Measuring the Benefits of Green Public Procurement in Canada

Evidence from the IISD GPP Model

IISD REPORT

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Andrea M. Bassi
Kieran McDougal

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Head Office

111 Lombard Avenue, Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org
Twitter: @IISD_news

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The MAVA Foundation was established in 1994 and is a family-led, Swiss-based philanthropic foundation with offices in Switzerland and Senegal.

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Written by Andrea M. Bassi and Kieran McDougal with support from Liesbeth Casier.

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Abbreviations and Acronyms

BAU	business as usual
CLD	causal loop diagram
FTE	full-time equivalent
GDP	gross domestic product
GHG	greenhouse gas
Gj	gigajoule
GPP	green public procurement
kWh	kilowatt-hour
LED	light-emitting diode
NEB	National Energy Board
SCC	social cost of carbon
S+D	sustainable plus domestic production
SD	system dynamics

1.0 Green Public Procurement Canada Model

Green public procurement (GPP) can have many short- and long-term economic, social and environmental benefits. Sustainable technologies reduce energy and other resource use and lower pollution emissions. In some cases, this can have direct economic benefits, such as reduced spending on energy or water. There are a number of positive environmental and social outcomes associated with the use of sustainable technologies as well, including: reduced greenhouse gas (GHG) emissions, cleaner water and healthier watersheds, improved health, more vibrant and connected communities, and well-paying jobs. These impacts also have economic costs. Acid rain caused by nitrous oxide and sulphur dioxide emissions can injure plants, reducing agricultural yields. Smog causes a number of illnesses, including asthma and heart attacks, placing a burden on the healthcare system. Nutrient-rich runoff causes algal blooms in Canada's lakes, hurting local industry and tourism.

These social and environmental impacts, and the resulting economic costs, are a large part of the motivation for GPP. However, it can be difficult to measure many of these impacts. As a result, procurement decisions are often made based on financial decisions alone. They do not factor in the longer-term economic, social, and environmental costs and benefits.

A more holistic assessment of public procurement has positive environmental and social impacts, but it may also result in financial savings and, indirectly, an increase in public revenues. To this end, IISD created a model to make a quantitative assessment of the economic, social and environmental impacts associated with the procurement of infrastructure, buildings (including the use of cement and steel) and vehicles in Canada.[1] This tool will provide a solid basis for a holistic assessment of procurement in Canada. A thorough assessment of all costs and benefits will help to establish the business case for GPP.

Sections 1.1 through 1.3 provide a description of the GPP model, including the general modelling approach and the specific parameters and scenarios included in the model. Sections 2 to 5 provide an overview of the model and selected results for four areas of public spending: **buildings, cement, steel and vehicles**. Section 6 provides a summary of the findings and a discussion of how they are relevant to the implementation of GPP in Canada.

1.1 General Modelling Approach

The GPP model uses an approach called system dynamics (SD). SD was first developed in the 1950s and applied to corporate and industrial systems. The first attempt to use SD to understand the relationship between the economy and the environment came in the early 1970s when its originator, Jay Forrester, created and released a so-called world model at the urging of the Club of Rome. Since then, SD has been employed to understand complex environmental problems.

SD captures and analyzes the drivers of change underlying complex systems. The SD approach allows for a set of variables to be mapped by causal relationships. Rather than focusing on correlations, SD extends the analysis to capture circular causality, with changes to one variable creating feedback to other variables (i.e., feedback loops). The explicit representation of feedback loops allows for a greater understanding of how systems change over time. This in turn allows complex systems, characterized by interdependence and nonlinearities, to be assessed using fairly simple, understandable models. SD enables the linkages and relationships between environmental, social and economic factors to be made clear. As a result, individual policy changes can be tested and understood.

SD is a flexible methodology that integrates economic and environmental variables in a single model. As a result, through the use of SD it is possible to capture environmental variables, as well as how they affect and are being affected by other components of the system, which can be difficult to assess using other approaches. This ability

[1] The IISD GPP Model was also used to assess the costs and benefits of GPP in China. For more information, see https://www.iisd.org/library/how-green-public-procurement-contributes-sustainable-development-china

is due to both the non-linear structure of models and the use of stock and flow variables. Stock variables allow for accumulation over time, an important feature for assessing environmental and social impacts.

1.2 Model Parameters and Scenarios

The GPP model for Canada analyzes four categories of public spending: cement, steel, buildings and vehicles. Cement and steel requirements, and related socioeconomic and environmental impacts, are utilized for the construction of infrastructure and buildings. These products are significant aspects of government procurement. As such, a move to GPP can shift these industries toward more sustainable production throughout the value chain, with accompanying economic, social and environmental benefits.

The procurement of these categories of public spending is simulated from 2016 to 2035. This is considered a reasonable time frame for government planning. The potential development of new technologies beyond this time frame introduces substantial uncertainty and would reduce the usefulness of the model.

There are three scenarios modelled for each product, with the exception of buildings, for which there are two scenarios. The scenarios are unique to each component. The total level of procurement is assumed to be the same across scenarios. However, the amount of this procurement using sustainable technology varies, as does the amount of procurement satisfied by domestic versus foreign production.

- The business-as-usual (BAU) scenario acts as a baseline for comparison and assumes that no change toward GPP is made. Existing procurement standards and policies are used for this scenario.
- The sustainable scenario assumes a change toward GPP over the time period. The pace of change is different for each component and is described in more detail in sections 2 through 5.
- The sustainable plus domestic production scenario assumes that public procurement is directed toward green products and construction materials (steel and cement) that are produced domestically. The sustainable plus domestic scenario is not run for buildings, as all buildings are produced domestically. The pace of change toward GPP is the same as for the sustainable scenario.

The parameters and scenarios for each product, including major inputs and assumptions around the pace of change, are explained in more detail under each public spending category.

The model allows for the quantitative analysis of several impacts, which generally fall into the following categories:

- **Economic impacts** include revenues, material and energy expenditure. Capital costs are included for vehicles and buildings.
- **Environmental impacts** include GHG emissions, carbon dioxide, methane and nitrous oxide. Emissions are captured from both the manufacturing process and the use of energy during manufacture. For vehicles and buildings, emissions are captured during the operational stage as well. The buildings component also considers water and energy consumption, as well as emissions for heating.
- **Social impacts** include employment, health impacts and impacts associated with climate change, as captured by the social cost of carbon, such as health impacts and increased flooding and droughts.

The use of electricity and fuel is considered for all products. Electricity and fuel use takes place during both the manufacturing/construction stage and the operational stage (for vehicles and buildings). This ensures that both the economic and environmental costs of energy use are included for all products.

Data for electricity and fuel prices is specific to Canada and was taken from the National Energy Board (NEB) *Canada's Energy Futures 2016: Update – Energy Supply and Demand Projections to 2040*, with prices for steel and cement producers derived from a weighted average tied to the distribution of these facilities across provinces (NEB, 2016).

Data for electricity and fuel emissions intensity was taken from a variety of sources:

- For Canadian steel and cement facilities: 2016 reports from the Canadian Energy and Emissions Data Centre (formerly the Canadian Industrial Energy End-use Data and Analysis Centre) at the Simon Fraser University.
- For non-Canadian steel facilities, a number of separate sources were used for the following key countries:
  - China, Germany, Mexico, United States (Hasanbeigi Rojas Cardenas, Price, & Triolo, 2015)
  - South Korea (Shim & Lee, 2016; Choi, Matsuura, Lee, & Sohn, 2016)
  - Japan (The Japan Iron and Steel Federation, 2016; World Steel Association, 2016)
  - Taiwan (Chen, 2012)
  - Brazil (International Energy Agency, 2007)

Given the very small share of imported cement in the Canadian market, no separate data was collected on the emission intensities of foreign cement producers.

1.3 Graphical Representations

Causal loop diagrams (CLDs) are graphical representations of the model that outline the main variables and the relationships between them, including feedback loops. CLDs are simplified representations of the model, reducing the number of variables and relationships for presentation purposes. Figure 1 provides a linear branch diagram of the cement and steel components. Both components have the same basic structure. Figure 2 shows a CLD for the vehicles component. There are two feedback loops on the left of the figure, both centred on the total stock of vehicles. If the stock of vehicles increases, depreciation will also increase. This creates a small feedback loop, as increased depreciation directly reduces the total car stock because old vehicles must be retired. In the larger feedback loop, as more vehicles are retired, they must be replaced, resulting in a higher replacement rate and greater procurement of vehicles. These two loops work to balance each other, as deprecation reduces the car stock, but also leads to higher procurement. The procurement of vehicles has a directly related cost (capital costs related to buying new vehicles). The stock of vehicles has a direct cost related to fuel use, as well as an indirect cost resulting from the GHG emissions. Both direct and indirect costs must be captured for a holistic assessment of the costs and benefits of GPP.

The GPP model has four components, each of which we also analyze separately. The cement and steel components assess the costs and impacts associated with production and imports due to government spending. The demand for steel and cement is driven by public spending on buildings and other public infrastructure. The buildings component adds greater complexity to the cement/steel use for buildings. Apart from the raw materials used during construction, it also considers the operational phase of a building and takes into account energy sources, heating and cooling, lighting and water-efficient technologies such as water recycling. The vehicle module is a stand-alone component.

