs, digestive system and skin because they are associated with the fine particulate matter emitted by coal plants. Some PAHs are known carcinogens.[161]

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[155] F.Goodarzi and H. Sanei, *The Deposition of Trace Elements on the Land/Surface Soil in the Wabamun Lake area, Alberta, Canada* (Geological Survey of Canada, 2002).

[156] Canadian Cancer Society, "Arsenic in drinking water,"

[157] National Library of Medicine, "Arsenic," *Tox Town*, 2012. http://toxtown.nlm.nih.gov/text_version/chemicals.php?id=3

[158] U.S. Department of Health and Human Services, *Report on Carcinogens*, Twelfth Edition (2011), 353. http://ntp.niehs.nih.gov/ntp/roc/twelfth/profiles/PolycyclicAromaticHydrocarbons.pdf

[159] W.F. Donahue, E.W. Allen and D.W. Schindler, "Impacts of coal-fired power plants on trace metals and polycyclic aromatic hydrocarbons (PAHs) in lake sediments in central Alberta, Canada," *Journal of Paleolimnology* 35 (2006), 111.

[160] Joshua Kurek et al., "Legacy of a half century of Athabasca oil sands development recorded by lake ecosystems," *Proceedings of the National Academies of Sciences*, 110 (2013).

[161] G. Liu, Z. Niu, D. Van Niekerk, J. Xue and L. Zheng, "Polycyclic aromatic hydrocarbons (PAHs) from coal combustion: emissions, analysis, and toxicology," *Reviews of Environmental Contamination and Toxicology* 192 (2008), 1. http://www.ncbi.nlm.nih.gov/pubmed/18020302

3.12 Ground-level ozone

3.12.1 As a pollutant

Ground-level ozone (O_3) is a secondary pollutant, formed when two main pollutants, nitrogen oxides and volatile organic compounds (VOCs), react in sunlight and stagnant air.[162] Because sunlight is needed for the reaction, air levels of ozone are also related to the weather and time of the day, and are higher in the summer months in Canada.[163] Coal plants emitted 383 tonnes of VOCs in 2010 and 313 tonnes of VOCs in 2011.[164,165] The upstream petroleum industry is the largest source of man-made VOCs in Alberta (321,337 tonnes emitted in 2011), accounting for 68 per cent of VOC emissions.[166] Coal plants are responsible for 10 per cent of the NO_x air emissions in Alberta.[167]

3.12.2 Known health risks

The main health impacts of ozone include acute and chronic damage to the respiratory system, with increased airway reactivity, airway permeability and airway inflammation, reduction in lung function, and increased respiratory symptoms.[168] Studies have linked ozone to reduced lung capacity in healthy adults and children, an increased rate of respiratory infections such as bronchitis and pneumonia particularly among young children, increased hospitalizations for lung disease, and increased rates of non-traumatic deaths.[169,170] Not only can ozone aggravate asthma symptoms, it has also been found that ozone may actually contribute to the development of the disease.[171]

People exposed to ozone can experience a variety of symptoms including coughing and wheezing, chest discomfort, reduced lung function, shortness of breath, and irritation of eyes, nose and throat.[172] Certain populations are at greater risk. Children who are active outdoors during the summer, when ozone levels are highest, are particularly at risk. Individuals with preexisting respiratory disorders, such as asthma and chronic obstructive pulmonary disease, are

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[162] Health Canada, "Let's Talk About Health and Air Quality."

[163] Kim Perrotta, *Beyond Coal: Power, Public Health and the Environment* (Ontario Public Health Association, 2002), 20. http://www.opha.on.ca/resources/docs/coal.pdf

[164] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[165] Environment Canada, "2011 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[166] Ibid.

[167] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[168] Health Canada, *Human Health in a Changing Climate.*

[169] Toronto Public Health, *Lakeview Generating Station – Health and Environmental Impacts* (2000). Board of Health Report summarizing background report entitled, Air Quality Modelling of Emissions from the Lakeview Generating Station prepared by SENES Consultants Limited.

[170] Ontario Medical Association, *Position Paper on Health Effects of Ground-Level Ozone, Acid Aerosols & Particulate Matter* (1998). Available at http://www.godel.net/environment/smog/OMAgroundlevelozone.htm

[171] John Peters, *Epidemiological Investigation to Identify Chronic Health Effects of Ambient Air Pollutants in Southern California*, prepared for the California Air Resources Board and the California Environmental Protection Agency (2001). http://www.arb.ca.gov/research/apr/past/94-331a.pdf

[172] Health Canada, "Ozone," *Environmental and Workplace Health*, 2010. http://www.hc-sc.gc.ca/ewh-semt/air/in/poll/ozone/index-eng.php

also at risk.[173] Effects on the respiratory system appear to be worsened as the duration of exposure to ozone increases. However, short-term exposure to ozone has also been associated with various cardiovascular effects including acute myocardial infarction,[174] arrhythmias[175] and heart rate variability.[176] The number of people who are potentially susceptible to the effects of ozone is potentially large given that 45 per cent of all deaths in Canada result from cardiopulmonary disease.[177]

3.13 Pollutants in a mixture

3.13.1 As pollutants

The air that we breathe is a dynamic mixture of numerous components. The composition of air at any given place or time depends on many natural and human-related factors and influences including industrial air emissions. We are exposed daily to a suite of pollutants, and the mixture of these pollutants can have different health impacts when combined than individual pollutants have on their own.

3.13.2 Health risks

There are various mechanisms by which pollutants can interact. The presence of one pollutant may influence the body's ability to protect against another pollutant. For example, metals damage biological defenses that exist in the body to serve as protective mechanisms against other toxic contaminants. Even though a metal may not exist in sufficient amounts to cause any disability, toxicity could result from exposure to other pollutants.[178] Negative synergism can occur when two pollutants act at the same or different steps in the same mechanistic pathway in the body. A third way that synergism happens is when the presence of one pollutant influences the dose of another pollutant.[179]

Matters are complicated however by the fact that synergistic, additive, and antagonistic effects are observed among different outcomes or at different times after exposure to mixtures of pollutants.[180] Among the co-pollutants that have demonstrated synergy are particulate matter, cigarette smoke, sulphuric acid, nitric acid and NO_2.[181]

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173 *Air Quality in Ontario: 2009 Report,* 2.

174 J.B. Ruidavets, M. Cournot, S. Cassadou, M. Giroux, M. Meybeck and J. Ferrières, "Ozone air pollution is associated with acute myocardial infarction," *Circulation* 111 (2005), 563.

175 D.W. Dockery et al., "Association of air pollution with increased incidence of ventricular tachyarrhythmias recorded by implanted cardioverter defibrillators," *Environmental Health Perspectives,* 113 (2005), 670.

176 S.K. Park, M.S. O'Neill, P.S. Vokonas, D. Sparrow and J. Schwartz, "Effects of air pollution on heart rate variability: The VA normative aging study," *Environmental Health Perspectives,* 113 (2005), 304.

177 Health Canada, *Human Health in a Changing Climate*.

178 Girja S. Shukla and Radhey L. Singhal, "The present status of biological effects of toxic metals in the environment: lead, cadmium, and manganese," *Canadian Journal of Physiology and Pharmacology* 62 (1984), 1015. http://www.nrcresearchpress.com/doi/abs/10.1139/y84-171

179 Joe L. Mauderly and Jonathan M. Samet, Is There Evidence for Synergy Among Air Pollutants in Causing Health Effects?, *Environmental Health Perspectives* 117 (2009), 1.

180 Ibid.

181 Ibid.

Although much research has gone into understanding the health effects of individual pollutants, very little is known about the effects of exposure to a mixture of pollutants. It is thus impossible to fully understand the health effects of the mixture of emissions from coal-fired generating stations, let alone with their interactions with other pollutants in the province. Not accounting for the interactions among pollutants in the body underestimates the health impacts and the economic damage estimates that follow.

Because we are simultaneously exposed to a complex mixture of air pollutants, it is sensible to take a multi-pollutant approach to air quality. The health burden from this simultaneous exposure to multiple pollutants may differ from the sum of individual effects estimated from single pollutant models.[182]

3.14 Greenhouse gases

3.14.1 As a pollutant

Globally, coal produces more greenhouse gas emissions than any other fossil fuel.[183] Coal power emits at least twice as much greenhouse gases for the same amount of electricity generated as natural gas — the next most polluting major source of electricity generation in Canada. The average coal-fired power plant in Alberta releases 1,053 tonnes of CO_2e for each GWh of electricity it produces.[184] Keephills 3 is the most recent coal unit built in Canada, and while it is notably more efficient than previous coal plants, its GHG intensity is still 848 t/GWh, twice the federal limit for plants built after 2015.

Because of coal power's high GHG intensity, combined with Alberta's continued heavy reliance on coal power, electricity in Alberta is the most GHG intensive in Canada. The Canadian average for GHG intensity from electricity generation in 2010 was 190 t/GWh; Alberta's average was 840 t/GWh — over four times as high.[185] It is clear that electricity grid GHG intensity is uniquely high in the provinces that rely on coal power — the non-coal-burning provinces do not come close to the national average that is buoyed by the coal-burning provinces (see Figure 10).

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[182] Francesca Dominici, Roger D. Peng, Christopher D. Barr, and Michelle L. Bell, "Protecting Human Health from Air Pollution: Shifting from a Single-Pollutant to a Multi-pollutant Approach," *Epidemiology* 21(2010), 187.

[183] International Energy Agency, *CO_2 Emissions from Fuel Combustion — Highlights* (2012), 18. http://www.iea.org/co2highlights/co2highlights.pdf

[184] Alberta Environment and Sustainable Resource Development, *Report on 2010 Greenhouse Gas Emissions* (2012). http://environment.alberta.ca/04055.html.

[185] Environment Canada, *National Inventory Report: 1990-2010* (2012), Part 3, 36, 45. Available at http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/can-2012-nir-11apr.zip

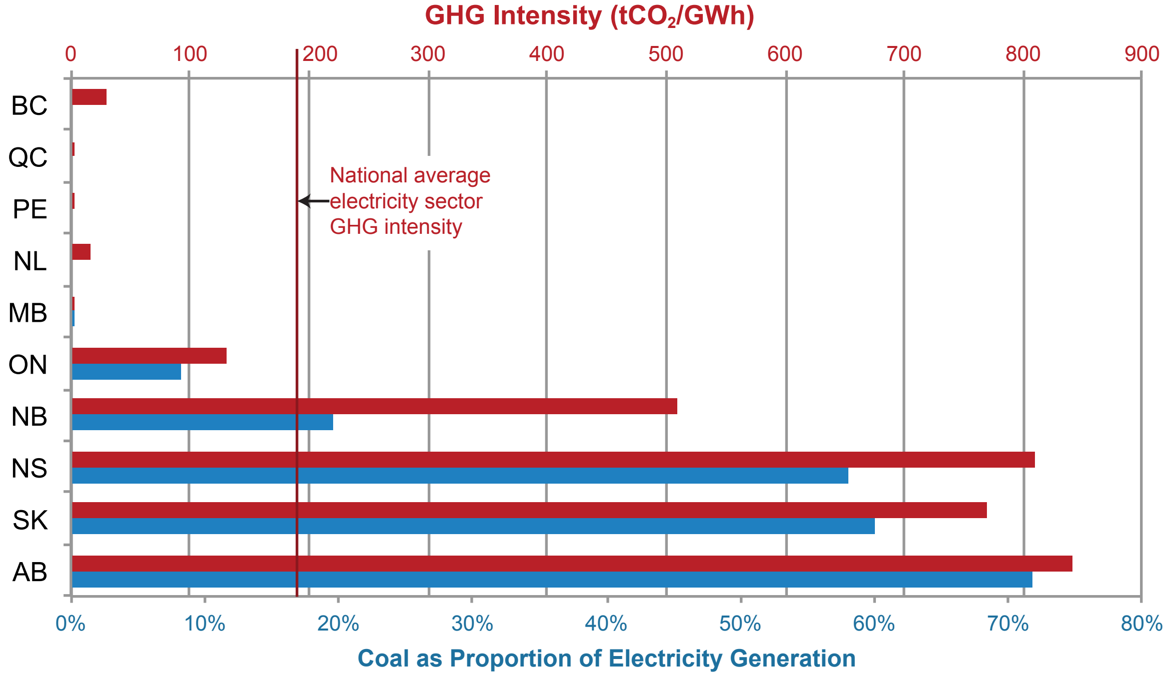

Figure 10. Provincial dependence on coal-fired electricity and electricity sector GHG intensity

Data source: Statistics Canada and Environment Canada[186]

Coal facilities, large electricity generators with by far the largest electricity generation GHG intensity are, not surprisingly, some of the largest GHG-emitting facilities in the province. In 2010, Alberta's coal-fired power plants emitted 43.2 megatonnes (Mt) CO_2e of GHGs, 18.5 per cent of all GHG emissions in the province.[187] This is second only to the 46.8 Mt emitted by all oil sands operations in the province, which includes oil sands in situ extraction as well as oil sands mining and upgrading (see Figure 11).[188] In fact, of Alberta's top seven GHG emitters in 2010, five were coal plants.[189] These same five coal plants also make up half of the top-10 list of the largest GHG emitters in Canada.[190]

[186] Statistics Canada, CANSIM Table 127-0006; Environment Canada, *National Inventory Report: 1990-2010*, Part 3, 36-45.

