Final Report

An Exploration into the Impact of Carbon Pricing in the Northwest Territories:

Revised Reference Case &
Quantitative Policy Analysis

March 4th, 2011

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Disclaimer

This report is an analysis of greenhouse gas abatement options prepared by M. K. Jaccard and Associates, Inc. for the Government of the Northwest Territories.

The policies and results presented in this report are academic in nature and do not reflect the official policy position of the Government of the Northwest Territories. The findings and views expressed are those of M. K. Jaccard and Associates, Inc. and should not be interpreted as part of the policies or programs of the Government of the Northwest Territories.

Executive Summary

The Government of the Northwest Territories (GNWT) is reviewing the progress of its most recent (2007) greenhouse gas (GHG) strategy, and is now interested in setting longer-term targets for emission reduction past 2011. To achieve this objective, the GNWT requires a forecast of territorial emissions with and without climate policies aimed at reducing GHG emissions. The objective of this report is to provide a quantitative analysis that can assist policy makers in understanding the potential effect climate policy may have on the Northwest Territories (NWT) and exploring opportunities for emissions abatement.

This analysis is not intended to be a comprehensive examination of policy alternatives, and does not prescribe a policy package that the NWT should implement. Rather, it provides reasonable approximations of the relative impacts of different policy options through simulations based on current information, knowledge and best estimates of currently available and emerging technologies. Given the twenty-year outlook included in this evaluation, it is expected that many economic, technological and energy supply and demand relationships will change.

In addition, the pricing scenarios and regulations modelled in this study were selected for the purposes of examining the impact of a range of potential policies on the economy of the NWT, and do not necessarily reflect the policy position of the GNWT.

In this study, the CIMS energy-economy model is used to:

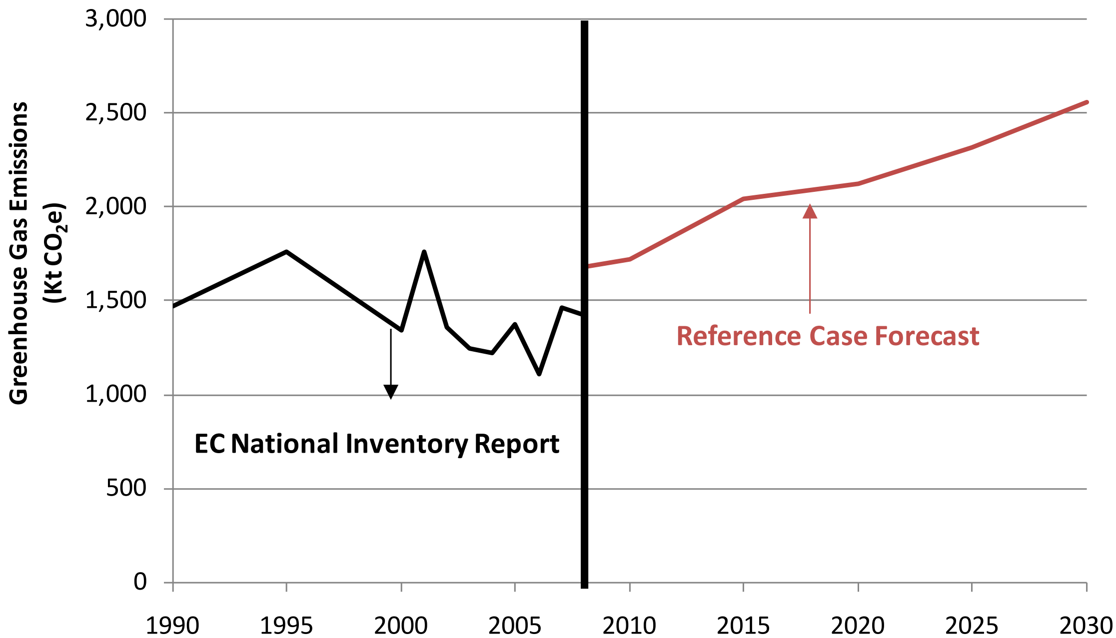
1. Forecast reference case greenhouse gas emissions in the NWT to 2030.
2. Explore the magnitude of future emissions reductions achieved by different possible carbon pricing scenarios under two development scenarios: the first development scenario assumes that the Mackenzie Gas Project (MGP) is not developed, while the second assumes it is. For each carbon price scenario, changes in territorial emissions, energy consumption and key energy and economic indicators are assessed. Comparison of these scenarios is relative to a reference case that assumes no MGP development in order to clarify the impact of the project on the region.

The North American GEEM computable general equilibrium model was also used to assess the overall economic impact of both carbon taxation and an emissions cap and trade system in 2020 on NWT GDP, employment, and firm output.

Reference case

- **In the absence of any additional mitigation policy (and without the development of MGP), greenhouse gas emissions in the NWT are projected to increase steadily over the entire forecast period reaching 2,587 kt CO_2e in 2030, 50% above 2010 levels (Figure ES1).** Territorial emissions are heavily influenced by activity in the mining, transportation and electricity sectors, which account for almost 90% of total reference case emissions in 2030. Activity in the electricity sector in turn is heavily influenced by mining activity, as well as demand from the residential and commercial sectors.

Figure ES1: Northwest Territories reference case greenhouse gas emissions



Quantitative policy analysis

The quantitative policy analysis explores the magnitude of emissions reductions achieved by a variety of carbon price scenarios under two distinct development scenarios. The scenarios modelled in this analysis simulate territorial emissions under a given strength of market-based policy, with emissions prices roughly equivalent to an economy-wide tax on GHG emissions.

In scenarios with carbon pricing, the price begins in 2012 and increase over the simulation period to 2030. In total, eight policy scenarios – two sets of carbon pricing scenarios under two different development scenarios – are modelled in CIMS. Table ES1 summarizes the carbon prices of the policy scenarios assessed in this analysis. Carbon prices that are introduced gradually into the economy are likely to minimize total policy costs.

