Global Warming and Canada: Getting to Zero by 2060

Introduction

This study takes as given that:

- Global warming is occurring.
- Humans, particularly Canadians, are playing a major role through their activities that release greenhouse gases into the atmosphere.
- Canadians will realize it is in their interest to reduce Canadian emissions even though in the short run a warmer climate may appear beneficial.

It addresses the question how will Canada reduce its emissions.

Current discussions address the short-term measures (e.g. carbon taxes, cap and trade) that could lead to long-term reduction in emissions. This study offers an alternative. It starts with where Canada needs to get (a zero-emission future), and addresses how to get there from now. The underlying premise is: "If you do not know where you are going, any road will get you there."

The goal is zero emissions. Any goal short of zero emissions increases greenhouse gases in the atmosphere, and adds to warming. The target year is 2060 – a little more than forty years into the future. Forty years is sufficiently long for:

- Retirement of those currently in the work force,
- The development of new production processes and new products,
- The replacement of capital equipment which emits greenhouse gases,
- A fair return on existing investments in emitting industries,
- Retrofitting existing buildings,
- The application and fine-tuning of current emission-reduction technologies, and
- The development of infrastructure, including the massive expansion of the electricity grid.
- Canadians will have adjusted their expectations so that no one will have a legitimate complaint that they have "lost" something by addressing climate change.

The approach is to take a sector-by-sector look at where Canada is currently emitting greenhouse gases, to identify the measures needed to reduce these emissions to zero in each sector, and to estimate the effect of these measures by 2060.

The measures needed to reduce emissions to zero will include:

Increased vigilance by Canadians and companies operating in Canada in voluntarily preventing emissions, based on a full understanding of the implications of global warming.

Increased regulation by governments, including the prohibition of some emitting activities and allowing other emitting activities only under strict regulation and monitoring.

Focused public research related to emissions reduction.

The application of existing emission-reduction technologies, and their incremental development over the period to 2060. A 2 percent annual reduction in emissions through these technologies would more than halve emissions in 40 years.

Revolutionary new technologies (e.g. nuclear fusion power generation) will likely be developed by 2060, but have not been included.

Chapter 1: Canada's Emissions

Although Canadians make up about 0.5 percent of the world population, their greenhouse gas emissions account for 2.0 percent of the world total.

Emissions go beyond fossil fuels. Emissions occur across the sectors. Some sectors have been able to reduce emissions from 1990 level.

Canada's 1990–2012 Green House Gas Emissions by Sector

Greenhouse Gas Categories	**1990**	**2012**	**2012**	**Change 1990-2012**	
	kt CO2 eq	**kt CO2 eq**	**% Total 2012**	**kt CO2 eq**	**% Total Change**
Total – All Sectors	590,253	708,713	100.0%	118,460	20.1%
Fossil Fuel Production, Fugitives, Transport	105,840	171,600	24.6%	65,760	62.1%
Electricity and Heat Generation	93,600	88,300	12.7%	-5,300	-5.7%
Stationary Combustion Sources excluding electricity & heat generation, fossil fuel production	129,310	116,770	16.7%	-12,540	-9.7%
Road and Off-Road Transportation	120,563	170,012	24.4%	49,449	41.0%
Aviation (Domestic)	7,100	6,100	0.9%	-1,000	-14.1%
Railways	7,000	7,600	1.1%	600	8.6%
Marine (Domestic)	5,000	5,800	0.8%	800	16.0%
Industrial Processes	55,990	56,621	8.1%	631	1.1%
Solvent and Other Product Use	180	310	0.0%	130	72.2%
Agriculture	47,100	54,130	7.8%	7,030	14.9%
Waste	18,570	20,670	3.0%	2,100	11.3%
Aviation (International)	6,100	9,100	1.3%	3,000	49.2%
Marine (International)	3,100	1,700	0.2%	-1,400	-45.2%

Action is needed in all sectors to reduce emissions to zero. No sector is exempt from the need to eliminate emissions.

Chapter 2: Fossil Fuels

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Fossil Fuels

Greenhouse Gas Categories	1990	2012	2012	Change 1990-2012	
	kt CO2 eq	kt CO2 eq	% Total 2012	kt CO2 eq	% Total Change
Total - All Sectors	590,253	708,713	100.0%	107,660	18.2%
Fossil Fuel Production, Fugitives, Transport	105,840	171,600	24.6%	65,760	62.1%
Fossil Fuel Production -Stationary Combustion Source	34,000	47,000	6.7%	13,000	38.2%
Fugitives - Venting	20,000	30,000	4.3%	10,000	50.0%
Fugitives - Natural Gas	11,000	19,000	2.7%	8,000	72.7%
Petroleum Refining - Stationary Combustion Source	16,800	16,800	2.4%	0	0.0%
Pipelines	6,850	5,700	0.8%	-1,150	-16.8%
Fugitives - Oil	4,200	6,500	0.9%	2,300	54.8%
Fugitives - Flaring	4,400	4,700	0.7%	300	6.8%
Fugitives - Coal Mining	2,000	1,000	0.1%	-1,000	-50.0%
Mining & Oil/Gas Extraction -Stationary Comb. Source	6,590	40,900	5.9%	34,310	520.6%