[187] Alberta Environment and Sustainable Resource Development, *Regulating Greenhouse Gas Emissions*, http://environment.alberta.ca/0915.html; Alberta Environment and Sustainable Resource Development, *Report on 2010 Greenhouse Gas Emissions.*

[188] Alberta Environment and Sustainable Resource Development, *Report on 2010 Greenhouse Gas Emissions.*

[189] Ibid.

[190] Tim Weis et al., *The High Costs of Cheap Power: Pollution from coal-fired electricity in Canada* (Pembina Institute, 2012), 4. http://www.pembina.org/pub/2349

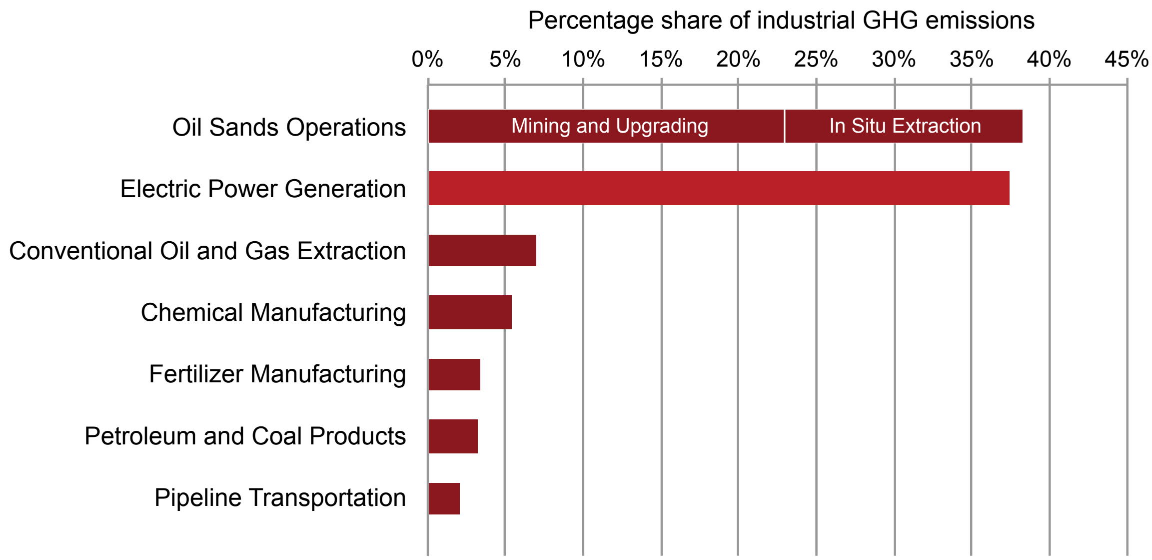

Figure 11. Industrial sources of greenhouse gas emissions in Alberta (2010)

Data source: Alberta Environment and Sustainable Resource Development[191]

In light of the unmatched GHG emissions from coal power among electricity generators and the wealth of alternative, lower-emitting options for electricity generation in the province, Alberta's heavy reliance on coal power is a major aspect of the province's GHG emissions problem. Alberta is the leading GHG emitter in Canada. In fact, Alberta's per capita GHG emissions from fuel combustion are higher than any of the countries in the world — 30 per cent higher than the next-highest per capita emissions country, Qatar.[192]

3.14.2 Health risks

Alberta's coal power greenhouse gas emissions will impact the health of Albertans — and global citizens more broadly — through their contributions to global climate change. Greenhouse gas emissions do not obey political boundaries. As such, Alberta's GHG emissions will not specifically impact Albertans; along with all other sources of global GHG emissions, they are expected to impact the health of Albertans and non-Albertans as well, though in different ways and to different extents.

The impacts of climate change can be categorized into two groups, depending on the proximity in causation between climate change and the health impact:

1. Direct exposures: "deaths and injuries resulting from violent storms and illnesses and distress related to extreme heat events" along with other long-term health effects of direct exposures; and
2. Indirect exposures: "the result[s] of changes induced by climate on other systems" — for example, "by creating conditions favourable to the occurrence of infectious disease outbreaks from food or water contamination, or the formation of smog."[193]

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[191] Alberta Environment and Sustainable Resource Development, *Report on 2010 Greenhouse Gas Emissions.*

[192] International Energy Agency, *CO_2 Emissions from Fuel Combustion – Highlights*.

[193] Health Canada, *Human Health in a Changing Climate,* 6.

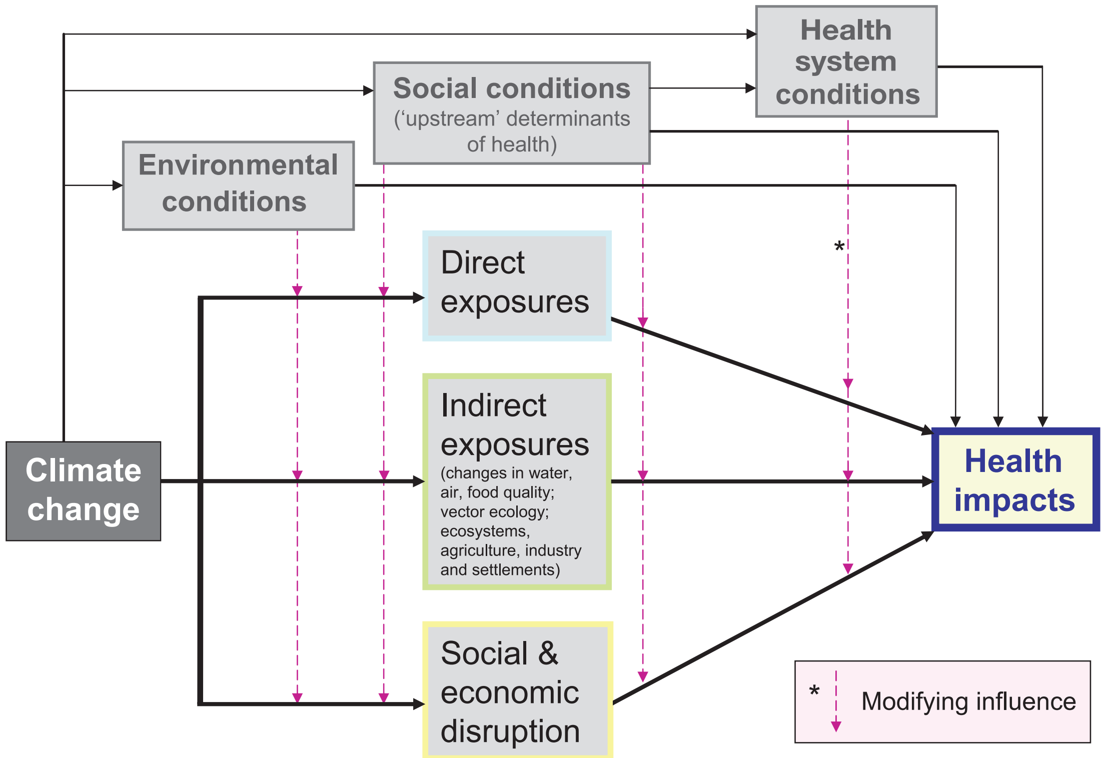

Figure 12. Pathways by which climate change impacts human health, with modifying influences of environmental, social, and health system conditions

Source: Confalonieri et al.[194]

A 2009 collaboration between The Lancet — one of the oldest and most respected peer-reviewed general medical journal and specialty journals in oncology, neurology and infectious diseases — and University College London, U.K., examined the potentially disastrous effects that climate change could have on health across the globe. The report pointed to climate change as potentially the biggest global health threat of the 21st century.[195]

Some of the most vulnerable and poorest people in the world are those expected to experience the worst impacts of climate change and with the least resources to successfully adapt to its changes, while having contributed the least to the GHG loading in the atmosphere that is responsible for climate change. This raises stark ethical issues in Alberta around humanity's responsibility for global health, given Alberta's lead ranking in per capita GHG emissions around the world. The cumulative nature of greenhouse gas emissions means that all emissions sources, particularly major ones such as coal, need to be urgently curtailed.

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[194] U. Confalonieri et al., "Human health," in *Climate Change 2007: Climate change impacts, adaptation and vulnerability. Working Group II contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report*, eds. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (2007), Figure 8.1. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm.

[195] UCL Lancet Commission, *Managing the Health Effects of Climate Change* (2009). http://www.thelancet.com/climate-change

3.14.2.1 Health risks in Alberta

There is not an extensive existing literature related to the health impacts of climate change in Alberta or even in Canada as a whole, though some recent modelling and research has improved the field's state of knowledge. While the precise extent of future health impacts from climate change in Alberta is uncertain, existing assessments of risk to health from climate change reveal a long list of potential health impacts in Canada and in Alberta more specifically. The types of threats to human health vary widely in nature, probability and magnitude, and the likelihood and intensity of these threats depend generally on the amount of global GHG release and, in turn, the extent of actual global average temperature increases that occur. Given that Canada is expected to experience higher rates of warming than most other countries in the world (much of Alberta is expected to experience 3–5 ºC increases in annual average temperatures between the late 1900s and mid-2000s), Alberta is certainly not excluded from health impacts that are expected to take place nationally and globally.[196]

The most obvious direct impacts on human health in Alberta expected from climate change is due to the projected increased risk of extreme weather events, such as heavy rains causing mudslides and floods, violent thunderstorms, and increased drought affecting water supplies and increasing the risk and intensity of wildfires. These climate-related weather events pose a direct physical threat to human bodily integrity and health, as well as threats such as illnesses from water contamination, food and water shortages, crowding in emergency shelters, etc.[197] Another important direct threat to health that may be less violent but is no less real and visible already is the medical risks of heat exhaustion and cardiovascular and respiratory diseases from more frequent and severe heat waves.[198] Within Canada, Alberta has been identified as particularly at risk for avalanches and mudslides in the mountains, heat waves and droughts across the prairies, and thunderstorms, hailstorms and tornadoes.[199] In addition to the 3–5 ºC temperature increases expected in Alberta by the 2050s, increases in annual average precipitation are expected by the 2080s (related to flooding, storms), but with decreased precipitation in some locations in the summer (related to droughts).[200]

Climate change also impacts air quality, linking in the various air pollution impacts on human health raised in the rest of this report. Climate change is projected to increase smog formation, wildfires, and pollen production. It might also lead to greater emissions of air contaminants due to changed personal behaviours, such as air conditioning use and driving. All of these outcomes, many of which are described further in other parts of this report as direct air impacts from coal power, increase risks to human health such as cardiovascular and respiratory diseases, increased risk of certain cancers, exacerbation of allergies and asthma, and premature death.[201]

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[196] Health Canada, *Human Health in a Changing Climate,* 8.; Elaine Barrow and Ge Yu, *Climate Scenarios for Alberta* (Prairie Adaptation Research Collaborative and Alberta Environment, 2005) 14. http://www.parc.ca/research_pub_scenarios.htm

[197] Health Canada, *Human Health in a Changing Climate*, 2, 7.

[198] Ibid.

[199] Ibid., 8.

[200] Barrow and Yu, *Climate Scenarios for Alberta*, 14.

[201] Health Canada, *Human Health in a Changing Climate,* 2, 7.

Climate change is likely to bring the emergence of new diseases that are rare in or exotic to Canada and to increase risks associated with existing infectious diseases. With changes to the geographic distribution of disease-carrying insects, ticks and rodents, new diseases can take hold in areas previously beyond their range. Moreover, higher temperatures and precipitation, as expected in Alberta, allows for faster maturation of pathogens in these vectors.[202] Examples of increased disease incidence projected in Canada include equine encephalitis and Rocky Mountain spotted fever, while a number of new diseases could emerge, along with the reemergence of those previously eradicated in Canada.[203]

Similarly, heavier rainfall events as expected in parts of Alberta can lead to contamination of drinking water due to run-off and leaching, as well as algal blooms leading to drinking water contamination and higher levels of certain toxins in fish. These projected impacts could lead to outbreaks of *E. coli*, *Cryptosporidium*, *Giardia*, typhoid, amoebas and other water-borne pathogens, as well as food-borne illnesses and other intestinal diseases.[204]

While Canadians are relatively well situated to respond to new health risks because of our health resources and social services, the increase in pressure on the medical system along with other climate-related risks to social conditions and infrastructure, plus changing demographics, "could increase the vulnerability of Canadians to future climate-related health risks in the absence of effective adaptations."[205] Moreover, existing gaps in public health and emergency management activities could become exacerbated and undermine Canadians' ability to respond to climate change and its health impacts.[206] Such risks are more daunting for some communities than others, particularly small communities, which often have "less capacity to plan for or cope with the effects of extreme events or health emergencies."[207] The result is that some of Alberta's remote rural communities may be especially vulnerable to climate-related health impacts over coming decades.