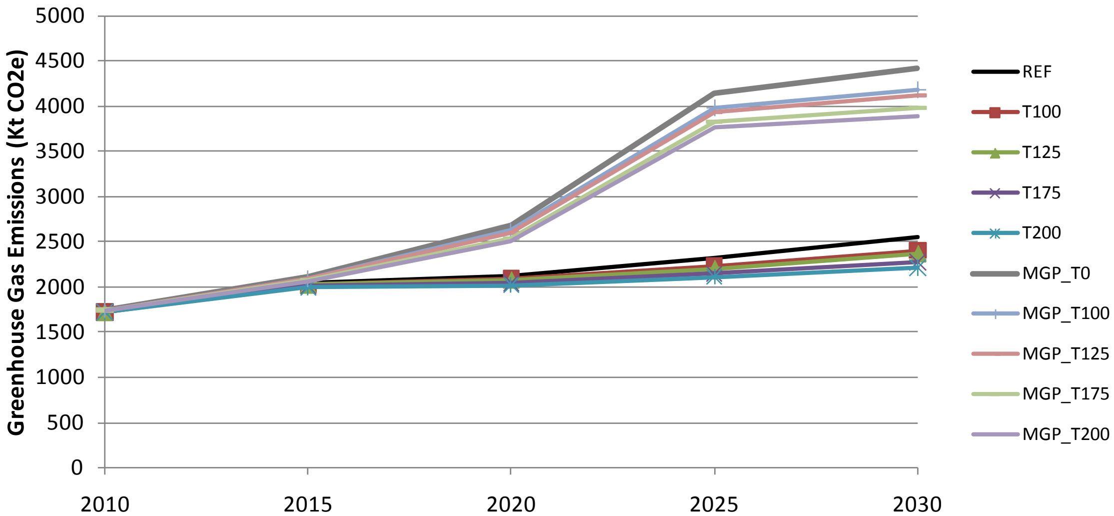
Table ES1: Carbon price paths of the policy scenarios

Policy Scenario	*Policy Code*	*2012-2015*	*2016-2020*	*2021-2025*	*2026-2030*
		Emissions Charges (2005$ / tonne)			
MGP is NOT developed					
Lower price	T100	$10	$25	$50	$100
Intermediate price Low	T125	$10	$30	$70	$125
Intermediate price High	T175	$10	$50	$100	$175
Higher price	T200	$10	$50	$125	$200
MGP is developed					
Lower price	MGP_T100	$10	$25	$50	$100
Intermediate price Low	MGP_T125	$10	$30	$70	$125
Intermediate price High	MGP_T175	$10	$50	$100	$175
Higher price	MGP_T200	$10	$50	$125	$200

Key findings from the quantitative policy analysis include:

- **By introducing an economy-wide carbon price, the NWT can achieve emissions reductions of about 6% to 13% relative to the reference case in 2030 if the MGP is assumed to not be developed (Figure ES4).** The stronger carbon prices are associated with higher reductions because they induce a greater range of abatement actions, such as energy efficiency and fuel switching to less carbon-intensive sources. In the MGP scenario, output from the natural gas sector increases substantially, as well as output from the freight and commercial sectors, due to indirect economic effects. This increased output causes emissions to grow significantly in all scenarios that include development of the MGP; even with carbon pricing, emissions still increase approximately 52% to 63% relative to the reference case in 2030. However, carbon pricing is likely to mitigate some of the potential impacts of the project, reducing emissions by around 5% to 12% relative to a scenario in which the MGP is developed and there is no carbon pricing.

Figure ES4: Greenhouse gas emissions in each policy scenario



- **The greatest emissions reduction opportunities, on an absolute basis, are likely concentrated in the electricity and transportation sectors.** In 2030, these sectors account for approximately 78% of the NWT's GHG emissions in the reference case when the MGP is assumed to not be developed. In response to carbon pricing, the electricity and transportation sectors account for roughly 70% of total emission reductions in the NWT. This proportion is equivalent to between 81 and 126 kt CO_2e of reductions depending on the strength of the carbon policy for the electricity sector, and between 27 and 115 kt CO_2e for the transportation sectors.
  - A key abatement action in the electricity sector is fuel switching away from diesel generation to renewable energy sources, especially hydroelectricity. In response to carbon pricing, the share of hydroelectricity increases from 43% to up to 51% in 2030. However, it is possible that with an aggressive hydro development policy, greater capacity could be developed and emissions further reduced.
  - In the transportation sector, carbon pricing causes efficiency improvements, an increased penetration of alternative fuels (e.g., biofuels), hybrids and zero emissions vehicles (e.g., plug-in electric). Limitations to abatement include climate (which affects the feasibility of electric and biofuel technology, primarily in the freight transportation sector) and the availability of low emission-intensive electricity generation.
- **The greatest emissions reduction opportunities, on a percentage basis relative to the reference case, are likely concentrated in the mining and residential sectors.** Across all policy and development scenarios, emissions reduction from the mining and residential sector average 16% and 13% lower than the reference case, respectively, by 2030.

- Key abatement actions in the residential sector include improvements to building shell efficiency and fuel switching to biomass (wood and wood pellets) and electricity (heat pumps) for space heating. In the mining sector, key abatement actions include switching to electric and high efficiency equipment for extraction and processing activities.

Several economic and energy indicators were analyzed to assess the impact of the policy scenarios on the economy of the NWT. Key points from this analysis are:

- **In both the MGP and no MGP scenarios, total capital investment increases in response to higher carbon prices. In the no MGP scenario, cumulative investment increases by between $47.0 to $68.6 million (2005$) from 2012 to 2030; in the MGP scenario, cumulative investment increases substantially more, between $9.25 and $9.29 billion (2005$) over the period, due to direct capital expenses in the natural gas sector, as well as greater output from the electricity, freight and commercial sectors.**
  - In the no MGP scenarios, the electricity sector is projected to experience the greatest increase in capital investment, between $31.0 and $39.7 million (2005$) over the study period. Some of this investment would be borne by the mining industry, because industrial power generation is included in the CIMS electricity sector. Capital investment in the residential and commercial sectors is largely associated with investment in more efficient building shells and space and water heating technologies. Increased investment in the freight sector is associated with the purchase of more efficient trucks. Conversely, reductions in investment occur in the personal transportation sector because consumers shift to smaller and higher occupancy vehicles, higher efficiency vehicles and some transit.
  - For many sectors of the economy, capital investment in the MGP scenarios follows similar trends. However, some sectors (e.g. natural gas and freight transportation) have higher investment costs due to changes in output. Investment in the residential sector is slightly lower in the MGP scenarios due to the lower capital cost of natural gas technologies, while investment is higher in the commercial, freight and electricity sectors due to greater output.
- **In the policy scenarios, household energy costs generally increase in response to the carbon pricing, with greater growth experienced between 2010 and 2020. By 2030 household energy costs are, on average only 3% higher than the reference case.** After 2020, growth in energy costs fall as capital stock is replaced by more efficient technologies, and between 2020 and 2030 average energy costs actually fall 1% in the higher price scenarios. In the MGP scenarios, the rise in energy costs is more muted in the later simulation periods due to the availability of natural gas in several communities.
- **In all policy scenarios, average vehicle fuel prices rise, increasing incrementally with higher carbon prices.** This increase occurs in part because higher priced bio-fuels, primarily ethanol, replace gasoline and diesel, and in part

because carbon charges are applied to conventional fuels. Average fuel prices increase about 20%, across all scenarios. Likewise, average annual fuel costs increase, though to a lesser extent than fuel prices (because vehicles become more efficient and require less fuel), peaking at 15% in 2030 with a carbon price of \$200/t CO_2e.