Getting to Zero by 2060

Getting to zero by 2060 means:

- The combustion of fossil fuels will substantially but not completely end. Some combustion will continue for national priorities (government services, remote mine sites, ferry services, essential air travel), where no alternatives exist. These emissions are estimated at about 4.83 percent of current emissions. Some extraction, processing and distribution of fossil fuels for purposes other than burning (e.g. plastics) will continue. Currently, these activities account for around 7.37 percent of total production. Exports particularly to the United States will disappear, since the other countries will be abandoning the combustion of fossil fuels. Canada's fossil fuel reserves will be sufficient to meet Canada's needs for the foreseeable future, primarily because removal from reserves will diminish.
- To the extent that fossil fuels continue to be used, the focus will be on fossil fuels that produce the most energy per emission. This means natural gas and conventional oil will be used, and tar sand and coal extraction will not.
- There will be some carbon storage facilities available, and where feasible, those who combust fossil fuels for national priorities will be required to capture, ship to a storage location and store CO_2. At the same time, those projects allowed to operate in 2060 will be selected in part because of their capacity for carbon capture and storage.
- Carbon capture and storage will not be the vehicle that allows current levels of combustion to continue into the future for several reasons:

    - Current capture technologies do not capture all the CO_2. Some emissions remain even where there is the desire for carbon capture and storage, so carbon capture and storage are only a partial solution to the greenhouse gas problems.
    - There are storage issues. The amount of CO_2 to be stored is huge, yet there remain questions about where it will be stored, how will it be stored, whether the storage is safe, and whether communities will accept storage in their neighbourhoods.
    - There are transportation issues related to getting the CO_2 from the place of combustion to the place of storage.
    - Carbon capture and storage increases the cost of using fossil fuels, and makes other technologies, particularly renewable technologies cost competitive. Put another way, the energy consumed in carbon capture and storage uses up a significant portion of the energy in the fossil fuel, thereby reducing the emission efficiency of the fossil fuel as a net source of energy.
    - Even if all the outstanding issues related to carbon capture and storage are answered eventually, it is unlikely that the questions will be answered and facilities built in time to address the greenhouse gas crisis. Other technologies are closer to implementation and will have occupied the field by the time carbon capture and storage is ready.
- Where extraction, processing and distribution do occur, there will be strict regulations to eliminate all emissions that are incidental. The current tolerance of unnecessary fugitive emissions will end.
- In addition, the selection of drill sites will focus on sites that are less likely to lead to fugitive emissions. Furthermore, there will be strict monitoring of sites to detect and stop fugitive emissions. The unpredictable nature of fracking may be problematic for the technology.
- Where oil and gas are extracted, refined and transported, the energy source will be electricity and not oil and gas combustion.

Projected Emissions

Projected Emissions for 2060: Fossil Fuels

Greenhouse Gas Categories	**2012**	**2060 Projection**	**Comments**
	kt CO2 eq	**kt CO2 eq**	
Fossil Fuel Production, Fugitives, Transport	171,600	5,512	Sector Total
Fossil Fuel Production - Stationary Combustion Source	47,000	0	Current emissions times zero, as electricity replaces fossil fuels to power production facilities
Fugitives - Venting	30,000	366	Current emissions times12.20 percent representing the residual 2060 demand (7.37 percent for non-energy uses

			and calculated 4.83 percent for combustion for national energy priorities) times 10 percent representing the residual after improvements to reduce venting.
Fugitives - Natural Gas	19,000	1,159	Current emissions times 12.20 percent representing the residual 2060 demand (7.37 percent for non-energy uses and calculated 4.83 percent for combustion for national energy priorities) times 50 percent representing the residual after improvements to prevent fugitive emissions.
Petroleum Refining - Stationary Combustion Source	16,800	0	Current emissions times zero, as electricity replaces fossil fuels in petroleum refining
Pipelines	5,700	0	Current emissions times zero, as electricity replaces fossil fuels in running pipelines
Fugitives - Oil	6,500	397	Current emissions times 12.20 percent representing the residual 2060 demand (7.37 percent for non-energy uses and calculated 4.83 percent for combustion for national energy priorities) times 50 percent representing the residual after improvements to control fugitive emissions
Fugitives - Flaring	4,700	287	Current emissions times 12.20 percent representing the residual 2060 demand (7.37 percent for non-energy uses and calculated 4.83 percent for combustion for national energy priorities) times 50 percent for improvements to control flaring.
Fugitives - Coal Mining	1,000	0	Current emissions times zero, as coal mining ends
Mining & Oil/Gas Extraction - Stationary Comb. Source	40,900	3,304	Oil and Gas makes up 50.0 percent of the subsector, based on minimum employment by size of business. Mining excluding coal makes up 44.7 percent, and coal 5.3 percent. Projected emissions equal (a) current emissions times 50.0 percent (oil and gas share) times 12.20 percent representing the residual 2060 demand (4.83 percent for combustion for national energy priorities and 7.37 percent for non-energy use) times 50 percent representing the residual after improvements in emission efficiency in oil/gas production PLUS (b) current emissions times 44.7 percent for the mining excluding coal share times 15 percent representing the residual for non-grid accessible mines (grid accessible mines will use electricity) times 50 percent representing the residual for improvements in emission efficiency in production times 75 percent representing the residual for emissions that are not captured PLUS (c) current emissions time 5.3 percent representing the coal mining share times 0 representing the disappearance of coal mines.