3.14.2.2 Global health risks

More attention has been paid to the projected global health impacts and costs of those impacts due to climate change at the global level. The extent and nature of impacts vary around the world according to the major climate change consequences expected (changes to temperatures, precipitation, weather events, etc.) and the capacity of local populations to deal with those changes. It is beyond the scope of this report to review in detail the health effects of climate change around the world, but aggregated data can give an indication of the size of the projected health problem. It is important to note that although these health impact studies focus on time periods that are decades into the future and are challenged by the uncertainties of future projections, researchers and on-the-ground health workers have already observed impacts on human health from temperature and precipitation changes due to climate change.

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202 Ibid.

203 Ibid., 7.

204 Ibid.

205 Ibid., 2.

206 D.J. Davidson, M. Haan and B. Parlee, *The Social Dimensions of Climate Change Vulnerability in Alberta: A Preliminary Assessment,* prepared for Alberta Environment (2008).

207 Health Canada, *Human Health in a Changing Climate* 2, 7.

Studies that attempt to tally the health care and welfare costs of health impacts related to climate change have important shortcomings — most notably, that they tend to focus on a limited number of specific health outcomes. However, reviewing the range of studies that probe the projected economic value of loss of life alone indicate that climate change could cost between $6 billion and $88 billion in 1990 US dollars.[208] This gives an indication of the magnitude of costs related to human health impacts due to climate change, though it would only be the tip of the iceberg relative to economic costs from disease and injury due to climate change, along with the health care costs associated.

Moreover, “mortality attributable to climate change is projected to be greatest in low-income countries”, where economic studies generally assign a lower value of life.[209] This has grave moral implications, given the common value of human life and the fact that these are the same populations with much lower, sometimes negligible historical GHG emissions, and therefore less responsibility for climate change itself. For a wealthy jurisdiction such as Alberta, with world-leading per capita GHG emissions, there is clear moral responsibility to consider the global health impacts of our emissions that place people around the world at greater risk of injury, illness and death.

[208] Confalonieri et al., “Human health,” 415.

[209] Ibid.

4. Populations at risk in Alberta

4.1 General population

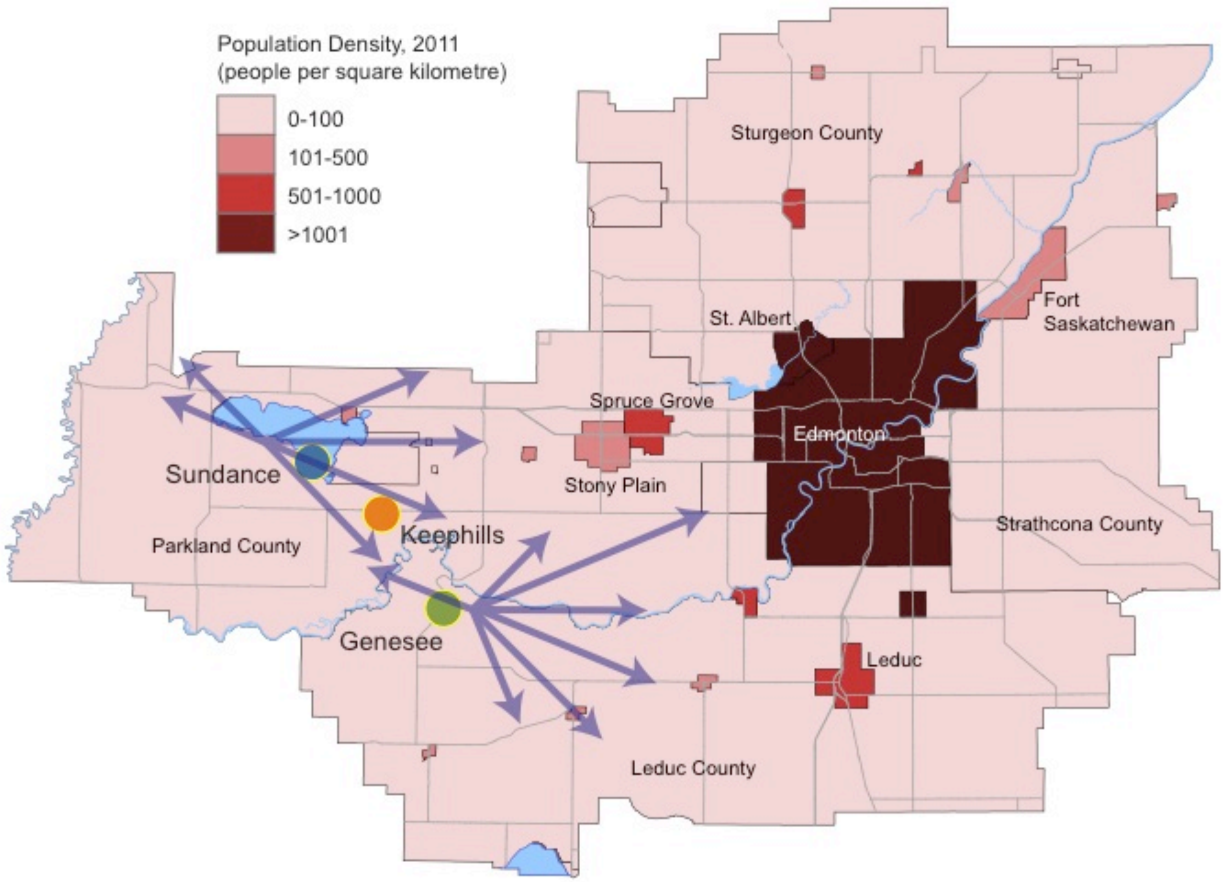

Figure 13. Coal-fired electricity generating stations near Edmonton, with population density and prevailing wind directions

Length of wind arrow is proportional to frequency of wind measured in that direction.

Data sources Statistics Canada,[210] WBK & Associates and Stantec Consulting[211]

For nine months out of every year, the prevailing winds bring air pollutants from three coal-fired generating stations towards the greater Edmonton area. In 2011, coal-fired generating stations

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[210] Statistics Canada, "Population and Dwelling Counts," Edmonton Census Metropolitan Area, 2011 and 2006 censuses. http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/hlt-fst/pd-pl/Table-Tableau.cfm?LANG=Eng&T=303&CMA=835&S=51&O=A&RPP=25

[211] Wind data from Genesee and Meadows air monitoring stations. WBK & Associates and Stantec Consulting, *TransAlta Generation Partnership and Capital Power Corporation Ambient Air Monitoring Program 2010 Annual Report,* prepared for Alberta Environment (2011). wcas.ca/documents/2010_amb_air_ann_report.pdf

upwind of Edmonton released 47,344 tonnes of nitrogen oxides and 51,267 tonnes of sulphur dioxide into the air, along with 4,251 tonnes of particulate matter (see Table 3).

Table 3. Emissions by coal-fired generating stations within 70 km of Edmonton

Generating Station	Nitrogen oxides (tonnes)	Sulphur dioxide (tonnes)	Total Particulate Matter (tonnes)
Sundance	18,779	20,038	2,220
Genesee	14,892	17,071	1,357
Keephills	13,673	14,158	674
Total	**47,344**	**51,267**	**4,251**

Data source: Environment Canada[212]

Research in the United States has also shown that people living near coal mines also have above-average rates of mortality and disease.[213] Open pit or strip mining results in elevated levels of dust containing hazardous substances found in coal seams, and there are also possible health risks associated with surface storage of coal processing and combustion wastes.[214] As 'mine-to-mouth' operations, the coal mines west of Edmonton will affect mostly the local area, but some longer-range transport of dust is also possible.

4.2 Fetal and newborn health

While in utero, the fetus is exposed to a wide range of substances that can cross the placenta.[215] The environment that a fetus exists within is linked not only to the mother's current environment, but also to her past exposures to pollutants. Because persistent substances are stored in fat tissue and contaminants such as lead are stored in bones and teeth, fetuses and breast-fed infants are exposed to even higher levels of toxic contaminants than adults.[216]

Exposure to toxic substances also has the greatest impact during the period of fetal development because of the immaturity of a fetus's detoxification system. Babies and children continue to be vulnerable to toxic contaminants as they move through the developmental stages.[217,218] They are also more at risk than adults because on a per body weight basis, they are exposed to higher

[212] Environment Canada, National Pollutant Release Inventory, http://www.ec.gc.ca/pdb/websol/querysite/query_e.cfm

[213] Geoff Keith et al., *The Hidden Costs of Electricity: Comparing the Hidden Costs of Power Generation Fuels*, prepared for The Civil Society Institute by Synapse Energy Economics (2012), 28. http://www.civilsocietyinstitute.org/media/pdfs/091912%20Hidden%20 Costs%20of%20Electricity%20report%20FINAL2.pdf

[214] Ibid.

[215] G.M. Solomon and PM Weiss, "Chemical contaminants in breast milk: Time trends and regional variability," *Environmental Health Perspectives* 110 (2002), A339.

[216] B.L. Gulson et al., "Pregnancy increases mobilization of lead from maternal skeleton," *Journal of Laboratory and Clinical Medicine* 130 (1997), 51.

[217] P.J. Landrigan et al, "Children's health and the environment: public health issues and challenges for risk assessment," *Environmental Health Perspectives;* 112 (2004), 257.

[218] S.G. Selevan, et al., "Identifying critical windows of exposure for children's health," *Environmental Health Perspectives* 108 (2000), 451.

levels of contaminants in the food or in the air. Babies and children are also more efficient at absorbing contaminants through their digestive system and their respiratory system.[219]

Fetal exposure to mercury is of particular concern. Babies born to mothers exposed to methylmercury are born with mercury-related losses of cognitive function, as methylmercury interrupts the regulation of complex molecular pathways.[220] Cases of methylmercury poisoning have demonstrated that children exposed *in utero* to methylmercury suffer from life-long symptoms including mental retardation, memory disability, attention deficits, hearing and vision loss, and deformities, while the mothers were generally left unaffected.[221]

Coal-fired generating stations emit over 44 per cent of the airborne mercury pollution from all sources in Alberta but the effect this pollution is having on Albertans is unknown. Alberta Health conducted a study that evaluated the concentrations of various chemicals in the blood serum of pregnant women in 2008, which estimated whole blood mercury concentrations to be in the range of approximately 0.8 nanogram/gram (ng/g) to 4.4 ng/g; this is well below Health Canada prescribed "level of concern" of 20 ng/g. However, studies done in New Zealand and the Faroe Islands and reported by the National Academy of Sciences point to developmental effects of mercury exposure occurring in children born to women with blood mercury concentrations greater than or equal to 3.41 ng/g. The Alberta Health study only tested blood serum, but serum is known to contain only a small fraction (five per cent) of total methylmercury, increasing the margin of error when extrapolated for overall blood mercury levels. Furthermore, the Alberta Health study does not provide a full picture of the methylmercury levels in this population, in part because the blood serum was grouped first into pooled samples providing an average for the region, which has the effect of masking potentially high levels of methylmercury in some individuals.

4.3 Children's health

In its report *No Breathing Room: National Illness Costs of Air Pollution*, the Canadian Medical Association (CMA) points to studies that provide "compelling evidence that exposure of young people to air pollution during the critical stages of lung development (up to around 17 years of age) can cause irreversible damage. One of the impacts is reduced lung function, which is proportional to concentrations of air pollutants, in particular $PM_{2.5}$."[222] There is also epidemiological evidence that suggests that babies and young children are also vulnerable to premature mortality.[223]

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219 K. Cooper and L. Vanderlinden, "Pollution, Chemicals and Children's Health," in *Environmental Challenges and Opportunities*, C.D. Gore and P.J. Stoett, eds (Toronto: Emond Montgomery, 2009).

220 P. Black, G. Pelletier and D. Lean, "Methyl mercury in the Canadian Arctic: Implications to Human Health," presented at ArcticNet 2005. www.arcticnet.ulaval.ca/pdf/posters_2005/black_et_al.pdf

221 K. Kondo, "Congenital Minamata Disease: Warnings From Japan's Experience," *Journal of Child Neurology* 15 (2000), 458.

222 Canadian Medical Association, *No Breathing Room: National Illness Costs of Air Pollution* (2008) , 3. http://www.cma.ca/multimedia/CMA/Content_Images/Inside_cma/Office_Public_Health/ICAP/CMA_ICAP_sum_e.pdf

223 D.P. Loomis, M. Castillejos, D.R. Gold, W. McDonnell and V.H. Borja-Aburto, "Air pollution and infant mortality in Mexico City," *Epidemiology* 10 (1999), 118.