- **Electricity prices vary significantly throughout the Territories and are affected to differing degrees by carbon pricing; however average generation costs increase by between about 3 and 7c/kWh relative to the reference case.** The greatest increase occurs with a carbon price that rises to \$200/tCO_2e by 2030, representing a 22% increase relative to the reference case**.** Rising electricity prices influence a variety of abatement actions including fuel switching and energy efficiency, which in the future will be influenced by whether and to what degree electricity prices reflect increases in generation costs.
- **The macroeconomic analysis indicates that NWT firms and households are better off with a carbon tax than a cap and trade system.** The analysis, based on North America reducing emissions by 17% below 2005 levels by 2020, indicates that the NWT would be slightly better off in GDP terms with a carbon tax where revenues are recycled one third to corporate taxes and two thirds to income taxes (the BC model), versus participating in an emissions cap and trade system where revenues are returned using a value added output based allocation. In addition, household consumption and general welfare is significantly better off under a carbon tax, due to the reduced income and corporate taxes associated with revenue recycling.
- **The macroeconomic analysis also indicates that if the MGP is built it could increase incomes and GDP significantly,** but that carbon pricing sufficient to reach a target of 17% below 2005 emissions levels by 2020, would reduce the MGP's value in GDP terms by about 20%. The mining sector is less affected by carbon pricing than the natural gas sector in the MGP scenario.

Limitations

- **This modelling analysis provides an integrated forecast showing how each sector is likely to respond to carbon pricing but does not contain data obtained from consultation with individual industries**. As such, the results may not, and should not be interpreted as, abatement opportunities at specific facilities.
- **CIMS includes all utility and industry generation in the electricity sector in the NWT.** By combining all generation, supply mix changes in either utility or industry generation affect total generation in the electricity sector (as well as cost of production and electricity prices). Any change to the average cost of electricity generation, resulting from the policy scenarios, influences abatement choices throughout the entire economy. Future research could disaggregate this sector and conduct a more detailed analysis of the impact of carbon policy on electricity generation in the NWT.

Recommendations for Further Research

- **A marginal abatement cost curve analysis of industry − aided by more detailed operational data − is likely to produce a more accurate list of abatement options and costs.** A marginal abatement cost curve analysis will detail the specific abatement actions sectors employ to respond to rising carbon prices. The use of CIMS for this task can be distinguished from other efforts to develop marginal abatement cost curves because CIMS aims to ensure a behaviourally realistic simulation: that is, how businesses and consumers are likely to respond to a policy, rather than how they should respond in order to minimize financial costs. Several studies have shown (e.g. the McKinsey studies) that many investments to reduce GHG emissions would reduce financial costs, because energy savings would offset the higher purchasing costs for many technologies.[1] However, cost curves developed from this perspective fail to incorporate the influence of non-financial factors on the decision making of businesses and consumers, including capital rationing, aversion to large up-front investment risks, perception of risk or consumer preferences. With improved access to industry specific data, MKJA could generate an analysis that identifies explicit abatement actions associated with specific carbon prices at various points in time.

[1] [1] McKinsey and Company, 2009, “Pathways to a low-carbon economy”.

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Introduction

The Government of the Northwest Territories (GNWT) released its most recent greenhouse gas (GHG) strategy in 2007. Now reviewing the progress of its strategy, the GNWT is interested in setting longer-term targets for emission reduction past 2011. To aid in these efforts, M. K. Jaccard and Associates, Inc. (MKJA) has been selected to perform a quantitative analysis that can assist policy makers in exploring opportunities for emissions abatement. The analysis will forecast territorial emissions without climate policy and assess the magnitude of future emissions reductions achieved by different strengths of carbon pricing.

This study is divided into three sections:

1. First, the CIMS energy-economy model is used to forecast reference case greenhouse gas emissions in the Northwest Territories without climate policy.
2. Second, CIMS is used to provide a quantitative policy analysis. In this analysis the magnitude of future emissions reductions achieved by different possible carbon pricing scenarios under two development scenarios is explored: the first development scenario assumes that the Mackenzie Gas Project (MGP) is not developed, while the second assumes it is. For each carbon price scenario, changes in emissions, energy consumption and key energy/economic indicators are assessed. Comparison of these scenarios is relative to a reference case that assumes no MGP development in order to clarify the impact of the project on the region.
3. Lastly, GEEM is used to provide an analysis of the macroeconomic impacts of carbon pricing policy design in the region. In this section, we will discuss the impact of carbon pricing (carbon taxation and cap and trade schemes, under the two development scenarios) on economic indicators such as GDP, employment, consumption and expenditures.

Reference Case

This section presents the inputs and assumptions that were used to generate the reference case forecast using the CIMS energy-economy model. A reference case forecast describes how the economy may evolve in the absence of any policies aimed at reducing greenhouse gas emissions. Once the reference case has been established, the CIMS model can forecast the GHG reductions and abatement actions that occur in response to various policies.

Assumptions for the Reference Case

The reference scenario described in this report is based on external inputs to the CIMS model and shows how the Northwest Territories (NWT) economy may evolve from the present to 2030. We use credible sources to guide these inputs, but no amount of research allows perfect foresight into the future of the economy and some of the key inputs underlying our assumptions are highly uncertain. If economic evolution takes a different path than the one projected here, future energy consumption and emissions will also be different. Therefore, this reference scenario should be regarded as just one possible reference scenario. We consider it a reasonable "business as usual" forecast based on historic trends and research into likely future technological and economic evolution, but the uncertainty remains large.

Some of the key assumptions to the reference case have been specified by the GNWT. This report builds on those assumptions and provides a detailed description of how these assumptions have shaped the reference case.