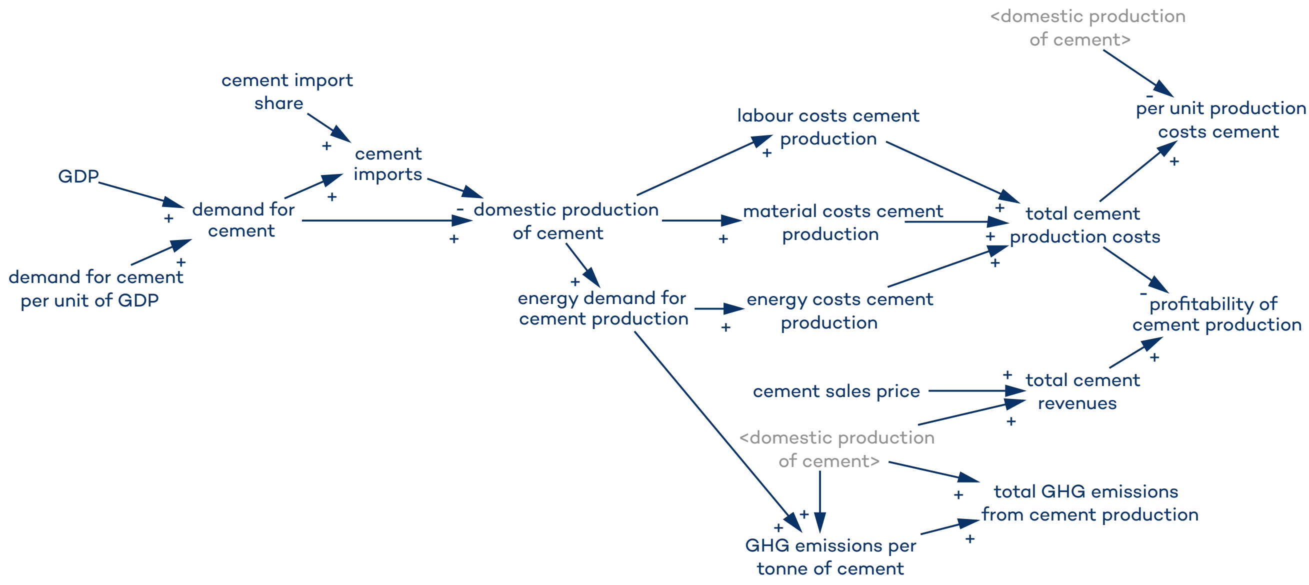

Figure 1. Cement and steel components of the CLD

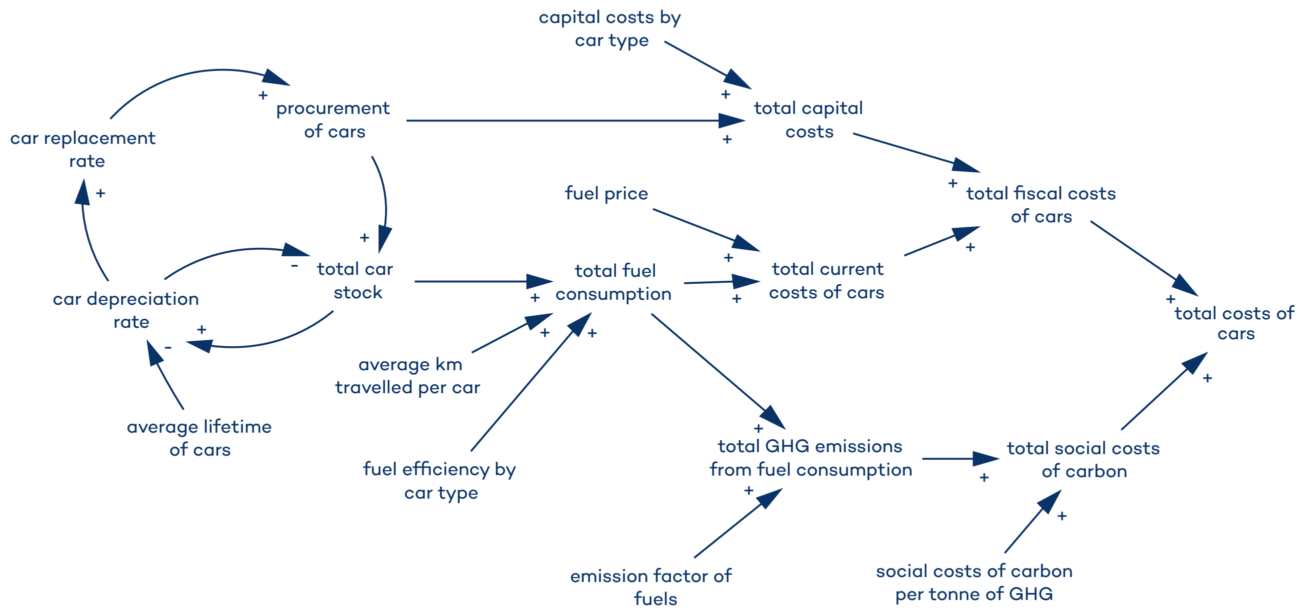

Figure 2. Vehicles components of the CLD

2.0 Buildings: Construction, retrofits and operations

2.1 Model Set Up

Buildings are a complex procurement category. The impacts of buildings occur both during the construction stage and during operations and management. However, a switch to a sustainable building stock does not only include new construction, but also the retrofit of existing conventional buildings with sustainable technologies. The model looks both at the construction and retrofit of public buildings.

For the construction of new buildings, the raw materials included in the GPP model—cement and steel—are key inputs. The type of material used, whether produced in a conventional or sustainable way, will have a major impact on the sustainability of building construction. The use of recycled materials is also possible in order to further reduce impacts. Raw materials are not a factor during the retrofit of existing buildings.

The impacts of buildings during the operations phase are dependent on the systems in place. The Canadian GPP model includes lighting, heating, cooling and appliances, as well as water recycling systems and the use of solar panels to produce energy. These systems affect the building's water and energy use.

Overall demand for buildings is based on the demand for floor space and assumed to change with population. Buildings are assumed to need replacing after their expected lifetime of 40 years has passed.

2.2 Scenario Definition

There are two scenarios considered for the buildings module. The BAU scenario assumes that government spending on public buildings is not allocated to the construction of sustainable buildings. The initial stock of buildings is assumed to be 2.7 per cent sustainable. In addition, there is no retrofitting of conventional buildings.

The sustainable scenario assumes that government spending is allocated to the construction of sustainable buildings and the retrofit of existing conventional buildings. It is assumed that 50 per cent of demolished buildings are rebuilt as sustainable buildings. In addition, the rate of retrofit is assumed to be 2 per cent of the conventional building stock per year. The sustainability of the construction phase is connected to the sustainability of cement and steel used for buildings. This connection to the cement and steel supply chain can also be established in the GPP model but was not done in this case.

During the operations phase, conventional and sustainable buildings differ across several key systems: lighting, heating, cooling, appliances, water consumption and the use of solar panels.

The lighting technologies considered for buildings are incandescent and light-emitting diode (LED) (Table 1). Conventional buildings are assumed to contain no LED lighting in 2010 with an increase to 50 per cent LED lighting by 2050. Sustainable buildings are assumed to use 100 per cent LED lighting from the beginning.

Table 1. Lighting technology per scenario

	Conventional	Sustainable
Incandescent	50%	0%
LED	50%	100%

Conventional buildings are assumed to rely on gas and electric heating, with some oil. Sustainable buildings primarily use wood biomass with some heating supplied by geothermal heat pumps (Table 2).

Table 2. Heating technology per scenario

	Conventional	Sustainable
Gas boiler	60%	15%
Oil boiler	15%	0%
Wood chip boiler	0%	30%
Wood pellet boiler	0%	30%
Geothermal heat pump	0%	25%
Electric heating	25%	0%

Cooling technology is assumed to have two tiers, with the second tier making use of energy-efficient air conditioners. Sustainable buildings are those that make use of these energy-efficient air conditioners (A-rated).

Sustainable buildings use appliances with greater energy efficiency. This results in reduced energy consumption in the building. Appliances are aggregated into one category, based on the average consumption per square metre (m^2), rather than attempting to disaggregate among the many different appliances found in a public building. Data comes from Statistics Canada (n.d.).

In terms of water use, sustainable buildings have advantages over conventional buildings in two areas. First, sustainable buildings make use of water-efficient technologies and appliances, which reduces the total consumption of water in the building. Second, sustainable buildings undertake water recycling, which reduces the demand for municipal water supply.

2.3 Key Inputs

Table 3 presents the key data inputs to the buildings module, including prices and energy use. These values are for 2015.

Table 3. Key model inputs, 2015

Variable		Units	Value
Initial demand for floor space		1,000 m^2	234,496
Lighting electricity use	Incandescent	kWh/bulb/hour	0.06
	LED	kWh/bulb/hour	0.01
Light bulb lifetime	Incandescent	Hours	1,200
	LED	Hours	50,000

Variable		Units	Value
Lighting technology price	Incandescent	CAD/bulb	1.25
	LED	CAD/bulb	33.95
Heating technology efficiency	Gas	kWh per fuel unit	1.04
	Oil	kWh per fuel unit	0.8
	Wood chips	kWh per fuel unit	0.79
	Wood pellets	kWh per fuel unit	0.84
	Geothermal heat pump	kWh per fuel unit	1
	Electric	kWh per fuel unit	1
Heating fuel price	Gas	CAD/unit	1
	Oil	CAD/unit	1
	Wood chips	CAD/unit	0.1
	Wood pellets	CAD/unit	0.1
	Geothermal	CAD/unit	1
Cooling technology energy requirements	Conventional	kWh/unit/hour	856.11
	Sustainable	kWh/unit/hour	980.18
Cooling technology capital cost	Conventional	CAD/unit	1,000
	Sustainable	CAD/unit	1,200
Appliance energy consumption	Conventional	kWh/m^2/year	33.1
	Sustainable	kWh/m^2/year	25

2.4 Results

The sustainable scenario has both economic and environmental benefits over the BAU scenario. The sustainable scenario assumes that only 50 per cent of demolished buildings are replaced with sustainable buildings. A more ambitious goal would further increase the benefits of the sustainable scenario as compared to the BAU scenario. Figure 3 shows the percentage of sustainable public buildings (with the rest being conventional buildings). Under the BAU scenario, the share of sustainable public buildings remains low, increasing from 2.7 per cent in 2016 to 3.2 per cent in 2035. Under the sustainable scenario, the share of sustainable buildings in the public buildings stock increases steadily, reaching 24.5 per cent in 2035.