The CMA report concludes that children are at increased risk of health effects of air pollution due to a number of factors:

> "Children and newborns inhale a higher volume of air for their body weight compared to adults and consequently take in higher levels of pollutants.
>
> They are still growing and developing and therefore their defense mechanisms are less well equipped than those of adults.
>
> A greater proportion of a child's time is spent outdoors and they are more active than adults, which also increases the amount of exposure to air pollutants."[224]

Air pollution may be a contributing factor in the development of asthma and in triggering asthma episodes in children. Between 1999 and 2005, there were 94,187 visits to emergency departments in Alberta for asthma. On average in Alberta, a child visits an emergency department for asthma every 34 minutes and a child is admitted to a hospital from an emergency department approximately once every six hours. These figures do not include the number of times that asthma sufferers visit a health clinic or other medical facility besides an emergency department.[225]

4.4 First Nations health risks

Country foods, i.e. foods obtained through hunting, fishing or gathering, continue to make up a large proportion of the diet of many aboriginal people. Consumption of fish is the main pathway for methylmercury to enter the body, so people who consume large quantities are particularly at risk from the health impacts of mercury. Although mercury is naturally occurring, on a global basis, emissions of mercury from human activity are about the same as from natural sources.[226]

The guideline for mercury concentration in fish for people relying on subsistence fishing is 0.2 µg/g based on long-term fish consumption patterns of over 100 grams per day of fish. The mercury levels measured in fish at Lac La Nonne, a lake 85 km northwest of Edmonton, were well above the level recommended for subsistence consumers. The mean mercury concentration in walleye in this lake is 0.63 µg/g and in northern pike is 0.56 µg/g. Subsistence consumers should avoid eating these fish from Lac La Nonne.[227]

Fish in another central Alberta lake, Lac Ste. Anne (75 km west of Edmonton), were within the limits for subsistence consumers, with mean mercury concentration in walleye of 0.13 µg/g and in northern pike of 0.14 µg/g. However, subsistence consumers eat on average 270 grams of fish per day, resulting in an average exposure level of 2.6 µg/kg body weight per day from walleye and 2.8 from northern pike for women of reproductive age. The recommended limit is 0.2 µg/kg

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[224] CMA, *No Breathing Room*, 14.

[225] Rhonda J. Rosychuk et al., "Asthma Presentations by Children to Emergency Departments in a Canadian Province: A Population-Based Study," *Pediatric Pulmonology* 45 (2010), 985.

[226] United Nations Environment Program, *The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport* (2008). http://www.chem.unep.ch/mercury/Atmospheric_Emissions/UNEP%20SUMMARY%20REPORT%20-%20CORRECTED%20May09%20%20final%20for%20WEB%202008.pdf

[227] Alberta Health and Wellness, *Human Health Risk Assessment: Mercury in Fish in Central Alberta* (2009), 23. http://www.health.alberta.ca/documents/Mercury-Fish-Lac-Nonne-Anne-2009.pdf

body weight per day for women. As a result, it is recommended that women of childbearing age limit their consumption of fish from this lake to 700 grams per week. Children should be eating far less than this.[228]

Currently, fish consumption advisories are listed for 47 lakes and rivers in Alberta.[229]

The above limits assume that there is a safe level of consumption of methylmercury for pregnant women. This is not yet proven. A study conducted by the U.S. National Research Council observed that the population at highest risk is the children of women who consumed large amounts of fish and seafood during pregnancy.[230] The National Academy of Sciences concluded that the risk to that population is likely to be sufficient to result in an increase in the number of children who have to struggle to keep up in school.[231]

4.5 Health of the elderly and people with chronic health conditions

In *No Breathing Room,* the Canadian Medical Association concluded that air pollution disproportionately affects different population groups. The most susceptible to premature mortality and illness are people over 65 or those with pre-existing respiratory and cardiovascular problems such as asthma, congestive heart failure or chronic obstructive pulmonary disease. The elderly may be more susceptible to injury from air pollution due to multiple diseases, reduced heart and lung function, diminished capacity to adapt to stress, and lower incomes.[232]

The CMA report provided a series of projections predicting the levels of premature mortality in Canada due to air pollution. The modeling revealed that the vast majority of deaths are among people over 65 years of age, leading the authors to conclude that "as an older Canadian population cohort — the baby-boomers — grows, the impact of air pollution will surely increase".[233]

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[228] Ibid.

[229] MyWildAlberta.com, "Fish Consumption Advisory," 2012. http://mywildalberta.com/Fishing/SafetyProcedures/FishConsumptionAdvisory.aspx

[230] *Toxicological Effects of Methylmercury*.

[231] U.S. EPA, *Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards*.

[232] CMA, *No Breathing Room*, 14.

[233] Ibid., 1.

5. Estimates of health damage

Estimating the direct impact of pollution on human health is very difficult — it took decades to definitively show a link between cigarette smoke and lung cancer.[234] Among other factors, health damage associated with air pollution can depend on dose, length of exposure, mixtures of pollutants, age, genetic predispositions, existing health problems, etc. In addition, baseline data needed to conduct general population health research can be difficult if not impossible to obtain. There has never been an epidemiological study done in Canada or Alberta examining the health impacts of pollution from coal plants, and although literature reviews have been compiled by groups such as CASA,[235,236] these are not specific to Alberta.

In the absence of data from an epidemiological study, models have been developed to estimate the health impacts of known pollutants. The Illness Costs of Air Pollution model was used in this analysis, and is compared to recent estimates done by Environment Canada as part of their regulatory impact analysis statement regarding the 2012 Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations. Environment Canada used the Air Quality Benefits Assessment Tool and the Air Quality Valuation Model to estimate the benefits its greenhouse regulations have on reducing other air pollutants. Environment Canada's results are presented as a comparison only.

5.1 About the modelling

This report first used the Illness Costs of Air Pollution model to estimate overall health impacts from air pollution in Alberta. Then, based on the contribution of coal-fired electrical plants to the overall pollution mix, the proportion of impacts attributable to burning coal was estimated. In addition, estimates were adjusted to account for stations going off-line at the end of their lifetime.

5.1.1 Illness Costs of Air Pollution (ICAP) model

In order to estimate the impact of air pollution resulting from coal plants on health in Alberta, the Illness Costs of Air Pollution model (ICAP) was used.[237] ICAP was developed for Canadian Medical Association in order to make health estimates related to air pollution in all 10 provinces.

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[234] University of Minnesota, "Researchers discover direct link between smoking and developing lung cancer in humans," media release, April 20, 2009. http://www.health.umn.edu/media/releases/link042009/index.htm

[235] Heidi Swanson, "Literature review on atmospheric emissions and associated environmental effects from conventional thermal electricity generation", prepared for Clean Air Strategic Alliance (2008). Available at http://www.hme.ca/reports/Coal-fired_electricity_emissions_literature_review.pdf

[236] Adrienne LeBlanc, *Compilation of Recent Abstracts (2002-2007) - Health Effects Associated with Thermal Electricity Generation,* prepared for Clean Air Strategic Alliance (2008). Available at http://www.hme.ca/reports/Health_effects_associated_with_coal-fired_electricity.pdf

[237] Canadian Medical Association, "The Illness Cost of Air Pollution – Alberta." http://www.cma.ca/index.php?ci_id=86784&la_id=1

The ICAP model uses population densities and air quality data to forecast known health impacts of pollutants for each province in Canada. ICAP estimates health damages in physical terms (i.e., illness rates) and economic terms (i.e., monetary damages associated with air pollution-related illnesses).[238] The model is based on the principal studies on the health effects of air pollution, including the chronic effects of exposure.[239]

There is an extensive body of evidence for health impacts related to a suite of pollutants; however, the greatest volume and weight of evidence are available for the effects of $PM_{2.5}$ and ozone. This allows for the development of risk coefficients for these predictive pollutants. Using a risk coefficient, it is possible to model the impacts on society at different concentrations using these pollutants as indicators.[240]

The model uses census data from Statistics Canada to model impacted population densities[241], and accounts for demographic changes including an aging population and population growth in Alberta.

Ambient air quality data used in the model is based on actual measurements from the National Air Pollution Surveillance Network. Data from U.S. air quality monitoring sites within 500 km were also used. Some adjustments of the data were necessary, and anomalies were removed prior to data processing. Data from the individual stations for each air pollutant were then interpolated using geographically-based algorithms. The result was a map of estimates that reflected the spatial behaviour of each of the pollutants. The ambient concentrations calculated for each population-weighted centroid was then fed into the ICAP model.[242] The model provides forecasts of health impacts and economic damages for 2008 to 2031.

The Canadian Medical Association has published the results of the Illness Costs of Air Pollution model for each province. Each provincial system incorporates all of the census divisions in the province and is based on medium population growth with medium migration trends forecast using Statistics Canada forecasts. The provincial systems incorporate the damages associated with $PM_{2.5}$ and ozone and assume constant ambient concentrations from 2008 to 2031.[243] The results for Alberta are shown in Table 4.

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[238] Canadian Medical Association, *No Breathing Room: National Illness Costs of Air Pollution — Technical Report*, prepared by DSS Management Consultants (2008). http://www.cma.ca/multimedia/CMA/Content_Images/Inside_cma/Office_Public_Health/ICAP/CMAICAPTec_e-29aug.pdf

[239] Ontario Medical Association, *The Illness Cost of Air Pollution: 2005-2026 Health and Economic Damage Estimates* (2005). https://www.oma.org/Resources/Documents/e2005HealthAndEconomicDamageEstimates.pdf

[240] Ibid.

[241] CMA, *No Breathing Room — Technical Report*, 9.

[242] Ibid., 95.

[243] Ibid., 28.

Table 4. The Illness Costs of Air Pollution Alberta health damages summary

	Example Years		
	2008	2015	2031
Acute premature deaths	173	217	366
Chronic premature deaths (inclusive of acute)	1,334	1,679	2,835
Hospital admissions (based on acute exposure)	894	1,068	1,616
Emergency department visits (based on acute exposure)	8,638	10,426	16,103
Minor illnesses (based on acute exposure)	1,734,300	1,868,300	2,173,000

Source: Adapted from CMA[244]

5.1.2 Accounting for coal combustion and station closures

In order to estimate the health impacts of air pollution from coal-fired generating stations, this report fine-tuned the results from the ICAP data to account for the proportion of air pollution that these facilities emit. As noted above, the model specifically accounts for the effects of $PM_{2.5}$ and ozone.

$PM_{2.5}$ can be produced directly from a source, or formed secondarily in the atmosphere through chemical reactions. Secondary components, including sulphates, nitrates, ammonium and organic carbon, make up anywhere between 30 and 90 per cent of ambient $PM_{2.5}$ concentrations. At monitoring stations across the U.S., sulphates comprised 7–47 per cent of $PM_{2.5}$.[245]

In Alberta, six percent of $PM_{2.5}$ emissions from all man-made sources are emitted directly by coal power plants. In addition, coal-fired generating stations emit 33 per cent of the SO_2 produced from all sources in the province.[246] The percent of $PM_{2.5}$ made up of sulphates was assumed as the most conservative value (seven per cent), suggesting that SO_2 from coal-fired generating stations accounts for around an additional two percent of the ambient $PM_{2.5}$ measured in Alberta (although this contribution could be as high as 15 per cent).

Thus, an estimated eight per cent of the total health impacts from $PM_{2.5}$ are linked to coal-fired power plants.

The emissions of NO_x from coal-fired power plants were used as a direct proxy for the percentage of ozone that is linked to coal-fired power plants and the related health impacts, based on observations that show one to three molecules of ozone are produced per molecule of NO_x emitted.[247] In Alberta, 10 percent of NO_x emissions from man-made sources come from coal-fired power plants.

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[244] Ibid., 46.

[245] William M. Hodan and William R. Barnard, *Evaluating the Contribution of $PM_{2.5}$ Precursor Gases and Re-entrained Road Emissions to Mobile Source $PM_{2.5}$ Particulate Matter Emissions,* prepared by MACTEC for the U.S. Federal Highway Administration, 8. http://www.epa.gov/ttnchie1/conference/ei13/mobile/hodan.pdf

[246] Environment Canada, "2010 National, Provincial and Territorial Emission Summaries for Key Air Pollutants."

[247] T. B. Ryerson et al., "Emissions lifetimes and ozone formation in power plant plumes," *Journal of Geophysical Research: Atmospheres* 103 (1998), 22569.

Although the ICAP model uses a continuation of current ambient concentrations for air pollution, the results presented here for the health impacts of coal take into account the eventual planned retirement of existing coal-fired generating stations (notably in 2019 and 2029), thus reducing the total amount of air pollution associated with coal-fired generating stations. Due to the current price differential between gas and wind compared to a new coal plant, it was assumed that no additional coal-fired generating stations are constructed as current units retire.

5.1.3 Sensitivity of the model

The ICAP model provides a conservative estimate of the health impacts and economic damages of pollution from combustion of coal. While the model accounts explicitly only for health effects associated with fine particulate matter and with ozone, health impacts of these pollutants are correlated with the impact from other pollutants.