Key economic drivers and assumptions

To develop the reference case forecast, CIMS requires external forecasts for the economic or physical output of each economic sector (e.g., the number of residential households or the amount of oil produced in the territories). We have also produced an alternative forecast in which it is assumed the Mackenzie Gas Project (MGP) is developed (the reference case presented in this analysis assumed the MGP is NOT developed). The MGP will have repercussions for the growth of other sectors in the NWT economy, which are reflected in the data below. In this report we do not consider this alternative scenario the "reference case". Instead scenarios modelled with the assumption that the MGP is developed will be considered a policy scenario to allow us to determine the impact of the MGP on region and on climate policy. Generally, assumptions related to the effects of the MGP were derived from the Conference Board of Canada[2] and the Wright Mansell report.[3] For the MGP scenario, we assume that construction begins by 2015 and production starts by 2020.

Table 1 summarizes the proposed external forecasts to be used in the reference case for each sector modelled in CIMS. The following discussion summarizes the reference case

[2] Conference Board of Canada, July 2010, Territorial Outlook: Economic Forecast.
[3] Wright Mansell Research Ltd., 2007, An evaluation of the economic impacts associated with the Mackenzie Valley gas pipeline and Mackenzie Delta gas development.

economic output forecast used in this report. These forecasts have been developed from a number of sources. Generally, a set of more concrete and project-based assumptions is used from 2010 to 2020, while growth is inferred from more generalized forecasts from 2020 to 2030. As has been emphasized throughout, this forecast reflects historic and anticipated trends, but is highly uncertain, particularly in the later years of the forecast.

Table 1: Reference case output forecast

	Units	*2010*	*2015*	*2020*	*2025*	*2030*
Demand Sectors						
Residential	*thousands of households*	14.6	15.5	16.2	16.8	17.2
Commercial	*average annual growth in floor space*	0.5%	0.5%	1.0%	0.7%	0.8%
Commercial (MGP)	*average annual growth in floor space*	1.7%	1.7%	3.1%	0.8%	0.8%
Passenger Transportation	*million passenger-km*	1,012	1,110	1,213	1,332	1,442
Freight Transportation	*million tonne-km*	1,530	1,561	1,516	1,607	1,710
Freight Transportation (MGP)	*million tonne-km*	1,530	1,629	1,875	1,986	2,115
Mineral Mining	*million tonnes ore*	8.3	12.1	20.6	24.8	29.1
Supply Sectors						
Natural Gas Extraction	*thousand cubic metres / day*	240	44	8	8	8
Natural Gas Extraction (MGP)	*thousand cubic metres / day*	240	44	34,002	34,002	34,002
Crude Oil	*thousand barrels / day*	14.6	11.3	8.7	6.7	5.2

Note: Electricity generation forecast is produced within the model; therefore supply forecasts reflect demand for electricity from all sectors.
Note: The freight transportation forecast does not include tkt from off-road vehicles, although energy consumption and emissions from this activity are included in the sector. Growth forecasts for off-road transportation are closely aligned with activity in the mining sector.

The main drivers of forecasted sector growth are population and gross domestic product (GDP), shown in Table 2. The population forecast was provided by the GNWT Bureau of Statistics. The GDP forecast is based on Conference Board of Canada projections to 2020, and informed by Informetrica projections for all territories from 2021 to 2030. Between 2010 and 2030, the population of the NWT is forecast to grow by 4.5 thousand, representing an average annual increase of 0.5%. We do not capture growth in population associated with the MGP because the bulk of any such increase would be largely associated with short-term construction activities (less than 5 years) and our analysis is focused on longer-term trends. However, the MGP will have a large and longer-term impact on GDP in the NWT. To calculate GDP for the no MGP scenario, we subtract the expected GDP impact anticipated by the Wright Mansell 2007 report[4] from the Conference Board GDP projection (which assumes the MGP proceeds). As shown in Table 2, the MGP boosts territorial GDP by $350 million (9%) in 2015 and by $1.9 billion (53%) for the rest of the forecast period.

[4] We use Case 2-6 because this scenario assumes production levels closest to that of the Conference Board of Canada projection and natural gas prices that are most in line with current trends.

Table 2: Northwest Territories economic and demographic forecast

	2010	2015	2020	2025	2030
Population (thousands)	43.7	45.3	46.6	47.5	48.2
Real GDP at Basic Prices (2005$ millions)					
MGP Scenario	3,692	4,193	5,563	6,253	7,099
No MGP Scenario	3,692	3,874	4,438	4,988	5,664

Energy demand sectors

In response to projected population growth, the residential housing stock is anticipated to grow at an average annual rate of 0.8% between 2010 and 2030 – slightly faster than population growth. The number of households increases from 14.6 thousand in 2010 to 17.2 thousand in 2030, representing a total growth of 17.6%. This forecast is based on GNWT population projections combined with Informetrica forecasts of the relative change in the number of persons per household.

The commercial sector is expected to expand in response to growth in GDP. Table 4 and Table 3 summarize the estimated share of floor space occupied by subsector, as well as the forecasted growth rate of floor space for the MGP and no MGP scenario, respectively. Based on trends in physical building footprints, commercial floor space grows by approximately 16% and 37% between 2010 and 2030 (in the no MGP and MGP scenarios, respectively), driven by growth in the transportation and warehousing, and office subsectors. The amount of floor space for each subsector was inferred from Natural Resources Canada's intensity data for British Columbia and the Territories, and energy consumption data from Statistics Canada.

Table 3: Share of total floor space and annual growth in the commercial sector, by subsector (No MGP Scenario)

Share of Total Floor Space			Average Annual Growth			
	2005		2010-2015	2015-2020	2020-2025	2025-2030
Accommodation and Food Services	3.9%		0.5%	0.7%	0.6%	0.6%
Arts, Entertainment and Recreation	0.2%		0.5%	0.7%	0.6%	0.6%
Educational Services	3.9%		0.5%	0.7%	0.6%	0.6%
Health Care and Social Assistance	10.1%		0.5%	0.7%	0.6%	0.6%
Information and Cultural Industries	14.0%		0.5%	0.7%	0.6%	0.6%
Offices	28.8%		0.5%	0.7%	0.6%	0.6%
Other Services	6.7%		0.5%	0.7%	0.6%	0.6%
Retail Trade	3.2%		0.7%	1.3%	1.0%	1.0%
Transportation and Warehousing	25.1%		0.6%	1.6%	1.1%	1.1%
Wholesale Trade	4.2%		0.7%	1.3%	1.0%	1.0%
Total Commercial	100.0%		0.5%	1.0%	0.7%	0.8%

Table 4: Share of total floor space and annual growth in the commercial sector, by subsector (MGP Scenario)