Chapter 3: Electricity and Heat Generation

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Electricity and Heat Generation

Greenhouse Gas Categories	1990	2012	2012	Change 1990-2012	
	kt CO2 eq	kt CO2 eq	% Total 2012	kt CO2 eq	% Total Change
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Electricity and Heat Generation	93,600	88,300	12.7%	-5,300	-5.7%

Getting to Zero by 2060

Getting to zero by 2060 means:

- An expansion of electricity production from renewable sources by about 3.76 times over the current level to replace the energy currently produced from fossil fuels.
- An electricity system based on:
    - A diverse array of renewable energy sources such as solar, wind, water, nuclear and geothermal energy sources.
    - The use of a diverse array of electricity storage systems (pumped hydro storage, hydro storage, batteries) at various levels (electricity producers, industry, households).
    - Super grids covering all of Canada and between Canada and the United States, and using high voltage direct current transmission lines to move power around the continent in response to supply and demand.
    - The operation of smart grids that increase efficiency.
- The decreasing reliance by households and industry on the grid as an energy source, driven by the desire for control over energy plus new technologies that facilitate the local production and utilization of renewable energy.
- The use of fossil fuels only for emergencies to manage peak loads and to address periods when the sun does not shine and the wind does not blow over a wide area.
- The capture of the fossil fuels that are used.

Projected Emissions

Projected Emissions for 2060: Electricity and Heat Generation

Greenhouse Gas Categories	2012	2060 Projection	Comments
	kt CO2 eq	kt CO2 eq	
Electricity and Heat Generation	88,300	2,208	Current emissions times 5 percent contingency, as electricity comes almost totally from renewable sources, with natural gas used to address demand spikes times 50

			percent for uncaptured emissions when natural gas is used.

Chapter 4: Stationary Combustion Sources

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Stationary Combustion Sources

Greenhouse Gas Categories	**1990**	**2012**	**2012**	**Change 1990-2012**	
	kt CO2 eq	**kt CO2 eq**	**% Total 2012**	**kt CO2 eq**	**% Total Change**
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Stationary Combustion Sources excl. electricity & heat generation, fossil fuel production	129,310	116,770	16.7%	-12,540	-9.7%
Manufacturing Industries	55,850	43,080	6.2%	-12,770	-22.9%
Iron and Steel	*4,950*	*5,480*	*0.8%*	*530*	*10.7%*
Non-ferrous Metals	*3,260*	*3,250*	*0.5%*	*-10*	*-0.3%*
Chemical	*8,220*	*10,100*	*1.4%*	*1,880*	*22.9%*
Pulp and Paper	*14,500*	*5,890*	*0.8%*	*-8,610*	*-59.4%*
Cement	*3,920*	*3,960*	*0.6%*	*40*	*1.0%*
Other Manufacturing	*21,000*	*14,400*	*2.1%*	*-6,600*	*-31.4%*
Construction	1,870	1,450	0.2%	-420	-22.5%
Commercial & Institutional	25,700	27,800	4.0%	2,100	8.2%
Residential	43,500	40,900	5.9%	-2,600	-6.0%
Agriculture & Forestry	2,390	3,540	0.5%	1,150	48.1%

Getting to Zero by 2060

Getting to zero by 2060 means:

- Where there is access to the grid, the conversion of industrial, residential, commercial and institutional facilities so that they stop using fossil fuels in stationary combustion equipment and start meeting their energy needs from the electricity grid, and non-grid renewable sources. Most current industrial, residential, commercial and institutional facilities have access to the grid.
- Recognizing that while this conversion may appear onerous, current emitters have over 40 years to carry out the conversion, a period sufficiently long that all combustion equipment will wear out and have to be replaced anyway, and buildings will need to be retrofitted.
- Where there is no access to the grid (e.g. remote industries, particularly mines and mineral refining operations; remote communities; rural homes), allowing the continuation of combustion of fossil fuels, subject to regulation and where feasible, carbon capture.
- Recognizing the considerable scope for the reduction in energy use, particularly in the residential and transportation sectors.