The Health Effects Institute (HEI),[248] which conducted a re-analysis of two important epidemiological studies of air pollution impacts in the United States, provides evidence that sulphur dioxide pollution is a significant predictor of an increased risk of mortality. This association between sulphur dioxide and mortality was observed and persisted when other possible confounding variables were included.[249]

The results of epidemiological studies conducted for the past several decades show that living where there are elevated ambient levels of air pollution from combustion sources is associated with increased mortality. The HEI reports that recent work has identified associations between short-term elevations of particulate matter in ambient air and a host of adverse health outcomes. These health impacts have been linked to much lower air pollution levels than previously thought to have an effect.[250] The ICAP model assumes that there is no threshold below which exposure to PM or ozone has no impact. This assumption was endorsed through a Canadian Medical Association expert workshop at which the experts concluded there is little evidence to suggest that an effect threshold exists for exposure to these air pollutants.[251]

The full suite of health impacts from pollution from coal combustion are not captured by the estimates provided below. As described in the health impacts section, numerous toxic contaminants are emitted by coal-fired generating stations. As a result, the estimates of health impacts to Albertans and the related economic damages presented are conservative.

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[248] The Health Effects Institute is an independent research organization that receives half of its core funding from the U.S. Environmental Protection Agency and half from the worldwide motor vehicle industry. http://www.healtheffects.org/about.htm

[249] Health Effects Institute, *Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality* (2000), iv. http://pubs.healtheffects.org/getfile.php?u=273

[250] Ibid. , 33.

[251] CMA, *No Breathing Room — Technical Report*, 79.

5.2 Premature deaths

The immediate risk from short-term exposure to air pollution is measured by acute premature mortality. An acute response is one that occurs within days of exposure to air pollution. Acute premature mortality is detected using a time-series epidemiological methodology.[252]

Most premature deaths are among people aged 65 and older. As Alberta's population ages, the annual number of people dying prematurely due to short-term exposure to air pollution increases. Retirement of coal plants in 2019 and in later years reduces the risk of acute premature mortality to Albertans, but 420 acute premature deaths are estimated to result from short-term exposure to air pollution from coal between 2008 and 2031.

A much greater number of people are expected to die prematurely due to chronic or long-term exposure to air pollution from coal plants. Chronic mortality is estimated to be about eight times as high as acute mortality.[253] As a result, the estimated total number of premature deaths of Albertans from exposure to air pollution from coal plants (acute plus chronic mortality) in 2008 was estimated at 107 people, which is expected to rise to 156 people in 2024, and then decline to 73 by 2031, for a total number of premature deaths of 3,085 people over this time frame.

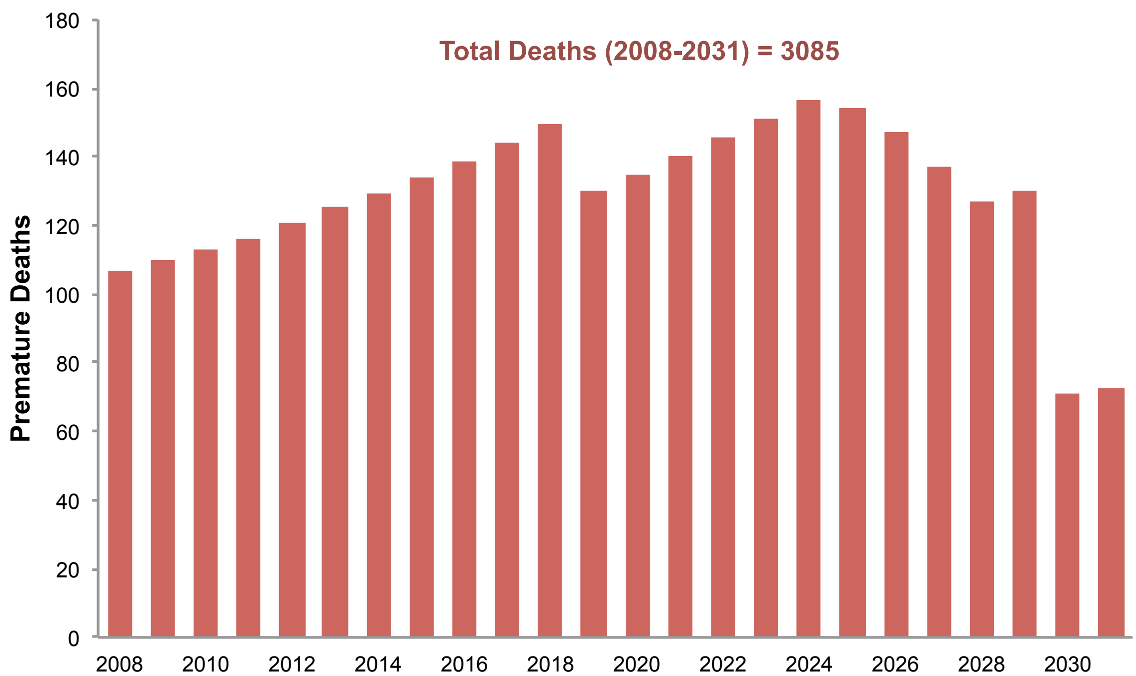

Figure 14. Estimated premature deaths due to air pollution from coal-fired generating stations in Alberta

A chronic response is associated with exposure to air pollution over many years. A cohort epidemiological methodology is used to estimate the risk of chronic premature mortality.[254]

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[252] Time-series design – a single population group is studied over a period of time, with measurements of factors of interest at specified time intervals.

[253] CMA, *No Breathing Room*, 6.

[254] Cohort design - a study of the same group of people (the cohort) at regular intervals over a relatively long period of time. Cohort studies allow researchers to observe a difference in the risk (incidence) of a disease over time.

Because there can be partial overlap of time-series and cohort studies, the conservative approach is to use one set of risk coefficients or the other, and not to combine them.[255]

5.3 Asthma

Exposure to air pollution is known to exacerbate respiratory illnesses and can trigger asthma attacks. The ICAP model provides estimates of the number of days that asthma sufferers are faced with asthma symptoms severe enough to result in absenteeism from work or school to recover. Estimates for asthmas symptom days are shown in Figure 15. Prior to retirement of coal plants in 2019 and later, short-term exposure to air pollution from these facilities result in 4,862–5,329 cases of asthma symptom days annually among Albertans. Without additional controls on pollution from coal-fired generating stations, between 2008 and 2031, a total of 105,527 asthma symptom days are expected to occur.

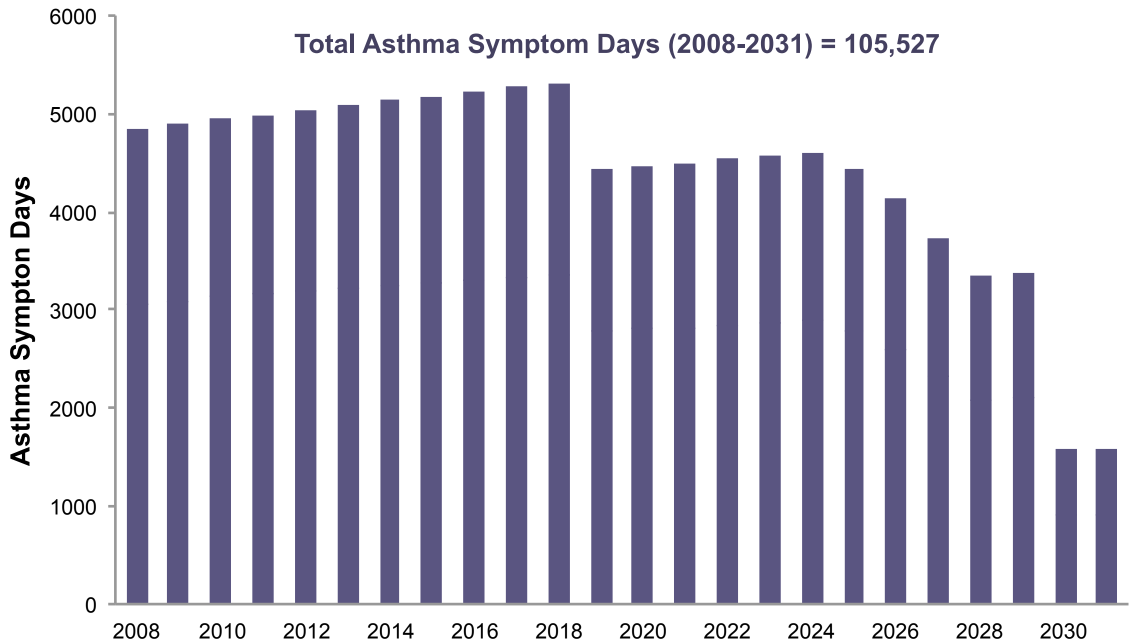

Figure 15. Estimated number of asthma symptom days due to air pollution from coal-fired generating stations in Alberta

5.4 Hospital admissions and emergency room visits

The expected number of hospital admissions for respiratory illnesses is based on time-series studies using the acute effects of air pollution. This does not take into account chronic exposure, so the health impact predicted is likely an underestimate. In other words, the effects of long-term exposure to air pollution are not accounted for.

People age 65 and older account for the largest proportion of hospital admissions for respiratory illnesses (around 40 per cent). However, young children up to the age of four also make up a

[255] CMA, *No Breathing Room*, 6.

significant portion of cases (around 20 per cent). Air pollution from coal plants is estimated to result in around 40 admissions annually. Over the period 2008 to 2031, it is estimated that about 900 admissions to the hospital for respiratory illnesses will result from acute exposure to pollution from coal-fired generating stations. For comparison, there were approximately 360,000 hospital stays in Alberta in 2009.[256]

People suffering from less severe symptoms of respiratory illness not requiring hospital admission are often treated at unscheduled emergency department visits. Air pollution from coal plants is estimated to result in around 250 emergency department visits annually. In 2008, around 40 per cent of emergency department visits for respiratory illnesses are estimated to be by elderly patients. This proportion is expected to grow to 60 per cent by 2031. Over the period 2008 to 2031, it is estimated that about 5,600 visits to emergency departments for respiratory illnesses will result from acute exposure to pollution from coal-fired generating stations. For comparison, there were around 1.9 million visits to emergency departments across Alberta in 2009.[257]

Like respiratory illnesses, the expected number of hospital admissions for cardiovascular disease is based on time-series studies using the acute effects of air pollution. This does not take into account chronic exposure, so the health impact predicted is conservative. More than any other category, the hospital admissions for cardiovascular disease is dominated by admissions of people age 65 and older. In 2008, this demographic accounts for 67 per cent of hospital admissions, and the proportion is expected to climb to 81 per cent by 2031. Over the period of 2008 to 2031, air pollution from coal-fired generating stations is expected to result in around 1,200 hospital admissions for cardiovascular conditions. Around 50 hospital admissions annually are expected to result from exposure to air pollution from coal plants.

As with hospital admissions, emergency department visits for cardiovascular illness are expected to be mainly by people ages 65 and older. In 2008, it is estimated that 66 per cent of visits were by seniors but by 2031, the proportion of visits to emergency departments in Alberta for cardiovascular illness is expected to grow to 81 per cent. The ICAP model suggests that pollution from particulate matter from coal-fired generating stations would result in around 13,000 visits to emergency departments by Albertans between 2008 and 2031. Visits to emergency departments for cardiovascular illness are estimated at around 550 annually.

5.5 Summary of ICAP estimates

A summary of the health effects to Albertans of air pollution from coal-fired generating stations is provided in Table 5 below. The impacts of particulate matter and ozone on the body are well-known and measurable. For these reasons, the ICAP model uses them as a basis for estimating the health impacts of air pollution. These results are an underestimate of the true impacts because they are based on acute exposure (other than premature mortality), but additional health impacts result from the long-term exposure to air pollution that Albertans are subject to.

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[256] Alberta Health Services, *Alberta Health Services Performance Report — September 2009*. http://www.albertahealthservices.ca/org/ahs-org-pr-performance-report.pdf

[257] Ibid.

Table 5. Summary of estimated health effects of air pollution from coal-fired generating stations in Alberta

	2008	2020	2031	Total (2008-2031)
Acute premature deaths	15	18	9	420
Long-term premature deaths (Inclusive of acute deaths)	107	135	73	3,085
Hospital admissions (respiratory cases)	36	39	17	897
Hospital admissions (cardiovascular cases)	44	53	24	1,209
Emergency dept. visits (respiratory cases)	223	245	113	5,666
Emergency dept. visits (cardiovascular cases)	479	577	299	13,229
Asthma symptom days (cases)	4,862	4,480	1,604	105,527

Although the model only includes two pollutants, the health effects of other pollutants — and the interaction among them — are partially accounted for by these estimates of health impacts. PM and ozone are both causative agents and markers for other correlated pollutants and their impacts.

As described in Section 3, air pollution from coal plants also contains heavy metals (mercury, lead, cadmium), complex compounds (dioxins and furans, hexachlorobenzene) and greenhouse gases as well as other criteria air contaminants (sulphur dioxide). Each of these substances has impacts on human health. The ICAP model does not address cancer risk or other illnesses that fall outside of those attributed to PM and ozone. However, where these pollutants contribute to illness or premature mortality captured within the ICAP model, these impacts are partly included in ICAP forecasts. The ICAP model does not capture any health effects related to greenhouse gas emissions.