Share of Total Floor Space			Average Annual Growth			
	2005		2010-2015	2015-2020	2020-2025	2025-2030
Accommodation and Food Services	3.9%		1.6%	2.1%	0.6%	0.6%
Arts, Entertainment and Recreation	0.2%		1.6%	2.1%	0.6%	0.6%
Educational Services	3.9%		1.6%	2.1%	0.6%	0.6%
Health Care and Social Assistance	10.1%		1.6%	2.1%	0.6%	0.6%
Information and Cultural Industries	14.0%		1.6%	2.1%	0.6%	0.6%
Offices	28.8%		1.6%	2.1%	0.6%	0.6%
Other Services	6.7%		1.6%	2.1%	0.6%	0.6%
Retail Trade	3.2%		2.3%	4.3%	1.0%	1.0%
Transportation and Warehousing	25.1%		1.8%	5.2%	1.1%	1.1%
Wholesale Trade	4.2%		2.3%	4.3%	1.0%	1.0%
Total Commercial	100.0%		1.7%	3.1%	0.8%	0.8%

Demand for personal transportation is driven by the growth of population and households. Passenger-kilometres increase from 1.01 billion in 2010 to 1.44 billion in 2030, representing an average annual growth of 2.0%. We do not develop a separate forecast for personal transportation in the MGP scenario due to (1) a lack of data with which to guide such a forecast, and (2) the short-term nature of much of the transportation increase which would be associated with construction activities.

With the development of the MGP, demand for freight transport is expected to increase significantly for the first three years of development, producing a short-term spike in demand that tapers off by the fifth year of development.[5] While demands from the mining, oil and gas sectors dominate freight activity, a portion of freight demand can also be linked to GDP growth in other sectors of the economy, particularly the commercial sector. As a result of GDP growth, activity in the commercial sector is anticipated to increase with the MGP, and hence freight activity is assumed to increase relative to growth in the commercial sector.[6]

Demand for freight transportation is largely driven by growth in commercial/institutional output. In the no MGP scenario, tonne-kilometres increase from 1.53 billion in 2010 to 1.71 billion in 2030; while in the MGP scenario, demand for freight transportation is boosted substantially, reaching 1.88 billion tonne-kilometres in 2020 and 2.11 billion in 2030 (an increase of 24% relative to the no MGP scenario). The average annual growth of tonne-kilometres over the forecast period is 0.5 and 1.3% in the no MGP and MGP scenarios, respectively.

The mineral mining sector is dominated by diamond extraction activities and is important in determining the GHG emissions profile for the NWT. Three diamond mines (EKATI, Diavik and Snap Lake) are currently operational and one (Gahcho Kué) is undergoing environmental assessment. To develop an output forecast for the mining sector, we compiled data on anticipated production levels from all current mines as well as those presently undergoing environmental assessment. The production assumptions for these mines are summarised in Table 5.

Note: It is not the individual project assumptions that are as important as long range totals of mining output in the NWT; many of the specific timeframes and ore throughput parameters for existing and future mines are subject to uncertainty. By developing a list of projects that are reasonably likely to be developed in the future, we are able to derive an estimate of potential future output from the whole industry in the NWT. If future output is lower or higher than what is forecasted here, it is likely that projected emissions and energy use will vary accordingly.

[5] ProLog Canada, 2005, Logistics opportunities and transportation impacts.
[6] Calculation of the MGP impact in the freight sector is a function of GDP impacts on the commercial sector and the relative contributions of GDP from the commercial sector to economy-wide GDP.

Table 5: Summary of project-specific mine production assumptions for 2010-2020

Mine	*Start Year*	*Lifespan*	*End year*	*Million tonnes ore per year*
Existing				
EKATI	1998	25	2020	5.3
Diavik	2003	18	2021	1.6
Snap Lake	2007	20	2027	1.1
Cantung (re-start)	2010	4.2	2014	0.4
Future				
Courageous Lake	**2016**	**15**	**2031**	**9.1**
Gahcho Kué	**2014**	**11**	**2025**	**2.0**
Nechalacho (Thor Lake)	**2014**	**18**	**2032**	**0.7**
NICO	**2013**	**18**	**2031**	**1.5**
Pine Point Pilot Project	**2012**	**1**	**2013**	**1.0**
Prairie Creek	**2012**	**14**	**2026**	**0.4**
Yellowknife Gold Project	**2012**	**7.5**	**2020**	**0.9**

Note: a variety of sources were used to compile this information, including environmental assessment documentation, company websites and the NWT & Nunavut Chamber of Mines, *Mining and Exploration in the Northwest Territories, 2008 Overview.* Where conflicts existed, data from the GNWT were assumed correct.

To account for other possible mining developments in the future, which are likely given the amount of exploration activities being carried out in the NWT, as well as extensions to the life of current or proposed projects, a linear growth of production was assumed from 2020 to 2030 for the sector. The resulting forecast for mining activity increases from 8.3 million tonnes of ore in 2010 to 29.1 million tonnes in 2030. Growth is most pronounced in the period from 2010 to 2015 due to anticipated production from mines presently undergoing environmental assessment.

> We have taken a conservative approach to modeling future mining development. Therefore the assumptions used to develop the mining forecast can be considered an aggressive or optimistic forecast. If future production is lower than what is forecasted in this analysis, it is likely that projected emissions and energy use would be lower as well.

Energy supply sectors

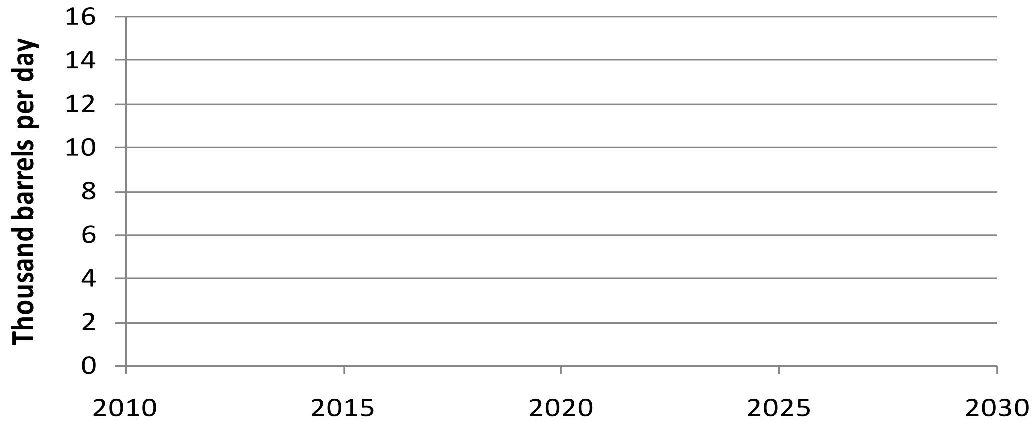
The main energy supply sectors in CIMS include crude oil extraction, natural gas extraction and distribution, and electricity generation. We discuss each of these in turn.