Projected Emissions

Projected Emissions for 2060: Stationary Combustion Sources			
Greenhouse Gas Categories	**2012**	**2060 Projection**	**Comments**
	kt CO2 eq	**kt CO2 eq**	
Stationary Combustion Sources excluding Electricity & Heat Generation and Fossil Fuel Production	116,770	2,919	Current emissions times 5 percent representing the residual after 95 percent of current stationary combustion sources get energy from the grid or create their own renewable sources, times 50 percent representing the residual after the remaining emissions are captured.

Chapter 5: Road and Off-Road Transportation

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Road and Off-Road Transportation					
Greenhouse Gas Categories	**1990**	**2012**	**2012**	**Change 1990-2012**	
	kt CO2 eq	**kt CO2 eq**	**% Total 2012**	**kt CO2 eq**	**% Total Change**
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Road and Off-road Transportation	120,563	170,012	24.0%	49,449	41.0%
Road Transportation	96,763	132,412	19.0%	35,649	36.8%
Light-Duty Gasoline Vehicles	*45,500*	*38,300*	*5.5%*	*-7,200*	*-15.8%*
Light-Duty Gasoline Trucks	*20,300*	*41,400*	*5.9%*	*21,100*	*103.9%*
Heavy-Duty Gasoline Vehicles	*7,440*	*6,910*	*1.0%*	*-530*	*-7.1%*
Motorcycles	*152*	*268*	*0.0%*	*116*	*76.3%*
Light-Duty Diesel Vehicles	*469*	*824*	*0.1%*	*355*	*75.7%*
Light-Duty Diesel Trucks	*702*	*2,130*	*0.3%*	*1,428*	*203.4%*
Heavy-Duty Diesel Vehicles	*20,000*	*41,700*	*6.0%*	*21,700*	*108.5%*
Propane & Natural Gas Vehicles	*2,200*	*880*	*0.1%*	*-1,320*	*-60.0%*
Off-Road Transportation	23,800	37,600	5.4%	13,800	58.0%
Off-Road Gasoline	*7,800*	*7,600*	*1.1%*	*-200*	*-2.6%*
Off-Road Diesel	*16,000*	*30,000*	*4.3%*	*14,000*	*87.5%*

Getting to Zero by 2060

Getting to zero by 2060 means:

- Vehicles powered by the combustion of fossil fuels will be substantially off the roads. Vehicles propelled by the combustion of fossil fuels will be reserved for priority situations for which there are no available alternatives. High priority non-routine long-distance trucking in remote locations comes to mind.
- Almost all consumer vehicles and light commercial vehicles will be battery-powered.

- Apart from propulsion systems, these vehicles will have other attributes to make them energy efficient (e.g. light-weight materials).
- Various initiatives will be established to reduce the amount of driving. Whatever driving there is will occur at energy efficient speeds.
- Biofuels and hydrogen will no longer be under serious consideration for consumer and light commercial vehicles.
- The demand for heavy duty road transportation will fall considerably, as rail alternatives in particular become more attractive, global trade patterns change, and 3-dimensional printing reduces the need to ship manufactured goods.
- Hydrogen-based technologies are likely to find a role in heavy duty road transportation where a robust, mobile source of energy is needed and distribution is simple. This includes trucking along fixed routes. Refueling points can be established at key points along the routes, with local production facilities based on windmills, solar panels and the like situated near the distribution points.
- Some use of fossil fuels for energy efficient heavy-duty road transportation may continue for national priorities.

Projected Emissions

Projected Emissions for 2060: Road and Off-road Transportation

Greenhouse Gas Categories	2012	2060 Projection	Comments
	kt CO2 eq	kt CO2 eq	
Road & Off-Road Transportation	170,012	8,621	Sector Total
Road Transportation	132,412	4,861	Subsector Total
Light-Duty Gasoline Vehicles	*38,300*	*0*	*Current emissions times zero, as vehicles become battery powered*
Light-Duty Gasoline Trucks	*41,400*	*0*	*Current emissions times zero, as vehicles become battery powered*
Heavy-Duty Gasoline Vehicles	*6,910*	*691*	*Current emissions times 10 percent, representing the residual after regulatory prohibitions on uses that do not meet the "national priority" test, the increased use of electrified railways, use of hydrogen power, emission efficiency improvements, and changes in shipping patterns*
Motorcycles	*268*	*0*	*Current emissions times zero, as vehicles become battery powered*
Light-Duty Diesel Vehicles	*824*	*0*	*Current emissions times zero, as vehicles become battery powered.*
Light-Duty Diesel Trucks	*2,130*	*0*	*Current emissions times zero, as vehicles become battery powered*
Heavy-Duty Diesel Vehicles	*41,700*	*4,170*	*Current emissions times 10 percent representing the residual after regulatory prohibitions on uses that do not meet the "national priority" test, the increased use of electrified railways, use of hydrogen power, emission efficiency improvements, and changes in shipping patterns*
Propane & Natural Gas Vehicles	*880*	*0*	*Current levels times zero as vehicles become battery powered*
Off-Road Transportation	37,600	3,760	Subsector Total