5.6 Environment Canada estimates

In 2010, Environment Canada introduced draft coal regulations to impose CO_2 limits on new coal plants as well as existing ones after they have reached the end of their economic lives, initially posted at 45 years[258] (five years longer than Alberta's CASA NO_x/SO_2 agreement). The regulations that were finalized in 2012 allowed most units to operate until they have reached 50 years of operation.[259] As part of the final regulations, Environment Canada published a cost-benefit analysis that estimated the regulations will reduce approximately 214 Mt of CO_2e between 2015 and 2035. In addition, Environment Canada estimates that the regulations will accrue "health benefits of $4.2 billion from reduced smog exposure associated with reduced risk of death, avoided emergency room visits and hospitalization for respiratory or cardiovascular problems."[260] Environment Canada projects that the regulations will reduce 160 Mt CO_2e of the greenhouse gas emissions in Alberta, which is approximately equivalent to 160 TWh of

[258] Environment Canada, "Canada moves to reduce emissions in the electricity sector," *Envirozine* 101 (2010). https://www.ec.gc.ca/envirozine/default.asp?lang=En&n=5AE042C9-1

[259] *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*, Table 18.

[260] Ibid.

electricity generation.[261] The analysis also projects the avoided health impacts in Alberta over the first 20 years of the regulations (2015-2035) as listed in Table 6.

Table 6. Cumulative avoided health impacts in Alberta from coal regulations, 2015-2035.

	Alberta
Premature deaths	590
Emergency room visits and hospitalizations	520
Asthma episodes	80,000
Days of breathing difficulty and reduced activity	1,900,000

Data source: Environment Canada[262]

Environment Canada describes its methodology as follows[263]:

> *To estimate how these emission reductions would impact human health and the environment, Environment Canada began by using A Unified Regional Air-quality Modelling System (AURAMS) model to predict how the emission changes would affect local air quality. This is a fully three-dimensional state-of-the-art numerical model described in peer-reviewed scientific literature. AURAMS combined the information on predicted emission 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.*
>
> *The AURAMS air quality modelling system was run for two years and four scenarios of anthropogenic emissions representing two different projection years: two scenarios (one for the BAU and the other for the regulatory scenario) were run for the year 2020, and the other two scenarios were run for the year 2030 to provide ambient air concentration of pollutants. The meteorological data used for these four scenarios was for the year 2006 and was generated by Environment Canada's weather forecast model.*
>
> *The ambient air concentration results were then used to estimate the incremental health and environmental benefits for those two years using the Air Quality Benefits Assessment Tool (AQBAT) and the Air Quality Valuation Model (AQVM2). However, in order to estimate the benefits for all the years between 2015 and 2035, linear interpolation and extrapolation techniques were used. More specifically, for the 2015–2020 period, benefits were assumed to be null in 2015–2017, as no change in air quality was expected, and interpolated linearly up to the 2020 value. For the 2020–2025 period, benefits were assumed to remain constant at the 2020 level as the air quality was not expected to improve significantly. For the 2025–2030 period, benefits were interpolated linearly between 2025 and 2030 values. Finally, benefits were assumed to remain constant between 2030 and 2035. Whenever the benefits were assumed to remain constant, estimates were adjusted to account for changes in population and base data. Note that this assumption provides conservative estimates for health and environmental benefits as*

[261] In 2010, coal's emissions intensity was 1053 Mt CO_2e/TWh. Alberta Environment and Sustainable Resource Development, *Report on 2010 Greenhouse Gas Emissions,* Table attachment.

[262] *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*.

[263] Ibid., Table 18.

the reductions in CACs are expected to increase over time due to more coal-fired unit retirements.

While Environment Canada's calculations are based on avoided emissions, as a first approximation, it is possible infer the impact of emissions from plants that continue to operate. In practice, some units are more polluting than others and the proximity of their plume of pollutants to population centres varies, so the relationship is not necessarily linear; however, as approximation, the per TWh health impacts can be estimated to be 3.7 premature death, 3.3 emergency room visits and hospitalizations, 500 asthma episodes and 11,875 days of breathing difficulty and reduced activity. In 2011, coal generated 31.2 TWh of electricity in Alberta,[264] which using the above factors would translate into 145 deaths, 127 emergency room visits and hospitalizations, 19,600 asthma episodes and 465,500 days of breathing difficulty and reduced activity (see Table 7 below).

Table 7. Health effects of air pollution from coal-fired generating stations in Alberta based on Environment Canada estimates

	2011
Premature deaths	145
Emergency room visits and hospitalizations	127
Asthma episodes	19,600
Days of breathing difficulty and reduced activity	465,500

[264] Alberta Electric System Operator, Annual Market Statistics Reports. www.aeso.ca/downloads/AESO_2011_Market_Stats.pdf

6. Health care and public costs of coal to Albertans

The Illness Costs of Air Pollution model was also used to estimates economic damages resulting from physical health effects. Results from this model are compared to estimates done by the American National Research Council, which measured external costs associated with local and global air pollution from coal-fired power plants in the United States, and those presented by Environment Canada. This section also presents an estimate of the total external cost to society of coal combustion for electricity.

6.1 ICAP cost estimates

In addition to estimates of physical health effects, the Illness Cost of Air Pollution (ICAP) model provides estimates of the corresponding economic damages that these illnesses represent. These economic damages are estimated according to four major cost categories: lost productivity, health care costs, pain and suffering, and loss of life.[265] The results of the Illness Cost of Air Pollution model have been annualized to show the economic damages of air pollution over time in constant 2006 dollars.[266]

Lost productivity includes the time lost due to treatment and recovery from air pollution-related illnesses and includes time lost by patients and caregivers. Lost time is valued at the average wage rate for the corresponding age of the person affected.

Healthcare costs include the costs of institutional care plus medication. The costs of doctor's visits and early development effects in children related to air pollution are not included in the healthcare costs. As a result, these economic damages forecasts are likely an underestimate of the full costs of air pollution in Alberta.

Economic damages associated with reduced quality of life due to pain and suffering relate to the amount that people are willing to pay to avoid illnesses that cause pain and suffering.[267]

Premature mortality is valued based on a willingness to pay to reduce the risk of premature death due to air pollution. The ICAP model uses a value of statistical life of $4.8 million. Premature mortality is the largest contributor to the economic cost of pollution.

Combining the economic damages related to the acute impacts of ozone and $PM_{2.5}$ for 2010 yields a cost to Albertans of $46 million; this is expected to climb to $63 million by 2024. The cumulative total of damages from 2008 to 2031 from pollution emitted by coal-fired generating stations in Alberta reaches nearly 1.3 billion dollars over that 24-year period.

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[265] CMA, *No Breathing Room — Technical Report*, 5.

[266] Ibid., 20.

[267] Ibid., 21.

As stated in the introduction to the modeling results, the long-term risk of exposure to particulate matter and ozone is expected to result in mortality rates that are seven to nine times that of the acute premature mortality rates. Using the value of statistical life, the economic damages associated with premature mortality are estimated at $262 million for 2008, climbing to $382 million in 2024, and estimated at $175 million in 2031 for a cumulative total over this period of $7.5 billion (see Figure 16), by far the largest set of costs. The total costs associated with pain and suffering related to chronic exposure to air pollution from coal plants is estimated at $4 million over this time frame.

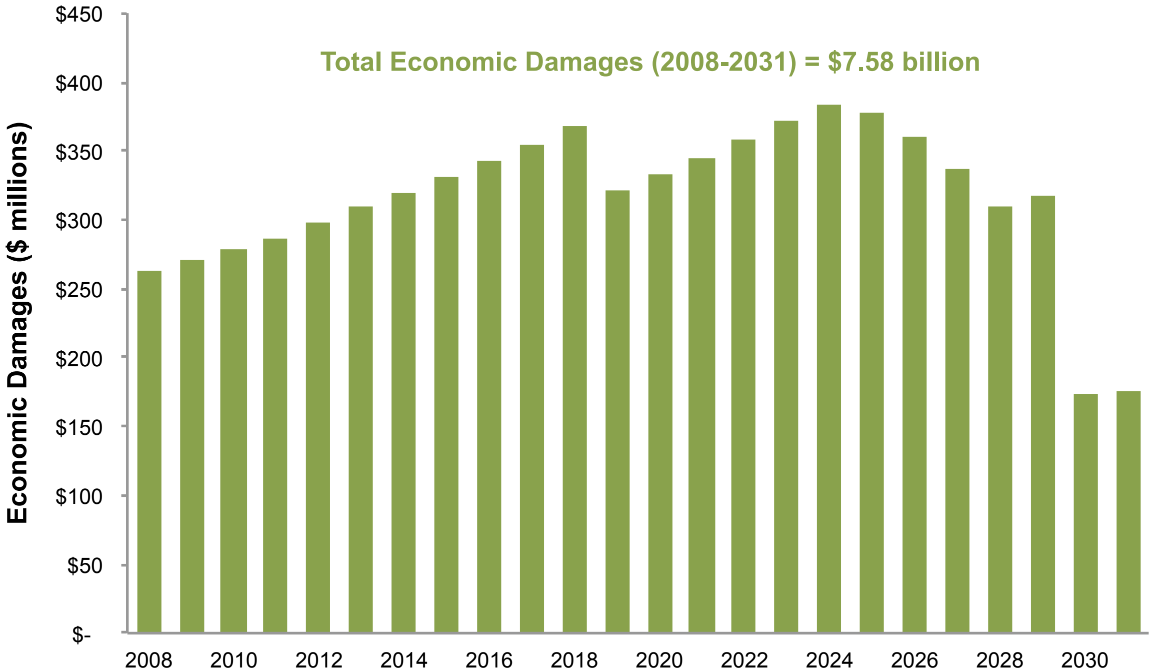

Figure 16. Total economic damages from physical health effects due to air pollution from coal-fired generating stations in Alberta

As noted in Section 5.5, the ICAP model accounts for more than just exposure to PM and ozone because of the correlated impacts from other pollutants. However, there are health impacts that are not captured by the model such as cancer or other illnesses not attributed to PM or ozone but related to other pollutants emitted by coal-fired generating stations. The health impacts of greenhouse gas emissions are also not accounted for. These health impacts will in turn have an impact on the economy, whether in terms of health care costs, lost productivity, or premature mortality.

The economic costs of environmental damages are also not considered in this report but would be an additional cost to society.

6.2 Air Pollution Emissions Experiments and Policy model cost estimates

The American National Research Council has measured the external costs associated with local and global air pollution from coal-fired power plants in the United States. The study looked at the diversity of damages in relation to the pollution intensity of the power plant and the location of the plant, which affects the size of the population exposed to pollution from the plant. The researchers recognized that the most economically efficient policy to address air pollution is a policy that targets the externality itself rather than the output associated with it. For this reason, information on damages per ton of emissions from coal was reported.[268]

The effects of emissions on ambient air quality on human health, visibility, agriculture and other sectors were modeled using the Air Pollution Emissions Experiments and Policy model which links emissions from power plants to ambient levels of pollution.[269] The researchers calculated the effects of 406 coal-fired power plants for the year 2005. The model was used to calculate the damages associated with emitting one ton of each of four pollutants (SO_2, NO_x, $PM_{2.5}$, PM_{10}) at each power plant. Damages per ton were then multiplied by the total number of tons of each of the four pollutants emitted at each plant to produce an estimate of the aggregate damages associated with emissions from each plant. The researchers also used electricity generation data to calculate the damages per kWh.[270]

The health damages are a significant component of the economic impact of pollution from coal-fired generating facilities. The accuracy of the model's health damages component is sensitive to the choice of values used for monetizing premature mortality. This study chose a value of statistical life of $7.2 million (2007 USD) based on willingness to pay.[271] This is lower than the value of statistical life of $4.8 million incorporated into the ICAP model.

The damages per ton of each of four pollutants at American coal-fired generating facilities exhibit a broad range and vary with plant location (based to a large extent on the number of people affected). However, variation in damages per kWh is primarily due to variation in pollution intensity (emissions per kWh) rather than variation in damages per ton of pollutant.[272] Table 8 uses the mean damage value per ton (converted to metric tonne) of each of four criteria air pollutants reported by the American National Research Council to calculate the damages resulting from air pollution emitted by coal-fired generating facilities in Alberta.

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[268] *Hidden Costs of Energy*.

[269] Nicholas Z. Muller and Robert Mendelsohn, *Measuring the Damages of Air Pollution in the United States* (2007). http://aida.econ.yale.edu/~nordhaus/Resources/Muller_overview.pdf

[270] Ibid.

[271] Ibid.

[272] *Hidden Costs of Energy*.