The NWT has abundant petroleum resource potential, with total discovered recoverable oil resources totalling 1.9 billion barrels.[7] Developed oil reserves are located at Norman Wells and Cameron Hills. Figure 1 shows oil output from 2010 to 2030, and is based on the NEB reference case scenario to 2020. For the rest of the period, growth in output is assumed equivalent to average growth between 2000 and 2020. Oil production is

[7] GNWT, 2009, Fact Sheet Northern Canada: Distribution of Ultimate Oil and Gas Resources.

anticipated to decrease over the simulation period, falling from 14.6 thousand barrels per day in 2010 to 5.2 thousand barrels per day in 2030.

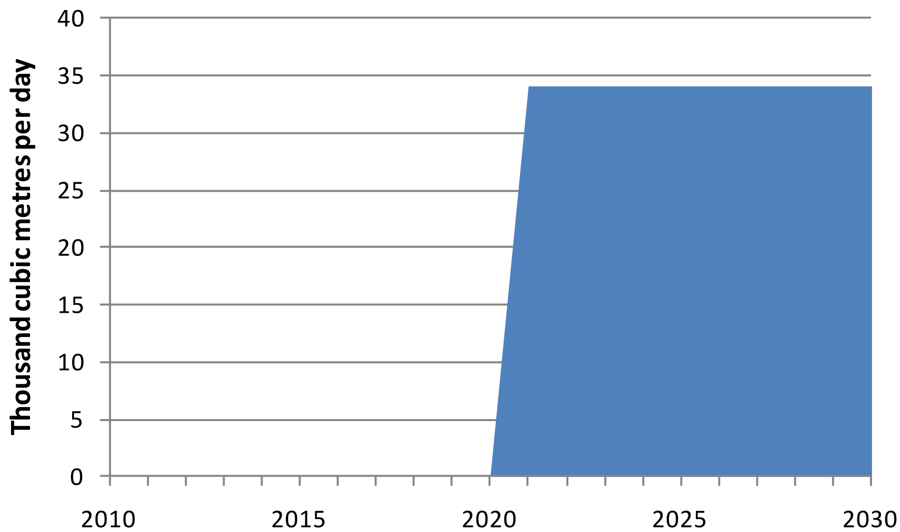
Figure 1: Crude oil supply forecast



Total discovered recoverable natural gas resources in the NWT total 32,727 billion cubic feet. [8] Developed gas reserves are located at Cameron Hills, Fort Liard, Normal Wells and Ikhil, near Inuvik. Natural gas production is also based on the NEB 2009 reference case scenario from 2010 to 2020, and then assumed constant from 2020 to 2030. Constant production during this period aligns with forecasts for output from the Mackenzie Valley Pipeline in the Wright Mansell report (Scenario 2). In the absence of the MGP, natural gas production in the NWT is forecast to decrease from 240 thousand cubic metres per day in 2010 to eight thousand cubic metres per day in 2020. If the MGP proceeds, production is anticipated to begin by 2020, remaining constant at 34 million cubic metres per day throughout the rest of the forecast period (see Figure 2).

[8] GNWT, 2009, Fact Sheet Northern Canada: Distribution of Ultimate Oil and Gas Resources.

Figure 2: Natural gas supply forecast from the Mackenzie Gas Project



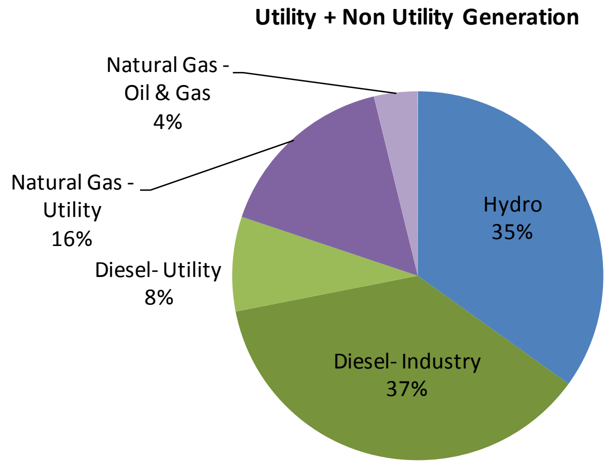
Projected energy demand, regional capacity and physical constraints all determine the supply mix forecast for electricity generation in the Northwest Territories. In CIMS, the forecast for electricity production from the electricity sector includes utility and industry generation (own production from the mining, oil and gas sector). This aggregation facilitated modeling the expansion of the hydro grid and replacement of diesel generation from mining activities in the NWT.

Due to its unique geography, industrial base and population size, electricity generation in the NWT is constrained by access to fuels and community demand. With the exception of Inuvik and Norman Wells, communities in the NWT rely on electricity primarily from either diesel or hydro power. For example, small remote communities such as Nahanni Butte rely on diesel electricity generation because access to other forms of generation such as natural gas is prohibitive, whereas larger communities with access to hydro resources or proximity to the hydro grid, such as Hay River, rely on hydroelectric generation. In Inuvik and Norman Wells a portion of electricity supply is generated from natural gas. Primary supply in Inuvik is generated from three natural gas generators with a combined capacity of 7.7MW.[9]

In 2009, 677GWh of electricity were generated in the NWT.[10] Of that total, approximately 47% of production was utility generated. Figure 3 shows electricity generation in 2009 by fuel for both utility and non-utility generation. In 2009, diesel accounted for 45% of generation (37% from industry and 8% from utility). Hydroelectricity accounted for 35%, while natural gas generation made up the remaining 20% (16% utility and 4% from the oil and gas sector)

[9] In addition to natural gas, Inuvik has approximately 6MW of diesel capacity.
[10] GNWT, *Generation Stats 2008-2010.xls*, email communication, received November 10th, 2010.