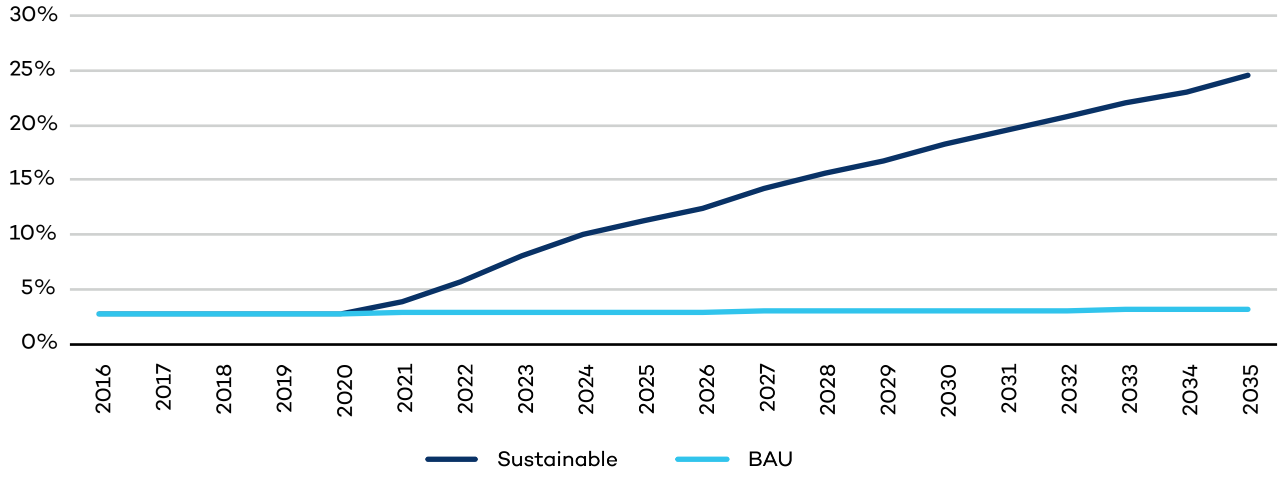

Figure 3. Share of sustainable buildings in total building stock, sustainable scenario

In the sustainable scenario, there is a decline in both operational and total costs for buildings. In 2035, total costs for the building stock are 3 per cent lower in the sustainable scenario than in the BAU scenario. This is largely due to a 6 per cent decline in the energy consumption of the building stock, which in turn reduces the energy expenditure (see Table 4).

The sustainable scenario results in lower emissions from the operation and management of the building stock. By 2035, emissions from operations are 7 per cent lower in the sustainable scenario than in the BAU scenario. This is due to reduced energy consumption (Figure 4).

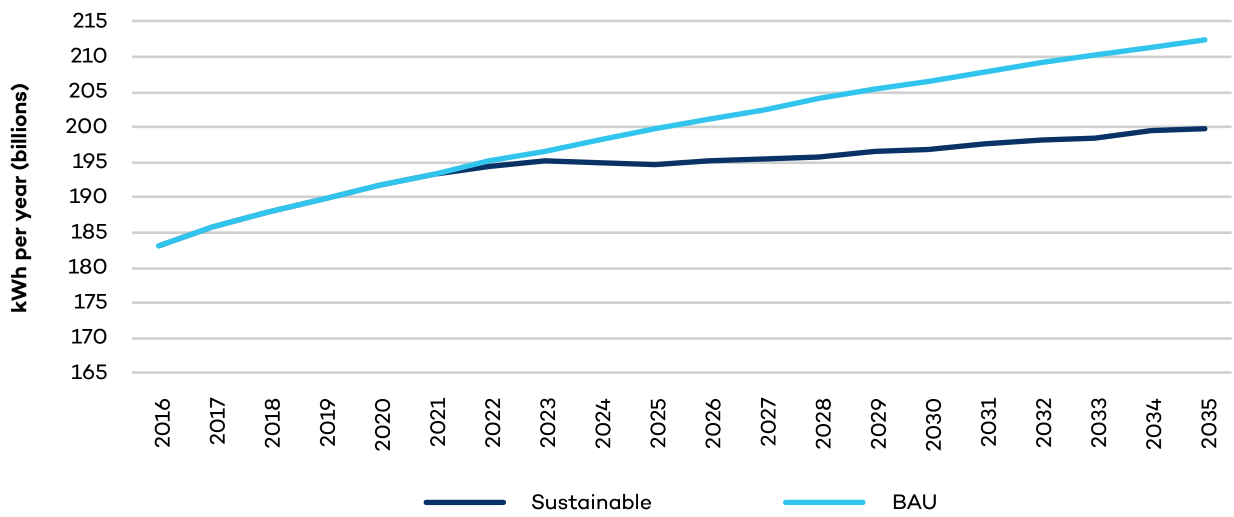

Figure 4. Energy consumption: Scenario comparison, 2016–2035

2.5 Summary

Table 4. Buildings summary

Indicator	Unit	2016	2020	2025	2030	2035
Share of sustainable buildings						
50% Sustainable + Retrofits	%	2.7	2.8	11.2	18.3	24.5
BAU	%	2.7	2.8	2.9	3.0	3.2
% to BAU: S*	%	0	0	11	21	29
Operation costs						
50% Sustainable + Retrofits	CAD/ year	17,564,688,384	18,157,340,672	18,589,515,776	18,929,891,328	19,160,745,984
BAU	CAD/ year	17,564,688,384	18,157,340,672	18,806,878,208	19,372,873,728	19,782,610,944
% to BAU: S	%	0	0	-1	-2	-3
Energy consumption						
50% Sustainable + Retrofits	kWh/ year	183,110,687,232	191,743,120,896	194,754,407,424	196,789,327,872	199,754,186,752
BAU	kWh/ year	183,110,687,232	191,743,120,896	199,658,642,944	206,626,225,152	212,490,827,264
% to BAU: S	%	0	0	-2	-5	-6
Emissions from operation of buildings						
50% Sustainable + Retrofits	tonne/ year	41,201,884	42,625,224	42,982,096	43,186,416	43,179,792
BAU	tonne/ year	41,201,884	42,625,224	44,191,856	45,564,380	46,571,728
% to BAU: S	%	0	0	-3	-5	-7

Indicator	Unit	2016	2020	2025	2030	2035
Overall per m^2 energy consumption						
50% Sustainable + Retrofits	kWh/ m^2/ year	377.6	375.7	366.9	359.6	353.2
BAU	kWh/ m^2/ year	377.6	375.7	373.2	370.8	368.3
% to BAU: S	%	0.0	0.0	-1.7	-3.0	-4.1
Emissions per m^2 (tonnes CO_2e/year)						
50% Sustainable + Retrofits	tonne/ m^2/ year	0.0914	0.0911	0.0880	0.0854	0.0832
BAU	tonne/ m^2/ year	0.0914	0.0911	0.0906	0.0901	0.0896
% to BAU: S	%	0.0	0.0	-2.9	-5.2	-7.2

**Note: BAU: S indicates business as usual compared to sustainable production, in this and subsequent tables.*

3.0 Cement

3.1 Model Set Up

Cement is used in the construction of both buildings and other infrastructure. For both buildings and infrastructure, the amount of cement used is dependent on the level of GDP. The GDP growth rate in the model is estimated based on the growth rates assumed in the NEB's (2016) *Canada's Energy Futures 2016* analysis. The amount of cement for buildings is also affected by the intensity of cement used in construction. Cement use intensity is estimated based on Statistics Canada (n.d.) input–output tables for the construction sector.

Total cement costs include material costs, employment costs and energy costs. The market price for cement materials is expected to change over the course of the model period. Initial prices for cement are different for use in buildings and use in infrastructure. The annual increase in cement prices is expected to be 2 per cent for buildings and 3 per cent for infrastructure.

Total labour costs depend on the level of employment related to cement production for infrastructure and buildings as well as on labour costs. Labour costs and the average employment factor per tonne of cement are based on historical data (Statistics Canada, n.d.).

Energy costs include both the use of electricity in cement production as well as the use of fuels. Fuel costs from cement production depend on the mix of fuels used in the production process. Historical data on fuel intensity has been used for coke, coal, propane and other fuels used in the production of cement. All fuel prices are based on historical data (Statistics Canada, n.d.).

GHG emissions also depend on the intensity of fuel use in the production of cement. Emission factors based on historical data are applied to the total amount of each fuel type used (Statistics Canada, n.d.). This allows for the calculation of the total emission of GHGs in carbon dioxide equivalent, which is further broken down into carbon dioxide, methane and nitrous dioxide.