Off-Road Gasoline	*7,600*	*760*	*Current emissions times 10 percent representing the residual after regulatory prohibitions on the use of fossil fuels not meeting the "national priority" test, use of hydrogen power, emission efficiency improvements.*
Off-Road Diesel	*30,000*	*3,000*	*Current emissions times 10 percent representing the residual after regulatory prohibitions on uses that do not meet the "national priority" test, use of hydrogen power, emission efficiency improvements.*

Chapter 6: Aviation and Marine

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Aviation

Greenhouse Gas Categories	1990	2012	2012	Change 1990-2012	
	kt CO2 eq	kt CO2 eq	% Total 2012	kt CO2 eq	% Total Change
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Aviation (Domestic)	7,100	6,100	0.9%	-1,000	-14.1%
Aviation (International)	6,100	9,100	1.3%	3,000	49.2%
Marine (Domestic)	5,000	5,800	0.8%	800	16.0%
Marine (International)	3,100	1,700	0.2%	-1,400	-45.2%

Getting to Zero by 2060

Getting to zero by 2060 means:

- International and domestic aviation and marine will substantially, but not completely, come to an end, because aviation and marine rely on the combustion of fossil fuels and carbon capture is not usually feasible.
- What aviation remains will be limited to national priorities (defense, government priorities, services to rural communities, strategic industrial purposes).
- The more fuel-efficient propeller-driven aircraft will replace jets. Air travel will be only for long-haul routes, because there will be viable alternatives such as railways on short-haul routes.
- Alternatives such as airships are unlikely to replace a significant amount of aviation based on fossil fuels.
- Domestic marine shipping will generally be replaced by:
    - Railways and trucking for inland shipping.
    - Battery powered and sail boats for inshore and inland fishing.
    - Hydrogen powered ferries for most routes, and for priority routes, fossil fuel powered ferries combined with the capture of CO_2 emissions.
- International shipping based on fossil fuels will be substantially eliminated. The alternatives (nuclear, sail powered, hydrogen powered) will fill the gap only on a minor basis. Some fossil fuel consumption and related emissions may continue for national priorities (strategic exports and imports), but emissions of CO_2 will be regulated and subject to carbon capture wherever practical.

- Globalization will be redefined. There will be substantially fewer imports from, and exports to sources outside the Americas. Imports and exports will be restricted to places that can be reached without international shipping. In Canada's case, this means the United States, Mexico, Central and South America, and the Caribbean. Exports of raw materials to Asia and Europe will disappear, but so will imports. Some economic doors, particularly the export of natural resources, will close, but others, notably manufacturing, will re-open. Trade within the Americas will continue, and will be based on electrified railways and hydrogen powered trucks. The Americas will need to become self-sufficient. Competition will be limited to competitors from the Americas.
- For manufactured products, 3-dimensional printing close to buyers will replace manufacture in distant countries, shipping to Canadian ports, and transportation within Canada by trucks or rail.
- Multinational corporations that carry out significant trade between subsidiaries in different continents will find this raison d'être no longer relevant. They will shift their focus to the exchange of ideas on patents, technologies, and operating procedures.
- Intercontinental business will be conducted through electronic means – video conferencing, email, etc. Without international marine and aviation, globalization as we know it will come to an end, but undoubtedly will evolve into different forms.

Projected Emissions

Projected Emissions for 2060: Aviation and Navigation (Marine)

Greenhouse Gas Categories	2012	2060 Projection	Comments
	kt CO2 eq	kt CO2 eq	
Aviation (Domestic)	6,100	305	Current emissions times 5 percent representing the residual as domestic aviation is limited to national priorities only
Marine (Domestic)	5,800	145	Current emissions times 5 percent representing the residual as domestic marine activities become tied to national priorities only times 50 percent for captured emissions
Aviation (International)	9,100	455	Current emissions times 5 percent representing the residual as international aviation is limited to national priorities only
Marine (International)	1,700	85	Current emissions time 5 percent representing the residual as international navigation activities become limited to national priorities only times 50 percent for captured emissions

Chapter 7: Railways

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Railways					
Greenhouse Gas Categories	**1990**	**2012**	**2012**	**Change 1990-2012**	
	kt CO2 eq	**kt CO2 eq**	**% Total 2012**	**kt CO2 eq**	**% Total Change**
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Railways	7,000	7,600	1.1%	600	8.6%

Getting to Zero by 2060

Getting to zero by 2060 means:

- Getting rid of engines based on fossil fuels.
- Electrifying the main lines and using electric engines.
- For other routes, using hydrogen engines, perhaps supplied by hydrogen produced at refueling points based on wind or solar power.