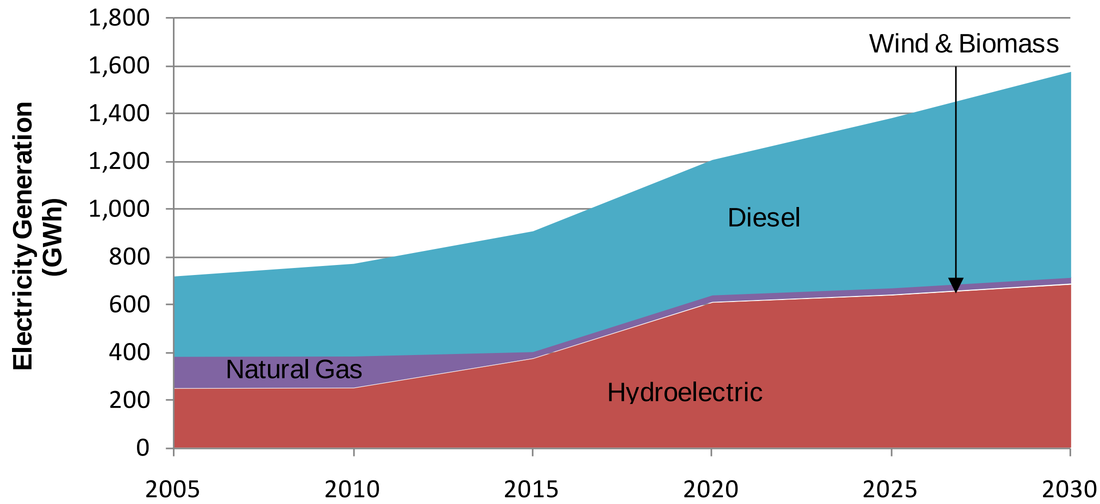
Figure 3: Electricity generation by fuel, 2009[11]



Given anticipated growth in the mining, residential and commercial sectors, electricity demand is projected to grow approximately 104% between 2010 and 2030. Thus, there will be a need to expand generation capacity in the NWT. Figure 4 shows the reference case electricity generation forecast by fuel type. In addition to existing capacity several new projects are anticipated to come on-line over the forecast period. Additions to capacity in the reference case include 56MW of hydroelectricity from the Taltson expansion (2013), 13MW from the Wha ti hydroelectric project in 2025, 300KW of wind energy from the Tuktoyaktuk project (2011), and an additional 300KW of wind power from other wind projects in the Beaufort region by 2020. By 2030 total hydroelectricity generation is 684GWh. In this report, it is assumed that only hydro projects in the later stages of project development are likely to occur within the study timeframe.[12] If future hydro development is greater than what is assumed in this analysis, sector emissions will likely be lower. Diesel accounts for most of the remaining generation (861GWh in 2030), whose increase is driven largely by projected expansion of the mining sector (although some diesel is replaced with hydropower from the Taltson project). Diesel generation also offsets natural gas generation, which is assumed to decline due to reduced gas extraction in Norman Wells.

[11]GNWT, *Generation Stats 2008-2010.xls*, email communication, received November 10th, 2010.
[12] Assumptions for hydro development between 2010 and 2030 were developed in consultation with the Department of Industry, Investment and Tourism of the GNWT.

Figure 4: Reference case electricity generation by fuel type



Note: Figure 4 represents all utility and non-utility generation. Generation calculation is after transmission and distribution losses.

For this study, wood is assumed to produce no net GHGs; we do not explicitly model biomass production because currently the production of pellets occurs outside the NWT. However, it is likely that local production could be established in the NWT within the timeframe of this study.

Energy Price Forecast

Energy prices

CIMS also requires an external forecast for fuel prices. Similar to sectoral output, a policy can change fuel prices if it changes the cost of fuel production. Reference case prices are based on historical energy prices, recently revised GNWT subsidy rates and forecasts from the US Energy Information Administration for refined petroleum products. In some cases, prices are assumed to remain constant in real terms after 2020. Table 6 shows the fuel price forecast that will be used for the reference case forecast.

Forecasting an average price for different energy commodities in the NWT requires a number of steps due to the wide variation in prices among communities. The historic price of refined petroleum products − heating oil, propane, gasoline and diesel − is based on data from the GNWT.[13] Average fuel prices for both residential and commercial consumers reflect regional prices weighted by population and sales data (where

[13] Historical prices for heating oil and propane are from an excel document sent to MKJA by Dan Wong entitled, *Fuel Costs - March 30 2009 Draft*. Historical gasoline and diesel prices (2010) are derived from data from the Public Works and Services, and Industry, Tourism and Investment Departments of the GNWT, as well as data from MJ Ervin & Associates' *Petroleum Price Links*: http://www.mjervin.com/index_files/RelatedLinks.htm.

available). The forecasted price of refined petroleum products reflect the long-run crude oil price used in the 2010 Annual Energy Outlook (AEO 2010), adjusted to reflect the higher costs of these fuels in the NWT.[14] Prices for wood and pellets were provided by the GNWT; average prices represent regional fuel prices weighted by population. Prices for wood and pellets are held constant over the forecast period.

The GNWT recently announced a revised and simplified electricity rate structure and subsidy program, which we assume to remain constant over the forecast period.[15] This structure sets common rates to each of seven zones across the NWT. Residential customers in any zone do not exceed the cost of electricity charged in Yellowknife for the first 600kWh/month in summer and 1000kWh/month in winter. The cost of electricity to commercial customers will not be subsidized under the current plan, although the GNWT intends to implement an energy conservation and efficiency program to help commercial customers reduce their electricity costs.

Several steps were required to calculate an average electricity price under this new regime. First, we calculated the effective electricity rate in each community and/or zone for both residential and commercial customers. For the residential sector, households in the NTPC Norman Wells, NTPC Snare and NUL (NWT) Thermal zones were assumed to have similar usage patterns as those in the NTPC Thermal zones (i.e., 12% of households exceeded 1,000kWh/month in winter). A blended rate was then calculated for each region to account for varying usage patterns, which was weighted by population to produce a single price for the territory. Forecasts of electricity prices, like all other fuels, are in real terms.

Like the other forecasts that are used as inputs to CIMS, the fuel price forecasts adopted here are uncertain, particularly in the longer term. In addition, the fuel price forecasts that we have adopted are intended to reflect long-term trends only, and will not reflect short-term trends caused by temporary supply and demand imbalances.[16]

[14] Energy Information Administration, Annual Energy Outlook 2010, http://www.eia.doe.gov/oiaf/aeo/index.html

[15] GNWT, Efficient, Affordable and Equitable: Creating a Brighter Future for the Northwest Territories' Electricity System, http://www.iti.gov.nt.ca/publications/2010/energy/ElectricityReviewResponseFinalMay13.pdf

[16] Demand for energy can vary significantly on a daily, monthly and yearly basis, but new supply can only be brought into production on a 1-10 year investment horizon, depending on the energy form. This leads to normal short-term imbalances in supply and demand, and significant short-term energy price changes in markets where energy prices are allowed to change in respond to market dynamics. CIMS is designed to represent a 5-year demand and investment horizon, a period representing a normal cycle from "boom to bust and back again."