Table 8. Estimate of annual economic damages related to health from emissions from coal-fired power plants in Alberta based on the Air Pollution Emissions Experiments and Policy model

	SO_2	NO_x	$PM_{2.5}$	PM_{10}
Mean damages of emissions from coal-fired power plants (2010 Canadian Dollars per tonne)[273,274]	$5,821	$1,606	$9,533	$461
Amount of pollutant emitted by coal plants in Alberta[275,276] (tonnes per year)	114,511	71,507	1,782	3,872
Damages per pollutant ($ millions)	$667	$115	$17	$1.8
Total damages ($ per year)	$800 million			
Damages per MWh	$17.18	$2.96	$0.44	$0.05
Total damages	**2.1 ¢/kWh**			

6.3 Environment Canada cost estimates

As was the case in the previous section, these figures can be contrasted with the Environment Canada calculations which estimate that reducing approximately 160 TWh of coal-fired electricity generation in Alberta would result in a net present value of $2.7 billion in health care savings[277], which would be equivalent to 1.7 ¢/kWh.

6.4 Cost estimates associated with mercury

As described in the health impacts section, exposure to methylmercury while *in utero* results in neurological development effects. Increasing levels of exposure results in reduced IQ levels. The percentage point drop in IQ can be measured and the impact on society through reduced earning power among other indices can be quantified. This has resulted in estimates of the economic benefit of reduction per tonne of mercury emitted.

Environment Canada's regulatory impact analysis statement of the federal coal regulations[278] reports the following:

> *Several studies in the economic literature have estimated and monetized the socio-economic value of mercury-related health impacts. Rice and Hammit (2005) estimated the value of health benefits from proposed caps on mercury emissions from U.S. power plants. With respect to the impacts of mercury on brain development, Rice and Hammit estimated that IQ*

[273] Ibid.

[274] Converted to metric tonnes and 2010 Canadian dollars. Reported in US short tons in 2007 U.S. Dollars: SO_2 $5,800, NO_x $1,600, $PM_{2.5}$ $9,500, PM_{10} $460 NOTE: All plants are weighted equally, rather than by the fraction of electricity they produce. 90% of damages are due to premature death – costs based on a Value of Statistical Life of $7.2 million (2007 USD).

[275] The values for SO_2, NO_x and PM are from 2011.

[276] The concentration-response functions in the air pollution literature are approximately linear in ambient concentrations. The unit values assigned to health and other endpoints are likewise assumed to remain constant over the relevant ranges of the endpoints.

[277] *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*.

[278] Ibid.

impacts had a value of $10,000 to $11,000 per kg of emissions, assuming that there is no lower threshold for impacts from exposure. If a non-zero threshold of impacts is assumed, then Rice and Hammit estimate the value of impacts to be lower at $3,900 to $4,500 per kg (in 2000 U.S. dollars).

To be conservative, the low value of US$3,900 per kg of emissions is used for the analysis. Adjusting the value of $3,900 in 2000 U.S. dollars gives a value of $5,880 in 2010 Canadian dollars.[279]

There is a range of estimates in the literature for the economic damages associated with reductions in IQ. The estimates come from various regions and depend on the economic conditions within that region. Higher economic damages are associated with losses of IQ in a knowledge-based economy.[280]

It is precautionary to assume that there is no lower threshold for the impacts of exposure to mercury. This is particularly true when referring to the safe amount of mercury that a fetus can be exposed to. For this reason, the following calculation regarding economic damages of mercury is based on the higher estimate of $10,800 per kg ($16,283 CAD 2010) of emissions provided by Rice and Hammit.[281] It should be noted that the error range for the damage estimates associated with exposure to mercury is much wider than the range associated with impacts from ozone and particulate matter due to the complicated impact pathway.

Alberta coal-fired generating stations emitted 642.9 kg of mercury in 2010, resulting in economic damages of an estimated $10.5 million in that year. In 2011, this number was down to 216 kg[282], or about $3.5 million, just over half of the value of the $6.5 million in royalties collected by the province that year.[283]

There is emerging evidence that exposure to mercury also increases the risk of cardiovascular disease in adults and associated premature mortality. If these risks are included, the economic damages associated with mercury are up to 50 times higher than the damages linked to loss of cognition, to over $180,000 per kg. Environment Canada does not include this number in their analysis due to the uncertainty associated with the quantification of these impacts, but notes that given the omission of these potentially significant impacts, their estimate should be seen as a low-end estimate of the value of potential health impacts from mercury.[284] If included, this would put the economic damages of mercury emissions from coal plants in Alberta into the $39 million range annually (based on 2011 emissions).

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[279] Ibid.

[280] Kyrre Sundseth, Jozef M. Pacyna, Elisabeth G. Pacyna, John Munthe, Mohammed Belhaj and Stefan Astrom, "Economic benefits from decreased mercury emissions: Projections for 2020," *Journal of Cleaner Production* 18 (2010) 390. http://mpp.cclearn.org/wp-content/uploads/2010/02/sundseth_k_et_al1.pdf

[281] Rice and Hammitt, *Economic Valuation of Human Health Benefits of Controlling Mercury Emissions from U.S. Coal-Fired Power Plants.*

[282] 2011 data is preliminary and unreviewed.

[283] Alberta Energy, *Coal and Mineral Development in Alberta 2011 Year in Review* (2012), 19. http://www.energy.alberta.ca/minerals/pdfs/2011_CMD_Annual_Report_FINALv4.4.pdf

[284] *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations.*

6.5 Cost comparison summary

6.5.1 Economic costs from health risks

The models discussed above provide a range of estimates for the economic damages associated with the health risks from air pollution emitted by coal plants. The range of costs is summarized in Table 9.

Table 9. Cost comparison of estimated economic damages from health impacts associated with air pollution from coal plants in Alberta

	Damages per kWh
ICAP Model[285]	0.7¢
Air Pollution Emissions Experiments and Policy model	2.1¢
Environment Canada	1.7¢

Studies in the United States have found estimates of non-climate damage from coal pollution to range from 3.2 ¢/kWh to 3.4 ¢/kWh.[286] Many of the American coal plants are closer to larger populations and therefore it is expected these figures would be somewhat higher than the damages in Alberta estimated in Table 9.

6.5.2 Other costs

The U.S. Interagency Working Group on the Social Cost of Carbon has estimated the economic damages associated with greenhouse gases based on global damages. From these, the working group created a range of estimates of the per ton social cost of carbon which includes the cost of changes in net agricultural productivity, effects on human health, property damages from increased flood risk, and the value of ecosystem services. The central value of these estimates for 2010 is $26/tonne of CO_2e emissions (2010 CAD). This is the base value that Environment Canada uses to estimate avoided climate change related damages, which are calculated using a growth rate estimated from the arithmetic average of the three models.[287] The U.S. Interagency Working Group also estimated the social cost of carbon in the event that higher than expected impacts from temperature changes are observed. The base value, which is expected to rise over time, is $79/tonne of CO_2e emissions (2010 CAD). The Working Group recommends that policy analyses include the full range of estimates in their sensitivity analysis.[288] Environment Canada uses a value of $104/tonne for 2010 to more accurately reflect the risk of low probability, high-cost climate damage scenarios in cost-benefit analyses, but cautions that this does not capture the extreme end of the spectrum on social cost of carbon estimates, which are as high as

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[285] Based on 2011 estimates of damages associated with chronic exposure to air pollution ($286 million) and on 2011 electricity generation from coal plants (38.8 TWh).

[286] M. Greenstone and A. Looney, *A Strategy for America's Energy Future: Illuminating Energy's Full Costs,* (2011), 7. http://www.hamiltonproject.org/papers/a_strategy_for_americas_energy_future_illuminating_energys_full_costs/

[287] *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*.

[288] Interagency Working Group on Social Cost of Carbon, United States Government, *Social Cost of Carbon for Regulatory Impact Analysis: Technical Support Document* (2010). http://www.epa.gov/otaq/climate/regulations/scc-tsd.pdf

\$1,000/tonne of CO_2e emissions.[289] Using the growth rate models, Environment Canada's Social Cost of Carbon estimates for 2012 have been updated to \$28.44/tonne to \$112.37/tonne.

Coal plants in Alberta emitted 43.2 Mt CO_2e in 2010, making them responsible for \$1.12 billion dollars of social costs at minimum, which is equivalent to 2.9 ¢/kWh, but these costs could be as high as \$4.49 billion, or 11.6 ¢/kWh. When added to the economic damages related to health risks from air pollution, the social cost is at minimum in the range of 3.6 to 5¢/kWh. These costs are based on a conservative estimate of the health related economic damages, and other than the economic damages associated with greenhouse gases, do not include the costs associated with environmental impacts from air pollution. This can be contrasted with the coal royalties paid in Alberta for thermal coal, which amounted just over \$6.5 million or the equivalent of 0.0017 ¢/kWh in 2011, and the average electricity pool price received by coal facilities in 2012 was 6.6 ¢/kWh.[290]

6.5.3 Total costs to society

The results from this section are summarized in Table 10. Even this conservative estimate of the social cost of coal is almost as much as the market price for electricity from coal.

Table 10. Summary of costs of coal-fired electricity in Alberta

	Cost (¢/kWh)
Greenhouse gas social cost	2.9 – 11.6
Economic damages from health impacts from air pollution	0.7 – 2.1
Economic damages from environmental impacts from air pollution	not calculated
Total societal costs	**3.6 – 13.7**
Pool price (2012)	6.6
Total cost of electricity from coal	**10.2 - 20.3**

As this report demonstrates, the full costs of electricity production from coal in Alberta are not priced into the price. Additional costs (externalities) are borne by taxpayers and society at large. This amounts to a subsidy for burning coal, and makes coal-powered electricity appear cheaper for society than it really is. In order to have a level playing field among all electricity producers, these externalities need to be priced into the cost of providing electricity from coal-fired generating stations. One way to do this would be to increase the royalty paid on coal to cover the societal costs of burning coal.

[289] *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations*.

[290] Alberta Electric System Operator, Annual Market Statistics Report Data File (2012). http://www.aeso.ca/downloads/2012_Annual_Market_Stats_Data_File.xlsx

7. Conclusions

Coal-fired electricity generation is not a benign source of energy. This report describes the numerous health risks associated with exposure to air pollution from coal plants. The body of epidemiological research on the impacts of exposure to primary particulate matter and to secondary particulate matter and ozone (formed from air contaminants emitted by coal plants) is extensive and unequivocal in its findings. There is a clear link between exposure to these pollutants and higher morbidity and premature mortality from respiratory and cardiovascular illnesses.

There has never been a study that attempts to quantify the health risks of air pollution from coal plants in Alberta. In the absence of that information, a model developed for the Canadian Medical Association, which quantifies the health damages from air pollution, was applied to Alberta. Using this model has given us an initial estimate of the health risks borne by Albertans and the associated economic damages that result from these health risks. We have translated these health associated costs into a cost per kWh of electricity produced and compared the results of this model to costs calculated from two other sources. The result is a range of health related costs from 0.7 to 2.1 ¢/kWh.

These are not the only costs of producing electricity from coal. Additional costs result from the environmental damages associated with various toxic air pollutants emitted by coal plants. Coal plants are also the biggest source of greenhouse gases in the electricity industry. Numerous health and environmental impacts are connected to greenhouse gases. Estimates of the economic damages from these impacts have been compiled into a Social Cost of Carbon. Based on the quantity of GHGs emitted by coal plants in Alberta, the social cost of carbon translates into a cost per kWh in the range of 2.9 to 11.6 ¢/kWh as summarized in Table 10.

Alberta has abundant reserves of easily accessible coal, which, in part thanks to very low royalties, has been an inexpensive fuel source for electricity generation over the past few decades. However, there is a growing awareness of the price that society pays for this electricity. Some of these costs are starting to be internalized on existing plants as mercury capture requirements increase and on newer plants as stricter air NO_x and SO_2 requirements are implemented. However, air pollutants and greenhouse emissions from Alberta's sizeable existing fleet are not fully internalized.

7.1 Finding a level playing field

Lower emissions options such as high-efficiency natural gas, combined heat and power and renewable energy technologies all offer important opportunities to reduce the emissions of the current as well as the future electricity fleet. Pairing renewable energy with natural gas takes advantage of the currently low gas prices, while making further emissions reductions than gas can make alone. Concurrently developing renewable energy will also help to mitigate against future gas price volatility. In spite of this opportunity, Alberta has never developed a comprehensive renewable energy policy.

A Renewable and Alternative Energy Project Team was established by CASA and produced its final report in March 2007. The team was not able to develop a policy itself but provided elements and policy options to be considered in developing a renewable energy framework for Alberta. The report recommended that the Government of Alberta develop and implement a policy framework to increase the supply of and demand for renewable and alternative electrical energy in Alberta and recommended that the government consult with stakeholders and consider their concerns in developing this policy framework.[291] The report also recommended that the policy framework should be developed and implemented in a timely manner — but six years have passed since the report was produced and the renewable policy framework has yet to be developed.

The CASA team identified certain objectives for a renewable energy framework. One key objective is that the policy must "*recognize and incorporate environmental costs and benefits into the marketplace, thus providing a more comprehensive price signal by valuing environmental attributes*".[292] A renewable energy policy for Alberta must take into account the unique aspects of Alberta's electricity market. For example, Alberta's electricity market is operated through a power pool with privately owned companies generating electricity. As a result, policies that are market-based and price in the environmental attributes of energy production are likely to fit well into Alberta's electricity market context.