Projected Emissions

Projected Emission for 2060: Railways			
Greenhouse Gas Categories	**2012**	**2060 Projection**	**Comments**
	kt CO2 eq	**kt CO2 eq**	
Railways	7,600	0	Current emissions times zero as railroads electrify mainlines, use hydrogen power from renewables elsewhere on other lines and batteries for shunting, etc.

Chapter 8: Industrial Processes

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Industrial Processes					
Greenhouse Gas Categories	**1990**	**2012**	**2012**	**Change 1990-2012**	
	kt CO2 eq	**kt CO2 eq**	**% Total 2012**	**kt CO2 eq**	**% Total Change**
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Industrial Processes	55,990	56,621	8.1%	631	1.1%
Mineral Products	8,360	8,360	1.2%	0	0.0%
Cement Production	*5,400*	*6,300*	*0.9%*	*900*	*16.7%*
Lime Production	*1,760*	*1,440*	*0.2%*	*-320*	*-18.2%*
Mineral Product Use	*1,200*	*620*	*0.1%*	*-580*	*-48.3%*
Chemical Industry	16,620	6,934	1.0%	-9,686	-58.3%
Ammonia Production	*4,510*	*5,770*	*0.8%*	*1,260*	*27.9%*
Nitric Acid Production	*1,000*	*1,100*	*0.2%*	*100*	*10.0%*
Adipic Acid Production	*11,000*	*0*	*0.0%*	*-11,000*	*-100.0%*
Petrochemical Production	*110*	*64*	*0.0%*	*-46*	*-41.8%*

Metal Production	22,620	16,327	2.3%	-6,293	-27.8%
Iron and Steel Production	*10,200*	*9,840*	*1.4%*	*-360*	*-3.5%*
Aluminum Production	*9,310*	*6,230*	*0.9%*	*-3,080*	*-33.1%*
SF6 Used in Magnesium Smelters and Casters	*3,110*	*257*	*0.0%*	*-2,853*	*-91.7%*
Production and Consumption of Halocarbons/SF6	990	8,000	1.1%	7,010	708.1%
Other & Undifferentiated Production	7,400	17,000	2.4%	9,600	129.7%

Getting to Zero by 2060

Getting to zero by 2060 means:

- Significant reductions on industrial processes because industries will:
  - Be regulated for greenhouse gas emissions.
  - Respond to regulations and other incentives by carrying out research, development and related investments to find ways to produce existing products with no or less emissions, to develop new products that can be produced without emissions, and to find ways to capture emissions in production processes so that they do not enter the atmosphere.
- A continuation of limited emissions where the foregoing does not work, the product is essential, and there are no alternatives.

Projected Emissions

Projected Emissions for 2060: Industrial Processes

Greenhouse Gas Categories	2012	2060 Projection	Comments
	kt CO2 eq	kt CO2 eq	
Industrial Processes	56,621	14,155	Current emissions times 50 percent representing the residual as emission efficiency improves times 50 percent for carbon capture

Chapter 9: Solvent and Other Product Use

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Solvent and Other Product Use

Greenhouse Gas Categories	1990	2012	2012	Change 1990-2012	
	kt CO2 eq	kt CO2 eq	% Total 2012	kt CO2 eq	% Total Change
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Solvent and Other Product Use	180	310	0.0%	130	72.2%

Getting to Zero by 2060

Getting to zero by 2060 means:

- Monitoring all solvents for their greenhouse gas effects.
- Prohibiting the production, import and use of solvents that have greenhouse gas effects unless authorized by the government in the case of national priorities that cannot otherwise be addressed.
- Supporting the development of solvents that meet Canadian needs and that do not have greenhouse gas effects.

Projected Emissions

Projected Emissions for 2060: Solvent and Other Product Use

Greenhouse Gas Categories	2012	2060 Projection	Comments
	kt CO2 eq	kt CO2 eq	
Solvent and Other Product Use	310	78	Current emissions times 25 percent representing the residual as emission efficiency improves and solvents are regulated against national priorities

Chapter 10: Agriculture

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Agriculture

Greenhouse Gas Categories	1990	2012	2012	Change 1990-2012	
	kt CO2 eq	kt CO2 eq	% Total 2012	kt CO2 eq	% Total Change
Total – All Sectors	590,253	708,713	100.0%	107,660	18.2%
Agriculture	47,100	54,130	7.8%	7,030	14.9%
Enteric Fermentation	16,000	18,000	2.6%	2,000	12.5%
Manure Management	5,700	6,400	0.9%	700	12.3%
Agriculture Soils	25,200	29,700	4.3%	4,500	17.9%
Direct Sources	*14,000*	*17,000*	*2.4%*	*3,000*	*21.4%*
Pasture, Range and Paddock Manure	*2,200*	*2,700*	*0.4%*	*500*	*22.7%*
Indirect Sources	*9,000*	*10,000*	*1.4%*	*1,000*	*11.1%*
Field Burning of Agricultural Residues	200	30	0.0%	-170	-85.0%

Getting to Zero by 2060

Getting to zero by 2060 means:

- Reduced meat and dairy consumption.
- Changes in the types of meats consumed (chicken versus beef and lamb).