3.2 Scenario Definition

There are three scenarios for cement. The scenarios differ in two key ways: the amount of cement produced domestically and the energy efficiency of cement production. The BAU scenario assumes that a small amount of cement required for infrastructure and buildings is imported. The level of imported cement is based on data from Statistics Canada (n.d.). The remaining demand is satisfied by domestic production of cement. In terms of energy efficiency, the BAU scenario assumes that there is no increase in the energy efficiency of cement production.

The sustainable scenario follows the BAU scenario in terms of share of imported cement. No move toward full domestic production is assumed; however, energy efficiency is assumed to increase over the time period. The level of efficiency increase is initially assumed to be 2 per cent per year. An increase in the energy efficiency of cement production reduces the amount of each type of fuel used in the production process. This in turn results in a decrease in the emissions related to cement production. The increase in energy efficiency applies only to the domestic production of cement.

The sustainable plus domestic scenario differs from the previous scenarios, as it assumes that a move is made toward producing all cement domestically. The primary goal of switching to domestic production is to further reduce the emissions associated with cement. Domestic Canadian sources are less emission intensive than imports. In this scenario, the total demand for cement remains the same, but it is entirely satisfied with domestic production. This scenario also assumes that the energy efficiency of cement production increases in the same way as in the sustainable scenario.

3.3 Key Inputs

Table 5 presents key data inputs for the cement module, including the GDP growth rate, initial prices and fuel prices. This data is for 2015 and in some cases will change over the model time period, as in the case of prices.

Table 5. Key input values, 2015

Variable		Units	Value
GDP growth rate		%/year	0.025
Cement initial market price	Buildings	CAD/tonne	574.43
	Infrastructure	CAD/tonne	880
Cement unit cost	Buildings	CAD/tonne	379.59
	Infrastructure	CAD/tonne	685.03
Increase in material cost	Buildings	%/year	1.02
	Infrastructure	%/year	1.03
Employment per unit of cement		Person/tonne	0.002223
Labour costs		CAD/person	56,732
Fuel prices (year 2015)	Middle distillate	CAD/GJ	22.9542
	Coal coke	CAD/GJ	14.49
	Electricity	CAD/GJ	21.65
	Petroleum coke	CAD/GJ	29.08
	Propane	CAD/GJ	16.539
	Residual fuel oil	CAD/GJ	9.32922
	Wood waste	CAD/GJ	4.8

Variable		Units	Value
Emission factors	Middle distillate fuel oil	Tonne/GJ	0.071
	Natural gas	Tonne/GJ	0.0000485
	Heavy fuel oil	Tonne/GJ	0.074
	Petroleum coke	Tonne/GJ	0.082
	Coal	Tonne/GJ	0.093
	Coal coke	Tonne/GJ	0.11
	Wood waste	Tonne/GJ	0.047
	Waste fuel	Tonne/GJ	0
	Propane	Tonne/GJ	0.06
Share of imported cement	BAU	%	2.73
	Sustainable	%	2.73
	S+D*	%	0
Cement energy efficiency increase	BAU	%	0
	Sustainable	%	2
		%	2

* *Note: S+D means "sustainable plus domestic production" in this and subsequent tables.*

3.4 Results

The sustainable plus domestic scenario performs best in terms of revenue and employment generation for both buildings and infrastructure (Table 6). This is because there is a higher level of cement production due to all cement being produced domestically. Revenues and employment are 2 per cent higher for the sustainable plus domestic scenario than the other scenarios by 2035.

Table 6. Production, revenue and employment, 2016 and 2035

	Production (tonne/year)			Revenue (CAD/year)			Employment (Person)		
	2016	2035	% change	2016	2035	% change	2016	2035	% change
Cement for buildings									
BAU	645,107	586,112	-9	370,568,736	336,680,096	-9	1,434	1,303	-9
Sustainable	645,107	586,112	-9	370,568,736	336,680,096	-9	1,434	1,303	-9
S+D	645,107	602,591	-7	370,568,736	346,146,496	-7	1,434	1,340	-7
Cement for infrastructure									
BAU	1,057,199	960,518	-9	930,335,296	845,255,808	-9	2,350	2,135	-9
Sustainable	1,057,199	960,518	-9	930,335,296	845,255,808	-9	2,350	2,135	-9
S+D	1,057,199	987,525	-7	930,335,296	859,021,824	-7	2,350	2,195	-7

The level of energy use is a little more complicated, which in turn affects energy expenditure and emissions. The BAU scenario uses the most energy by far for both buildings (Figure 5) and infrastructure (Figure 6), although energy use does decline over the time period due to a decline in total production. The sustainable scenario uses the least energy, and therefore results in lower energy expenditure and lower levels of emissions (Figure 7, Figure 8). The sustainable plus domestic scenario uses slightly more energy than the sustainable scenario due to the increased domestic production of cement starting from 2020. The trend is the same for buildings and cement, though the numbers are different.

Global emissions may tell a different story. Energy use and emissions rise in Canada as more cement is produced domestically. However, this domestic production offsets foreign production that is, on average, more emission intensive. Assuming total demand for cement remains the same, global emissions will fall despite the slight rise in Canadian emissions.