While the Specified Gas Emitter Regulation (SGER) requires large greenhouse gas emitters such as coal plants to reduce their emissions intensity by 12 per cent or pay $15/tonne into a technology fund, coal units are therefore required to pay at most 0.18 ¢/kWh. The SGER also allows renewable energy to receive offset credits at a value of $15/tonne of CO_2, however the availability of credits and their long-term declining value are not a significant enough bridge to encourage widespread adoption of renewables. A strengthened carbon price would provide a steadier signal to spur renewable energy development.

Pricing in the additional health and environmental costs of coal puts coal on par with numerous sources of low and non-polluting sources of electricity. Between 2007 and 2011, the federal government offered a production incentive known as ecoEnergy Renewable Power.[293] The program paid 1 ¢/kWh to incent the development of low-impact renewable energy,[294] which would result in a net societal cost savings on the order of at least 3 ¢ for every kWh of coal displaced. Similarly, the U.S. Environmental Protection Agency has calculated that for every dollar spent to reduce mercury and toxic air pollution, Americans get three to nine dollars in health benefits.[295]

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[291] Clean Air Strategic Alliance, *Recommendations for a Renewable and Alternative Electrical Energy Framework for Alberta* (2007), 1. http://www.casahome.org/Projects/ProjectsAdminController.aspx?Command=Core_Download&EntryId=796

[292] Ibid., 7.

[293] Natural Resources Canada, "ecoENERGY for Renewable Power," 2012. http://www.nrcan.gc.ca/ecoaction/6444

[294] Natural Resources Canada, "Terms and Conditions of the ecoENERGY RP," 2008. http://www.nrcan.gc.ca/ecoaction/power/conditions/6557

[295] U.S. Environmental Protection Agency, "Healthier Americans," *Mercury and Air Toxics Standards (MATS)*, 2012. http://www.epa.gov/mats/health.html#impacts

7.2 Leadership opportunities for GHG reductions

In 2012, the federal government passed greenhouse gas emissions regulations that allow coal units to operate on average 49 years in Alberta, with over half being allowed to operate until they are a full 50 years old. It is widely anticipated that the Alberta government will look to negotiate an equivalency agreement on how these federal regulations will be implemented in Alberta.

The federal greenhouse gas regulations allow for an end of life that is up to 10 years longer than the previously established end-of-life timeframe in Alberta.[296] This creates a risk that the weaker federal regulation could be used as a benchmark. Briefing notes prepared by Environment Canada revealed that industry lobbyists pushed the department to extend the operating span from Environment Canada's originally proposed 45 years out to 50 years[297]; which was already more than a proposal of 40 years made previously by the Canadian Electricity Association.[298] If Alberta's current NO_x/SO_2 regulations were to be weakened to the federal end-of-life timeframe, enabling the average coal unit in Alberta to operate until it is 49 years of age, it would allow for an additional 20-30 per cent more NO_x/SO_2 pollution would occur. Figure 17 illustrates the cumulative additional NO_x and SO_2 pollution that would be allowed if the weaker federal end-of-life timeframe were to be implemented.

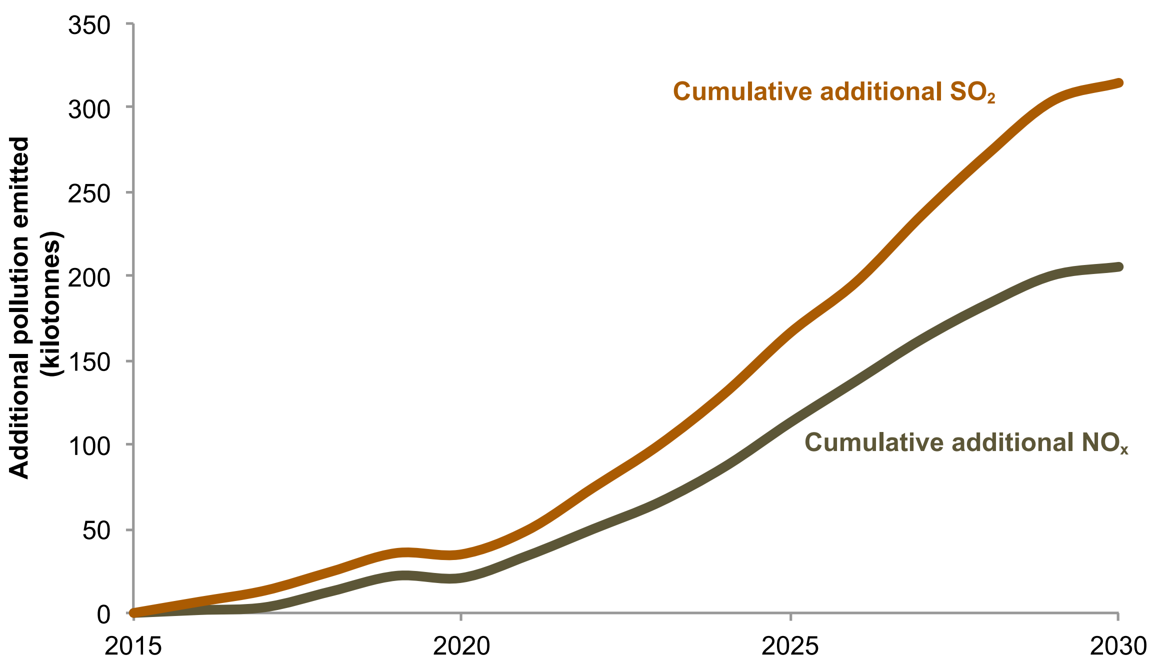

Figure 17. Cumulative additional pollution from Alberta coal plants if NO_x and SO_2 regulations are weakened to federal end-of-life

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[296] As discussed on page 17 of this report, the "end-of-life" for a coal unit under the Alberta framework is its "design life", which is defined as the "date of expiry of the PPA term or 40 years from the date of commissioning, whichever is greater".

[297] Mike de Souza, "Feds pressured by coal industry to weaken regulations, records reveal," *Postmedia News*, April 22, 2012. http://www.canada.com/news/Feds+pressured+coal+industry+weaken+regulations+records+reveal/6497750/story.html

[298] Canadian Electricity Association, *Electricity and Climate Change, Towards a Sustainable Future* (2002), 7. http://www.electricity.ca/media/pdfs/backgrounders/climatechangeE.pdf

Conversely, if the Alberta government were to use the CASA-recommended 40 year end-of-life timeline it implemented in 2006 with respect to GHG emissions, it would achieve a reduction of at least 10 Mt of CO_{2e} by 2020 if all coal capacity was simply replaced with natural gas (Figure 18); this timeline would cumulatively provide almost twice the reductions of the current federal regulations between 2015-2030 (Figure 19). Ontario's coal phase-out over a 10-year timeframe has demonstrated an annual 10 Mt reduction of greenhouse gas emissions. A more stringent end-of-life standard, combined with an even greater portion of renewable energy, could see even further reductions in both GHG and criteria air contaminants.

Clearly any harmonization of federal regulations in Alberta should not further weaken the allowable lifespan.

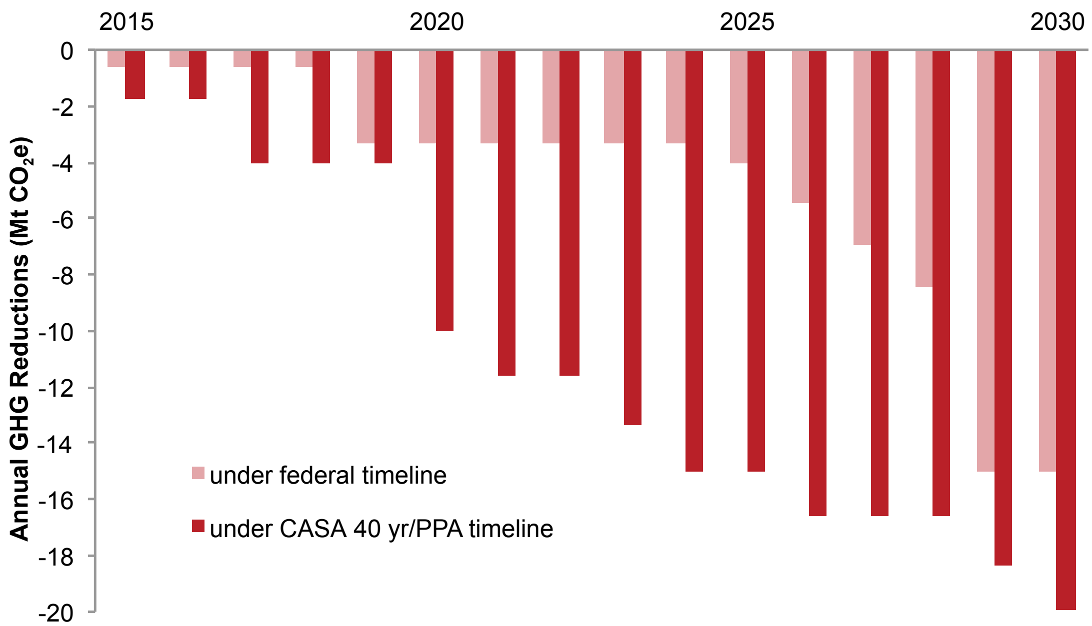

Figure 18. Comparison of greenhouse gas reductions using different end-of-life regulations CASA end-of-life consensus of 40 years or PPA timeline compared to federal coal regulations timeline

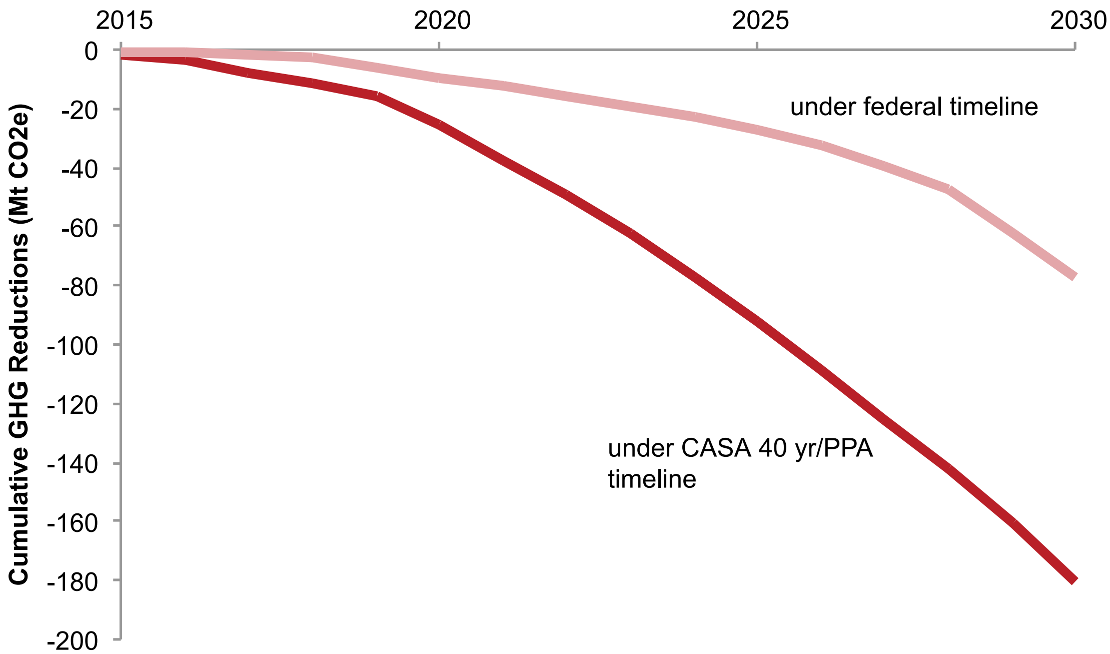

Figure 19. Comparison of cumulative greenhouse gas reductions using different end-of-life regulations CASA end-of-life consensus of 40 years or PPA timeline compared to federal coal regulations timeline

A phase-out of conventional coal power in Canada is inevitable, as former federal Environment Minister John Baird stated: "We're never going to get to our reduction targets if we continue to build dirty coal plants."[299] How many decades the coal phase-out will take will depend on decisions governments make in the near term. The current federal regulations will allow the last existing coal unit in Alberta to operate until 2062, while Ontario will have phased out its coal fleet by the end of 2014. Nova Scotia, which had a heavier dependence on coal than Alberta, has legislated targets that would require 40 per cent renewable electricity by 2020 to cut its coal dependence in half. Alberta has the opportunity to go further than the weak aspects of the federal regulations that allow coal units to run for 50 years, thereby reducing greenhouse emissions, along with other health damaging pollutants.

[299] John Baird, CTV News, March 10, 2008. Available at http://www.ctvnews.ca/baird-unveils-tough-rules-for-industrial-polluters-1.281607#ixzz2NRitppBX