- Vaccines, changes in feed, and other mechanisms to reduce the methanogens in the digestive tracks of livestock, particularly cattle and sheep.
- Manure management for livestock at the same methane-management standard as for human waste.
- The introduction of genetically modified crops that can fix nitrogen without the application of nitrogen fertilizers.
- Where nitrogen fixation is impractical, seed inoculation practices instead of broadcast fertilizer, as a more efficient way to deliver nitrogen to plants.
- The development of plants more efficient in taking up nitrogen from fertilizers.

Projected Emissions

Projected Emissions for 2060: Agriculture

Greenhouse Gas Categories	2012	2060 Projection	Comments
	kt CO2 eq	kt CO2 eq	
Agriculture	54,130	2,385	Sector Total
Enteric Fermentation	18,000	900	Current emissions times 5 percent, representing the residual as demand for beef and dairy consumption fall, costs rise because of manure control, switching to non-greenhouse gas meats (farmed fish, chicken), and more emission efficient animal husbandry
Manure Management	6,400	0	Current emissions times zero, as manures are methane-managed like municipal waste
Agriculture Soils	29,700	1,485	Current emissions times 5 percent contingency representing the residual as nitrogen fixation replaces nitrogen fertilizers
Field Burning of Agricultural Residues	30	0	Current emissions times 0, as the practice is disallowed

Chapter 11: Waste

Past Emissions

Canada's 1990–2012 Green House Gas Emissions: Waste

Greenhouse Gas Categories	1990	2012	2012	Change 1990-2012	
	kt CO2 eq	kt CO2 eq	% Total 2012	kt CO2 eq	% Total Change
Total – All Sectors	590,253	697,913	100.0%	107,660	18.2%
Waste	18,570	20,670	3.0%	2,100	11.3%
Solid Waste Disposal on Land	17,000	19,000	2.7%	2,000	11.8%
Wastewater Handling	830	1,000	0.1%	170	20.5%
Waste Incineration	740	670	0.1%	-70	-9.5%

Getting to Zero by 2060

Getting to zero by 2060 means:

- Keeping organic waste out of waste sites to the extent possible.
- Where it gets into, or has gotten into, waste sites, collect the methane produced within the site, and:
    - Where possible, use the methane to produce organic compounds. By locking the methane in these compounds, the greenhouse gases are kept out of the atmosphere.
    - Use the methane to produce energy.
    - Ensure that whatever methane remains does not get into the atmosphere by converting the methane to CO2 through burning, since the greenhouse gas effects of CO2 are significantly less.

Projected Emissions

Projected Emissions for 2060: Waste

Greenhouse Gas Categories	2012	2060 Projection	Comments
	kt CO2 eq	kt CO2 eq	
Waste	20,670	5,395	Sector Total
Solid Waste Disposal on Land	19,000	4,560	Uncaptured emissions (current emissions times 20 percent) PLUS captured emissions (80 percent of current emissions) times 5 percent representing the residual as methane is converted to CO2, which has 5 percent global warming effect compared to methane
Wastewater Handling	1,000	500	Current emissions times 50 percent representing the residual as emission efficiency increases
Waste Incineration	670	335	Current emissions times 50 percent representing the residual as emission efficiency increases

Chapter 12: Conclusions

The Six Percent Solution

Canada should be able to reduce emissions by 2060 to about 5.96 percent of the current level.

Projected Emissions for 2060: Sector Summary

Greenhouse Gas Categories	2012	2060 Projection	Reference
	kt CO2 eq	kt CO2 eq	
Total – All Sectors	708,713	42,263	National Total
Fossil Fuel Production, Fugitives, Transport	171,600	5,512	Fossil Fuels

Electricity and Heat Generation	88,300	2,208	Electricity and Heat Generation
Stationary Combustion Sources excluding Electricity & Heat Generation and Fossil Fuel Production	116,770	2,919	Stationary Combustion Sources
Road and Off-Road Transportation	170,012	8,621	Road and Off-road Transportation
Aviation (Domestic)	6,100	305	Aviation Domestic
Railways	7,600	0	Railways
Marine (Domestic)	5,800	145	Marine Domestic
Industrial Processes	56,621	14,155	Industrial Processes
Solvent and Other Product Use	310	78	Solvents
Agriculture	54,130	2,385	Agriculture
Waste	20,670	5,395	Waste
Aviation (International)	9,100	455	Aviation International
Marine (International)	1,700	85	Marine International

Getting greenhouse gas emissions to 6 percent of current levels by 2060 is a good start, but the goal is zero emissions, and the sooner we get there, the better our lives.