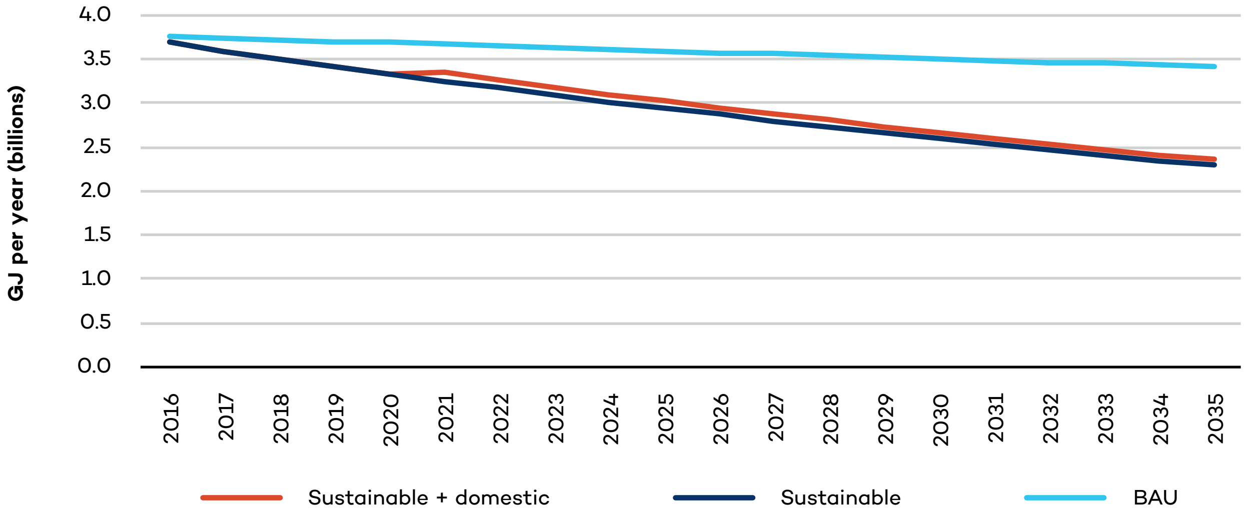

Figure 5. Energy consumption: Cement for buildings

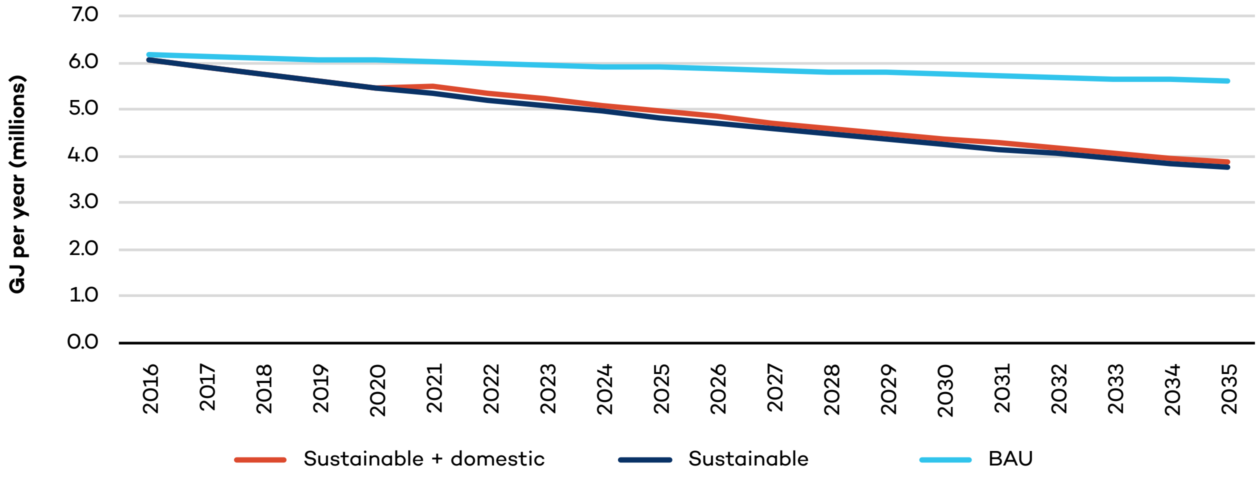

Figure 6. Energy consumption: Cement for infrastructure

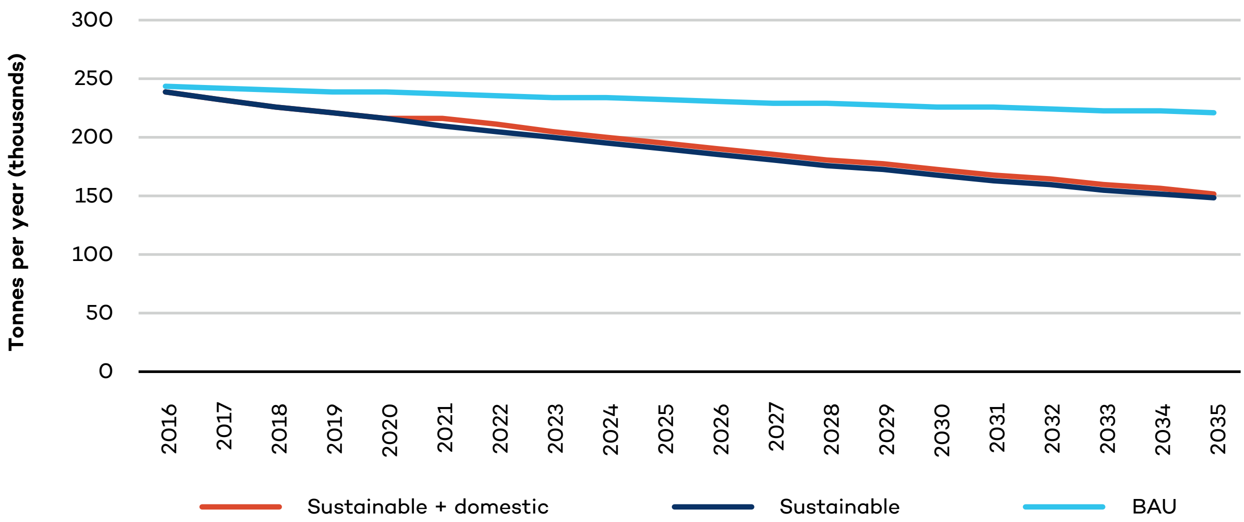

Figure 7. Total emissions: Cement for buildings

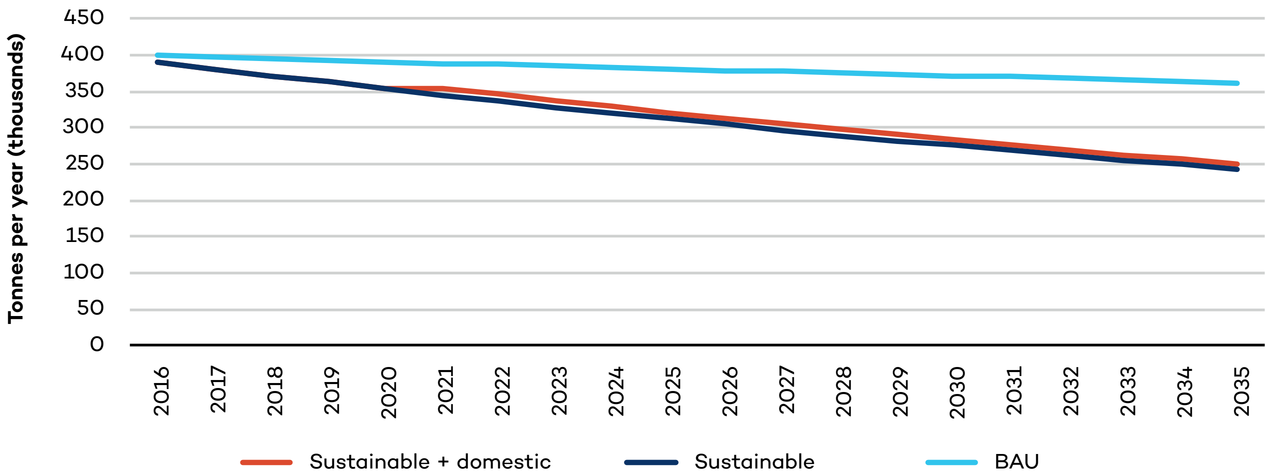

Figure 8. Total emissions: Cement for infrastructure

Emissions related to the import of cement are currently not included in the model. If these emissions were considered, it would lessen the gap between the sustainable and the sustainable plus domestic scenarios.

3.5 Summary

Table 7 (cement for buildings) and Table 8 (cement for infrastructure) present summary results of the cement module.

Table 7. Cement for buildings

Indicator	Unit	2016	2020	2025	2030	2035
Production						
S+D	tonne/year	645,107	632,212	633,789	617,993	602,591
Sustainable	tonne/year	645,107	632,212	616,456	601,092	586,112
BAU	tonne/year	645,107	632,212	616,456	601,092	586,112
% to BAU: S+D	%	0	0	3	3	3
% to BAU: S	%	0	0	0	0	0
Employment						
S+D	person	1,434	1,405	1,409	1,374	1,340
Sustainable	person	1,434	1,405	1,370	1,336	1,303
BAU	person	1,434	1,405	1,370	1,336	1,303
% to BAU: S+D	%	0	0	3	3	3
% to BAU: S	%	0	0	0	0	0

Indicator	Unit	2016	2020	2025	2030	2035
Energy consumption						
S+D	GJ/ year	3,689,057	3,337,527	3,027,639	2,671,412	2,357,099
Sustainable	GJ/ year	3,689,057	3,337,527	2,944,839	2,598,355	2,292,637
BAU	GJ/ year	3,763,534	3,688,308	3,596,386	3,506,755	3,419,358
% to BAU: S+D	%	-2	-10	-16	-24	-31
% to BAU: S	%	-2	-10	-18	-26	-33
Energy expenditure						
S+D	CAD/ year	48,398,708	51,032,880	51,973,560	51,773,664	46,700,920
Sustainable	CAD/ year	48,398,708	51,032,880	50,552,188	50,357,760	45,423,744
BAU	CAD/ year	49,375,812	56,396,532	61,736,868	67,963,128	67,747,336
% to BAU: S+D	%	-2	-10	-16	-24	-31
% to BAU: S	%	-2	-10	-18	-26	-33
Energy expenditure (% of costs)						
S+D	%	13	14	14	14	13
Sustainable	%	13	14	14	14	13
BAU	%	13	15	17	18	19
Emissions						
S+D	tonne/ year	238,678	215,934	195,885	172,837	152,502
Sustainable	tonne/ year	238,678	215,934	190,528	168,111	148,331
BAU	tonne/ year	243,496	238,629	232,682	226,883	221,229
% to BAU: S+D	%	-2	-10	-16	-24	-31
% to BAU: S	%	-2	-10	-18	-26	-33

Table 8. Cement for infrastructure

Indicator	Unit	2016	2020	2025	2030	2035
Production						
S+D	tonne/year	1,057,199	1,036,068	1,038,651	1,012,765	987,525
Sustainable	tonne/year	1,057,199	1,036,068	1,010,246	985,068	960,518
BAU	tonne/year	1,057,199	1,036,068	1,010,246	985,068	960,518
% to BAU: S+D	%	0	0	3	3	3
% to BAU: S	%	0	0	0	0	0
Employment						
S+D	person	2,350	2,303	2,309	2,251	2,195
Sustainable	person	2,350	2,303	2,246	2,190	2,135
BAU	person	2,350	2,303	2,246	2,190	2,135
% to BAU: S+D	%	0	0	3	3	3
% to BAU: S	%	0	0	0	0	0
Energy consumption						
S+D	GJ/year	6,045,616	5,469,530	4,961,686	4,377,903	3,862,806
Sustainable	GJ/year	6,045,616	5,469,530	4,825,994	4,258,176	3,757,166
BAU	GJ/year	6,167,668	6,044,388	5,893,746	5,746,859	5,603,633
% to BAU: S+D	%	-2	-10	-16	-24	-31
% to BAU: S	%	-2	-10	-18	-26	-33
Energy expenditure						
S+D	CAD/year	79,315,656	83,632,528	85,174,112	84,846,528	76,533,328
Sustainable	CAD/year	79,315,656	83,632,528	82,844,776	82,526,144	74,440,288

Indicator	Unit	2016	2020	2025	2030	2035
BAU	CAD/ year	80,916,928	92,422,464	101,174,192	111,377,776	111,024,128
% to BAU: S+D	%	-2	-10	-16	-24	-31
% to BAU: S	%	-2	-10	-18	-26	-33
Energy expenditure (% of costs)						
S+D	%	8	9	9	9	9
Sustainable	%	8	9	9	9	9
BAU	%	9	10	11	12	12
Emissions						
S+D	tonne/ year	391,144	353,872	321,015	283,245	249,919
Sustainable	tonne/ year	391,144	353,872	312,236	275,499	243,084
BAU	tonne/ year	399,041	391,065	381,319	371,815	362,549
% to BAU: S+D	%	-2	-10	-16	-24	-31
% to BAU: S	%	-2	-10	-18	-26	-33

4.0 Steel

4.1 Model Set Up

Like cement, steel is used in the construction of both buildings and other infrastructure. The amount of steel used for buildings and infrastructure is dependent on the level of GDP. The GDP growth rate in the model is estimated based on the NEB's (2016) *Canada's Energy Futures 2016* analysis. The amount of steel for buildings and infrastructure is also affected by the intensity of steel use in construction. Steel use intensity is estimated based on Statistics Canada (n.d.) input–output tables for the construction sector.

Total steel costs include material costs, employment costs and energy costs. The market price for steel material is expected to change over the course of the model period. Initial prices for steel are different for use in buildings and use in infrastructure. The annual increase in steel prices is expected to be 3 per cent for both buildings and infrastructure.

As with cement, the total labour costs of steel production for buildings and infrastructure depend on the level of employment and labour costs. Labour costs and average employment per unit of output are based on historical data from Statistics Canada (n.d.).

Energy costs include both the use of electricity in steel production as well as the use of fuels. Fuel costs relating to steel are calculated in the same way as cement. Fuel costs from steel production depend on the mix of fuels used in the production process. Historical data on fuel intensity has been used for coke, coal, propane and other fuels used in the production of steel. All fuel prices are based on historical data from Statistics Canada (n.d.).

GHG emissions also depend on the intensity of fuel use in the production of steel. Emission factors based on historical data are applied to the total amount of each fuel type used. This allows for the calculation of the total GHG emissions in carbon dioxide equivalent, which is further broken down into carbon dioxide, methane and nitrous dioxide.

4.2 Scenario Definition

There are three scenarios for steel. The scenarios differ in two key ways: the amount of steel produced domestically and the energy efficiency of steel production. The BAU scenario assumes that about 17 per cent of steel required for infrastructure and buildings is imported. The level of imported steel is based on data from Statistics Canada (n.d.). The remaining demand is satisfied by domestic production of steel. In terms of energy efficiency, the BAU scenario assumes that there is no increase in the energy efficiency of steel production.

The sustainable scenario follows the BAU scenario in terms of share of imported steel. No move toward full domestic production is assumed to be made; however, energy efficiency is assumed to increase over the time period. The level of efficiency increase is initially assumed to be 2 per cent per year. An increase in the energy efficiency of steel production reduces the amount of each type of fuel used in the production process. This in turn results in a decrease in the emissions related to steel production. The increase in energy efficiency applies only to domestic production of steel, as the increase is assumed to be related to a change in Canadian policy.

The sustainable plus domestic scenario differs from the previous scenarios, as it assumes that a move is made toward producing all steel domestically. Like the cement sector, the goal of encouraging domestic steel production is to gain further environmental benefits. Canadian produced steel is, on average, lower in emissions intensity than imported steel. In this scenario, the total demand for steel remains the same but is entirely satisfied with domestic production. This scenario also assumes that the energy efficiency of steel production increases in the same way as in the sustainable scenario.

4.3 Key Inputs

Table 9 presents key data inputs for the steel module, including the GDP growth rate, initial prices, fuel prices and emission factors. The data is for 2015, and some inputs may change over the course of the model, such as the market price.

Table 9. Key input values, 2015

Variable		Units	Value
GDP growth rate		%/year	0.025
Steel initial market price		CAD/tonne	3,074
Steel unit cost		CAD/tonne	1,298.95
Increase in material cost		%/year	1.03
Employment per unit of steel		%/tonne	0.001016
Labour costs		CAD/person	70,908
Fuel prices (year 2015)	Middle distillate	CAD/GJ	22.9542
	Coal coke	CAD/GJ	14.49
	Electricity	CAD/GJ	26.71
	Petroleum coke	CAD/GJ	27.56
	Propane	CAD/GJ	16.539
	Residual fuel oil	CAD/GJ	9.32922
	Wood waste	CAD/GJ	4.8
Emission factors	Middle distillate fuel oil	Tonne/GJ	0.071
	Natural gas	Tonne/GJ	0.0000485
	Heavy fuel oil	Tonne/GJ	0.074
	Petroleum coke	Tonne/GJ	0.082
	Coal	Tonne/GJ	0.093
	Coal coke	Tonne/GJ	0.11
	Wood waste	Tonne/GJ	0.047
	Waste fuel	Tonne/GJ	0
	Propane	Tonne/GJ	0.06

Variable		Units	Value
Share of imported steel	BAU	%	17.96
	Sustainable	%	17.96
	S+D	%	0
Steel energy efficiency increase	BAU	%	0
	Sustainable	%	2
	S+D	%	2

4.4 Results

As with cement, the sustainable plus domestic scenario for steel results in higher revenues and employment due to higher levels of domestic steel production (Table 10). Revenues and employment in the sustainable plus domestic scenario are 20 per cent higher than the other scenarios by 2035. This is largely due to the fact that a larger portion of steel is currently imported. Domestic production would have to ramp up accordingly to replace imports.

Table 10. Production, revenue and employment, 2016 and 2035

	Production (tonne/year)			Revenue (CAD/year)			Employment (Person)		
	2016	2035	% change	2016	2035	% change	2016	2035	% change
Steel for buildings									
BAU	246,679	224,120	-9	758,292,480	688,946,368	-9	251	228	-9
Sustainable	246,679	224,120	-9	758,292,480	688,946,368	-9	251	228	-9
S+D	246,679	273,184	11	758,292,480	839,768,896	11	251	278	11
Steel for infrastructure									
BAU	1,166,727	1,060,029	-9	3,586,518,528	3,258,530,304	-9	1,185	1,077	-9
Sustainable	1,166,727	1,060,029	-9	3,586,518,528	3,258,530,304	-9	1,185	1,077	-9
S+D	1,166,727	1,292,088	11	3,586,518,528	3,971,879,680	11	1,185	1,313	11

The large increase in domestic production under the sustainable plus domestic scenario is accompanied by an increase in energy consumption and emissions (see Figure 9 for buildings, Figure 10 for infrastructure). The sustainable scenario fares considerably better than the other scenarios here, although there are also substantial energy and emissions savings in the sustainable plus domestic scenario. It may be the case that the higher domestic emissions in the sustainable plus domestic scenario are offset by a decrease in global emissions. Steel production expands in Canada, which results in greater energy use and emissions. However, the switch to domestic steel reduces the need for non-Canadian production, which in turn reduces emissions.

The jump in energy consumption from 2020 to 2021 is caused by the replacement of imported steel with domestic steel. There is a large increase in domestic production during this time, as more than 17 per cent of the total steel demand is satisfied by imports prior to 2020.

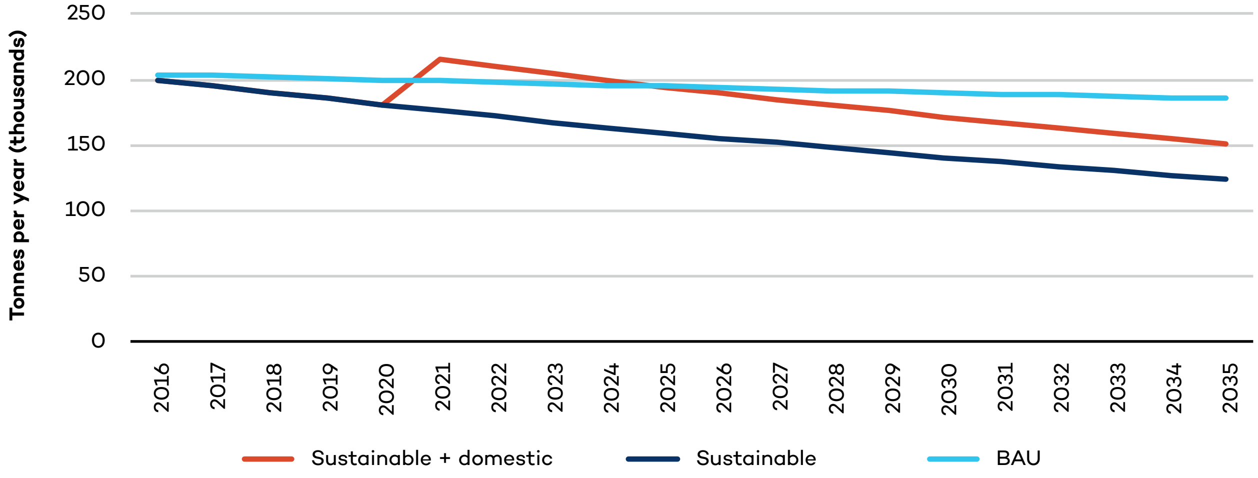

Figure 9. Production emissions: Steel for buildings

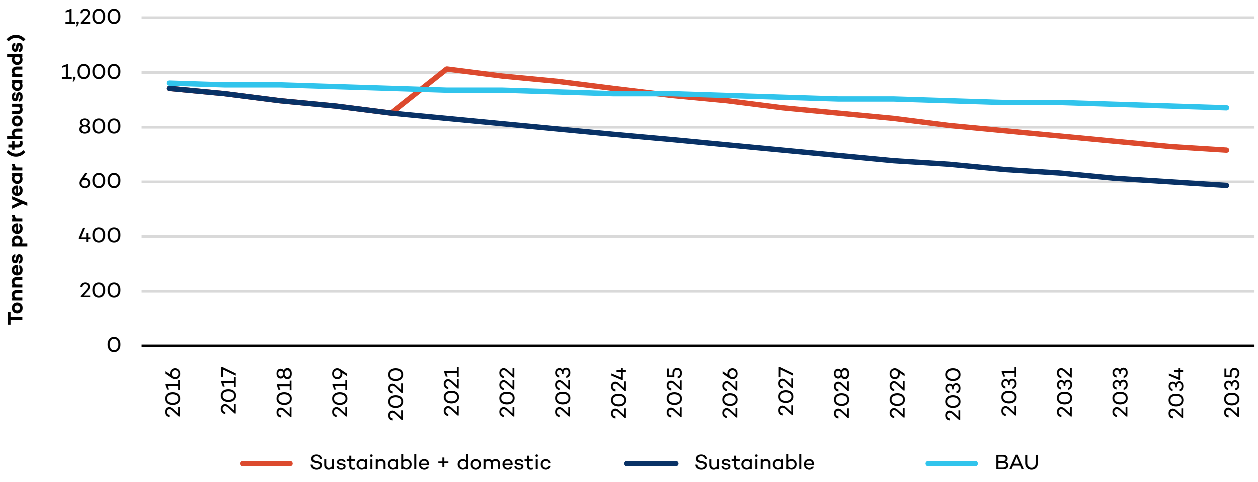

Figure 10. Production emissions: Steel for infrastructure

The total emissions follow the same trend as energy consumption, as emissions related to steel are primarily related to fuel use. Observing only domestic emissions, it seems that the sustainable scenario outperforms the sustainable plus domestic scenario. However, when we include the emissions from imported steel, it is clear that the sustainable plus domestic scenario reduces emissions the most. By 2035, there are 86,892 tonnes of emission per year associated with steel imports for buildings and 410,977 tonnes of emissions per year associated with infrastructure (Table 11). In the sustainable scenario, there are no emissions associated with the import of steel.