Canada in 2060

What will Canada be like in 2060?

It will continue to combust some fossil fuels for energy purposes, but at only about 4.38 percent of the current rate. The oil and gas industry will be function at about 12.20 percent of current levels, thanks to non-energy uses, which currently account for about 7.37 percent of final demand. About 26 percent of the combusted fossil fuels will be captured. Fossil fuels will be combusted primarily in response to national priorities that cannot be addressed in any other way.

Canadians will not be flying much. Flying will be reserved for national priorities, and will occur in propeller-driven aircraft at low altitudes.

Marine travel will be limited to national priorities such as coastal ferries.

Trade will be primarily within the Americas and not transoceanic, because the latter requires the combustion of fossil fuels for the operation of large ships.

The electricity sector will be several times larger than at present, and will rely on a mixture of renewable and nuclear energy sources, combined with high voltage direct current transmission lines and a smart grid. Pressure on electricity grids will be offset to some extent by energy production by households and businesses. Unfortunately, the shores of the great lakes will probably be dotted with wind turbines.

Industries and residences will convert from using fossil fuels to produce heat and electricity to securing the energy either from the electricity grid or from their own renewable sources. Industries should be more efficient at managing fossil fuels, forced in part by regulations over greenhouse gas emissions.

Railways will see rapid growth, but they will have to rely primarily on electricity for main routes, and hydrogen on others. The sector will see rapid expansion, as it replaces aviation and marine and other forms of transportation.

Cars and light trucks will be powered by batteries. Heavy trucks on regular schedules will use hydrogen. Some fossil fuel use is likely to continue where alternatives do not exist and there is a national priority. A by-product will be cleaner air.

Through regulatory pressures to reduce greenhouse gases, industries will not only capture emissions from existing industrial processes, but develop new processes with fewer emissions or new products that do not require emissions. Industrial processes will be the largest emitter of greenhouse gases by 2060.

Emissions from enteric fermentation in animals will approach zero as the demand for animal products falls, farmers are regulated to control emissions, feed regimes are adjusted, and methane producing bacteria in animal guts are reduced or eliminated. Farmers will be forced to manage manure so that methane is either not produced, or is controlled and burned if it is produced. Nitrogen fertilizer use and related emissions will substantially come to an end, with the advent of nitrogen fixation in major crops.

Waste management processes will be improved to substantially reduce organic matter in landfills and to deal with the remaining organic matter in ways that do not produce methane. Where organic matter enters landfills, the methane likely to emerge will be captured and burned.

With the few exceptions listed above, Canadians will be able to keep much of their current lifestyle. The primary casualty will be air travel. New forms of leisure activities will emerge to replace air travel.

The Way Forward

The starting point to a zero-emissions future is legislation prohibiting emissions by individuals, companies and other Canadian entities without a license issued by the Government of Canada, starting in 2060 and authorizing the Government of Canada to issue licenses allowing emissions only for national priorities where there are no alternatives.

The legislation would focus the attention of all on emission reduction, give all parties fair warning about their future, and allow them sufficient time to make whatever adjustments are needed.

In addition to the legislation, the Government of Canada should request all sectors to provide sector-specific plans on how they will comply with the legislation by 2060. Those that are currently emitting greenhouse gases – oil and gas producers, electricity and heat generators, stationary combusters (manufacturers; constructors; commerce, institutional and residential owners; farmers and foresters), road and off-road transporters, railways, aviators, mariners, industrial processors, users of solvents,

agriculturalists, waste managers – need to explain how **they** plan to eliminate their emissions, and what help they need from governments, businesses, citizens and other sources.

The plans will provide the foundation for a partnership between government and all sectors to reduce Canada's emissions. Regarding the plans:

The plans may not be followed when the time comes, but those that have plans to do better than those that do not.

All sectors need to be involved, and to take action. It is neither fair nor sufficient to focus attention on producers and combusters of fossil fuels.

The role of governments is to support emitters with their emission reduction plans.

Sectors that do not produce plans can expect neither sympathy nor support from others.

The path forward is likely to involve slow reductions in the short term that will rapidly escalate toward 2060, where the reduction is expected to be around 94 percent from 2012 levels.

It is not sufficient to make a drastic reduction in emissions by 2060. All emissions will add to global warming. Emission reduction work will not end in 2060. In many respects, it will have just started. Beyond 2060, hope lies in revolutionary, new technologies; the continued evolution of existing emission-reducing technologies; marginal improvements of regulatory regimes; and lifestyle changes including doing without and living for the purpose of helping each other.

Those of us alive in 2060 will regret the distant 2060 target, and wish it had been 2050 or sooner. By then, we will realize a lot can be done in a short time where there is a will and focus.