Table 11. Steel emissions, 2035

	Domestic emissions (tonnes per year)	Emissions from imports (tonnes per year)	Total emissions (tonnes per year)
Steel for buildings			
S+D	151,437	0	151,437
Sustainable	124,239	86,892	211,131
BAU	185,297	86,892	272,189
Steel for infrastructure			
S+D	716,257	0	716,257
Sustainable	587,617	410,977	998,594
BAU	876,403	410,977	1,287,380

4.5 Summary

Table 12 (buildings) and Table 13 (infrastructure) present summary results for the steel module.

Table 12. Steel for buildings

Indicator	Unit	2016	2020	2025	2030	2035
Production						
S+D	tonne/year	246,679	241,749	287,328	280,167	273,184
Sustainable	tonne/year	246,679	241,749	235,724	229,849	224,120
BAU	tonne/year	246,679	241,749	235,724	229,849	224,120
% to BAU: S+D	%	0	0	22	22	22
% to BAU: S	%	0	0	0	0	0
Employment						
S+D	person	251	246	292	285	278
Sustainable	person	251	246	239	234	228
BAU	person	251	246	239	234	228

Indicator	Unit	2016	2020	2025	2030	2035
% to BAU: S+D	%	0	0	22	22	22
% to BAU: S	%	0	0	0	0	0
Energy consumption						
S+D	GJ/ year	4,367,909	3,951,691	4,250,051	3,749,997	3,308,779
Sustainable	GJ/ year	4,367,909	3,951,691	3,486,742	3,076,498	2,714,522
BAU	GJ/ year	4,456,091	4,367,022	4,258,185	4,152,060	4,048,580
% to BAU: S+D	%	-2	-10	0	-10	-18
% to BAU: S	%	-2	-10	-18	-26	-33
Energy expenditure						
S+D	CAD/ year	51,143,592	51,674,940	61,064,372	56,121,920	50,150,404
Sustainable	CAD/ year	51,143,592	51,674,940	50,097,212	46,042,424	41,143,392
BAU	CAD/ year	52,486,272	58,675,924	64,182,696	66,433,256	66,744,200
% to BAU: S+D	%	-3	-12	-5	-16	-25
% to BAU: S	%	-3	-12	-22	-31	-38
Energy expenditure (% of costs)						
S+D	%	13	13	13	13	12
Sustainable	%	13	13	13	13	12
BAU	%	13	15	17	17	18
Emissions						
S+D	tonne/ year	199,912	180,862	194,518	171,631	151,437
Sustainable	tonne/ year	199,912	180,862	159,582	140,806	124,239
BAU	tonne/ year	203,948	199,871	194,890	190,033	185,297

Indicator	Unit	2016	2020	2025	2030	2035
% to BAU: S+D	%	-2	-10	0	-10	-18
% to BAU: S	%	-2	-10	-18	-26	-33

Table 13. Steel for infrastructure

Indicator	Unit	2016	2020	2025	2030	2035
Production						
S+D	tonne/ year	1,166,727	1,143,406	1,358,983	1,325,114	1,292,088
Sustainable	tonne/ year	1,166,727	1,143,406	1,114,910	1,087,123	1,060,029
BAU	tonne/ year	1,166,727	1,143,406	1,114,910	1,087,123	1,060,029
% to BAU: S+D	%	0	0	22	22	22
% to BAU: S	%	0	0	0	0	0
Employment						
S+D	person	1,185	1,162	1,381	1,346	1,313
Sustainable	person	1,185	1,162	1,133	1,105	1,077
BAU	person	1,185	1,162	1,133	1,105	1,077
% to BAU: S+D	%	0	0	22	22	22
% to BAU: S	%	0	0	0	0	0
Energy consumption						
S+D	GJ/ year	20,659,028	18,690,432	20,101,592	17,736,474	15,649,630
Sustainable	GJ/ year	20,659,028	18,690,432	16,491,347	14,551,003	12,838,956
BAU	GJ/ year	21,076,104	20,654,832	20,140,060	19,638,120	19,148,688
% to BAU: S+D	%	-2	-10	0	-10	-18
% to BAU: S	%	-2	-10	-18	-26	-33

Indicator	Unit	2016	2020	2025	2030	2035
Energy expenditure						
S+D	CAD/ year	241,895,376	244,408,496	288,817,984	265,441,520	237,197,856
Sustainable	CAD/ year	241,895,376	244,408,496	236,946,272	217,768,224	194,597,120
BAU	CAD/ year	248,245,872	277,521,280	303,566,816	314,211,328	315,682,016
% to BAU: S+D	%	-3	-12	-5	-16	-25
% to BAU: S	%	-3	-12	-22	-31	-38
Energy expenditure (% of costs)						
S+D	%	13	13	13	13	12
Sustainable	%	13	13	13	13	12
BAU	%	13	15	17	17	18
Emissions						
S+D	tonne/ year	945,529	855,429	920,016	811,768	716,257
Sustainable	tonne/ year	945,529	855,429	754,781	665,975	587,617
BAU	tonne/ year	964,618	945,337	921,776	898,803	876,403
% to BAU: S+D	%	-2	-10	0	-10	-18
% to BAU: S	%	-2	-10	-18	-26	-33

5.0 Vehicles

5.1 Model Set Up

The total stock of vehicles is based on the public sector's estimated vehicle stock growth, which was derived from a variety of Statistics Canada (n.d.) sources on new motor vehicle sales, capital expenditure on passenger vehicles and light trucks by North American Industry Classification System grouping, annual vehicle registrations and vehicle kilometres driven. Growth in the estimated public sector vehicle fleet was based on population growth projections derived from the NEB's (2016) *Canada's Energy Futures 2016* analysis. Three types of vehicles are included in the model: gas, hybrid and electric vehicles. The share that each type makes up of the total stock of vehicles is determined by the scenarios.

Both the capital costs and current costs for vehicles are included. Capital costs are the costs associated with purchasing the car itself. Current costs are based on the costs associated with the purchase of fuel and energy costs. Fuel prices are expected to grow over the time period. Together, the capital and current costs make up the total fiscal cost of the car.

Emissions are estimated based on fuel use. Both the fuel efficiency and number of kilometres driven affect the amount of energy consumption and, hence, emissions. Electric vehicles do not use gasoline but do produce emissions through the generation of the electricity consumed.

5.2 Scenario Definition

There are three scenarios in the vehicle module. The BAU scenario assumes that almost all vehicles purchased (more than 99 per cent) are gasoline vehicles. The light green scenario assumes that 15 per cent of vehicles purchased are hybrid and that 15 per cent are electric by 2020. The dark green scenario assumes that 30 per cent of vehicles purchased are hybrid and that 30 per cent are electric by 2020. The rest of the vehicles purchased are gasoline.

5.3 Key Inputs

Table 14 presents key data inputs for the vehicles module, including the upfront cost of vehicles' energy efficiency and the annual usage.

Table 14. Key input values, 2015 year

Variable		Units	Value
Initial stock of vehicles		Vehicles	100,000
Desired growth of car stock		Vehicles	18,241
Capital costs	Gasoline vehicle	CAD/car	34,997
	Hybrid vehicle	CAD/car	38,997
	Electric vehicle	CAD/car	54,997

Variable		Units	Value
Energy efficiency	Gasoline vehicle	Litres/km	0.0772
	Hybrid vehicle	Litres/km	0.0551
	Electric vehicle	kWh/km	0.28
Annual usage		Km/car/year	36,521.7

5.4 Results

The total costs for both the light and dark green scenarios are lower than the BAU scenario by 2035 (Figure 11). This is largely due to a greatly reduced fuel cost. The share of hybrid vehicles in the total stock of vehicles reaches 77 per cent by 2035, while the share of electric vehicles reaches 19 per cent. As a result, the total costs in both the light green and dark green scenarios are 32 per cent lower than in the BAU scenario by 2035.

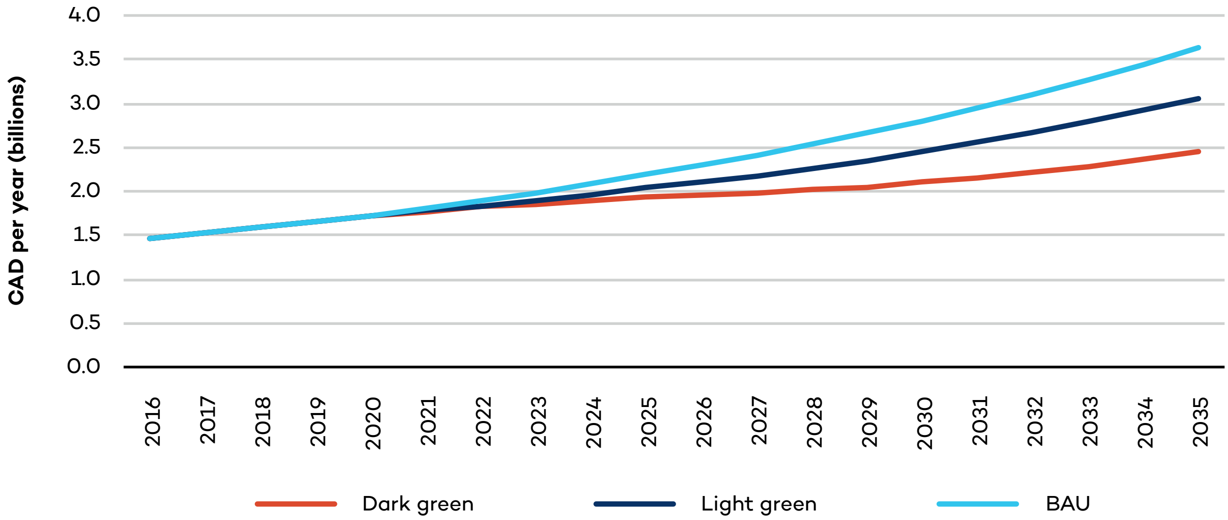

Figure 11. Total costs: Scenario comparison

Due to the decline in fuel use, there is also a large decline in emissions between the BAU and other scenarios (Figure 12). Emissions continue to increase over the whole time period in the BAU scenario as the total stock of vehicles increases. In the light and dark green scenarios, emissions decline the most as gasoline vehicles are replaced by hybrid and electric vehicles. Once most gasoline vehicles have been replaced, the reduction in emissions begins to slow down.

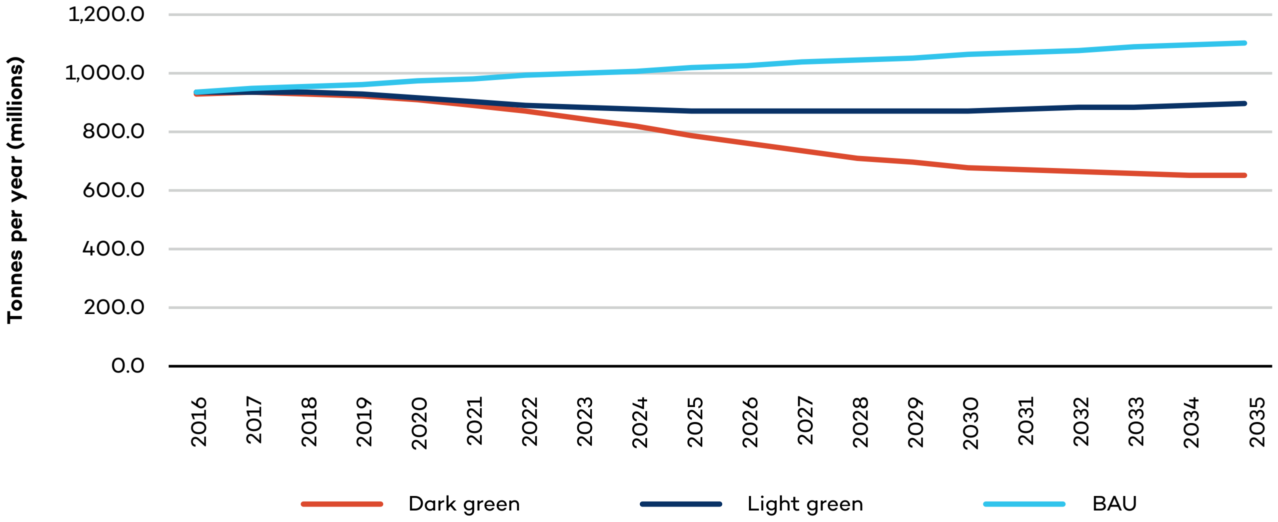

Figure 12. Total emissions: Scenario comparison

6.0 Results Summary

The GPP model for Canada reveals the economic, environmental, and social benefits and costs of public spending on conventional products versus more sustainable ones. When applied to cement, steel, buildings and vehicles, the model reveals that GPP has economic, social and environmental benefits over BAU.

The primary benefit of GPP is lower costs over the time period. Total production costs for all steel and cement (both buildings and infrastructure) indicate that the sustainable scenario has the lowest costs. By 2035, almost CAD 3.4 billion per year is being spent on the production of cement and steel under the BAU scenario, while less than CAD 3.2 billion is spent in the sustainable scenario. The sustainable plus domestic scenario has the highest costs (CAD 3.6 billion), largely due to the steel sector, as a sizable portion (17 per cent) is currently imported.

Total capital and operating costs can be calculated for buildings and vehicles. Total capital costs include all costs related to constructing new buildings and buying new vehicles. Operating costs include energy expenditures for heating and cooling buildings, as well as fuel and energy expenditures for vehicles. For both capital costs and operating costs, there are substantial benefits for the sustainable and the sustainable plus domestic scenarios over the BAU scenario. By 2035, both the sustainable and sustainable plus domestic scenarios save almost CAD 2 billion per year in operating costs over the BAU scenario.

Table 15. Costs: Scenario comparison

Scenario	Unit	2016	2020	2025	2030	2035
Total production costs (steel and cement)						
S+D	CAD/ year	3,542,298,784	3,489,900,224	3,907,117,088	3,793,033,408	3,662,319,424
Sustainable	CAD/ year	3,542,298,784	3,489,900,224	3,403,350,048	3,305,262,496	3,191,683,648
BAU	CAD/ year	3,552,570,272	3,544,167,456	3,513,570,176	3,468,553,408	3,397,276,832
Total capital costs (vehicles and buildings)						
Sustainable	CAD/ year	940,279,186	1,006,284,272	1,024,633,534	1,000,607,925	969,498,565
BAU	CAD/ year	927,248,062	954,798,313	987,866,136	1,018,372,932	1,043,002,891
Total operating costs (vehicles and buildings)						
Sustainable	CAD /year	18,373,603,200	19,156,525,952	19,757,243,648	20,284,960,896	20,894,015,488
BAU	CAD/ year	18,375,249,472	19,221,080,192	20,293,595,136	21,446,220,544	22,663,701,248

Increases to employment and public revenues are the primary social benefits of pursuing a GPP strategy in Canada. While the cost of steel and cement production is higher for the sustainable plus domestic scenario, it has the benefit of producing more employment and higher revenues than the other two scenarios. As imported steel is substituted with domestic steel, the number of jobs and revenue generated from procurement begins to increase relative to the other scenarios. By 2035, the sustainable plus domestic scenario produces almost a billion more in revenue than the other scenarios and results in almost 400 new jobs.

Table 16. Employment and revenue, scenario comparison

Scenario	Unit	2016	2020	2025	2030	2035
Employment (steel and cement)						
S+D	FTE*	5,220	5,116	5,390	5,256	5,125
Sustainable	FTE	5,220	5,116	4,988	4,864	4,743
BAU	FTE	5,220	5,116	4,988	4,864	4,743
Revenues (cement and steel industry)						
S+D	CAD/ year	5,645,715,040	5,532,867,136	6,338,839,616	6,180,859,712	6,026,816,896
Sustainable	CAD/ year	5,645,715,040	5,532,867,136	5,394,974,304	5,260,517,728	5,129,412,576
BAU	CAD/ year	5,645,715,040	5,532,867,136	5,394,974,304	5,260,517,728	5,129,412,576

**Note: FTE = full-time equivalent*

Reductions in emissions, and the costs associated with those emissions, are a major benefit of GPP. The sustainable plus domestic scenario performs best in reducing total emissions. It produces 4,679,798 million tonnes less GHG emissions in 2035 than under the BAU scenario.

The social cost of carbon (SCC) is a measure used to estimate the financial costs associated with carbon dioxide and other GHG emissions. The SCC used in the GPP model is based on the Canadian estimate by Environment and Climate Change Canada (2016). This measure can be used to estimate the savings associated with the reduction in emissions from the BAU scenario to the sustainable and sustainable plus domestic scenarios. Both the sustainable and sustainable plus domestic scenarios result in substantial savings over the BAU scenario. The sustainable plus domestic scenario has greater savings (CAD 278 million by 2035) due to the greater reduction in emissions.

Table 17. Emissions: Scenario comparison for operations of buildings, manufacturing of cement and steel, and vehicles (with the sustainable scenario for vehicles corresponding to the dark green scenario in section 5.2)

Scenario	Unit	2016	2020	2025	2030	2035
Emissions						
S+D	tonne/ year	44,460,001	45,685,807	45,423,844	45,341,570	45,143,819
Sustainable	tonne/ year	44,460,001	45,685,807	45,733,183	45,663,073	45,474,844
BAU	tonne/ year	44,497,737	45,912,439	47,466,707	48,828,056	49,823,617
SCC savings						
SCC estimate	CAD/ tonne	40.7	45.1	49.8	54.5	59.6
S+D	CAD/ year	1,535,855.20	10,221,103.20	101,734,577.40	190,013,487.00	278,915,960.80
Sustainable	CAD/ year	1,535,855.20	10,221,103.2	86,329,495.20	172,491,573.5	259,186,870.8

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Head Office

111 Lombard Avenue, Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

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