Table 6: Reference case price forecast for key energy commodities

	Units	2010	2015	2020	2025	2030
Electricity						
Residential	2005¢/kWh	25.07	25.09	25.11	25.13	25.14
Commercial	2005¢/kWh	28.09	27.97	27.85	27.71	27.60
Heating Oil	*2005$ / GJ*					
Residential	*2005$ / GJ*	31.90	38.89	42.11	43.48	44.73
Commercial	*2005$ / GJ*	27.24	34.24	37.45	38.82	40.08
Propane	*2005$ / GJ*					
Residential	*2005$ / GJ*	29.91	36.90	40.11	41.49	42.74
Commercial	*2005$ / GJ*	29.91	36.90	40.11	41.49	42.74
Diesel	*2005$ / GJ*	27.79	34.79	38.00	39.38	40.63
Gasoline	*2005$ / GJ*	32.76	39.75	42.97	44.34	45.59
Wood	*2005$ / GJ*	9.14	9.14	9.14	9.14	9.14
Pellets	*2005$ / GJ*					
Residential	*2005$ / GJ*	17.59	17.59	17.59	17.59	17.59
Commercial	*2005$ / GJ*	15.44	15.44	15.44	15.44	15.44
Crude Oil	*2005$ / Barrel*	83.53	85.87	104.41	112.34	119.57

Note: All prices in Canadian dollars. All prices are in real terms.

Reference case energy and emissions outlook

Employing the economic assumptions highlighted above, we used CIMS to develop an integrated reference case forecast for energy consumption and greenhouse gas emissions through 2030. The CIMS model captures virtually all energy consumption and production in the economy.[17]

The reference case forecast for total energy consumption is shown in Table 7, while Table 8, Table 9 and Table 10 show refined petroleum product, natural gas and natural gas liquids and electricity consumption, respectively. The residual energy consumption of other fuel types (total minus refined petroleum products, natural gas and electricity consumption) is not explicitly shown in this report.

[17] This excludes energy consumption in the construction, forestry and agriculture sectors that is not related to off-road transportation. CIMS also excludes non-energy fuel use.

Table 7: Reference case total primary and secondary energy consumption

	Units	2010	2015	2020	2025	2030
Primary Energy						
Demand Sectors						
Residential	*PJ*	1.3	1.3	1.3	1.3	1.3
Commercial	*PJ*	3.5	3.4	3.4	3.4	3.4
Transportation	*PJ*	10.7	14.5	14.4	15.4	16.6
Mining Sector	*PJ*	1.3	1.7	2.7	3.1	3.5
Supply Sectors						
Electricity Generation	*PJ*	7.0	7.7	9.3	11.2	13.1
Oil and Gas	*PJ*	1.7	1.3	0.9	0.6	0.5
Total	*PJ*	**25.6**	**30.0**	**32.1**	**34.9**	**38.5**
Secondary Energy						
Demand Sectors						
Residential	*PJ*	0.4	0.5	0.5	0.6	0.6
Commercial	*PJ*	0.8	0.8	0.9	0.9	0.9
Transportation	*PJ*	0.0	0.0	0.0	0.0	0.0
Mining Sector	*PJ*	1.0	1.5	2.4	2.9	3.4
Supply Sectors						
Electricity Generation	*PJ*	0.0	0.0	0.0	0.0	0.0
Oil and Gas	*PJ*	0.0	0.0	0.0	0.0	0.0
Total	**PJ**	**2.3**	**2.8**	**3.8**	**4.4**	**5.0**

Note: Producer consumption of energy (e.g., natural gas in the oil and gas extraction sector) is included in these totals. Energy consumption in the electricity generation sector includes consumption of water, wind, and biomass using coefficients adopted from the International Energy Agency.[18] Primary energy represents all energy consumption less electricity consumption.

Table 8: Reference case refined petroleum product consumption

	Units	2010	2015	2020	2025	2030
Demand Sectors						
Residential	*PJ*	0.9	0.9	0.9	0.9	0.9
Commercial	*PJ*	2.1	2.1	2.1	2.0	2.1
Transportation	*PJ*	10.7	14.4	14.3	15.3	16.5
Mining Sector	*PJ*	1.3	1.7	2.7	3.1	3.5
Supply Sectors						
Electricity Generation	*PJ*	4.6	6.1	6.8	8.5	10.3
Oil and Gas	*PJ*	1.3	1.0	0.7	0.4	0.2
Total	***PJ***	**21.0**	**26.2**	**27.4**	**30.2**	**33.5**

[18] International Energy Agency, 2007, "Energy Balances of OECD Countries: 2004-2005". Renewable electricity generation is assumed to require 1 GJ of energy (e.g., wind, hydro) for each GJ of electricity generated.

Table 9: Reference case natural gas and natural gas liquids consumption

	Units	*2010*	*2015*	*2020*	*2025*	*2030*
Demand Sectors						
Residential	*PJ*	0.2	0.3	0.2	0.2	0.1
Commercial	*PJ*	1.4	1.3	1.3	1.3	1.3
Transportation	*PJ*	0.0	0.0	0.0	0.0	0.0
Mining Sector	*PJ*	0.0	0.0	0.0	0.0	0.0
Supply Sectors						
Electricity Generation	*PJ*	1.4	0.3	0.3	0.3	0.3
Oil and Gas	*PJ*	0.1	0.1	0.1	0.1	0.2
Total	***PJ***	**3.2**	**2.0**	**2.0**	**1.9**	**2.0**

Note: This includes propane consumption.

Table 10: Reference case electricity consumption

	Units	*2010*	*2015*	*2020*	*2025*	*2030*
Demand Sectors						
Residential	*PJ*	0.4	0.5	0.5	0.6	0.6
Commercial	*PJ*	0.8	0.8	0.9	0.9	0.9
Transportation	*PJ*	0.0	0.0	0.0	0.0	0.0
Mining Sector	*PJ*	1.0	1.5	2.4	2.9	3.4
Supply Sectors						
Electricity Generation	*PJ*	0.0	0.0	0.0	0.0	0.0
Oil and Gas	*PJ*	0.3	0.2	0.2	0.1	0.1
Total	***PJ***	**2.6**	**3.0**	**4.0**	**4.5**	**5.1**

Note: Electricity consumption in the mining sector reflects a "net" value, i.e. consumption less own generation from diesel.

Table 11 shows greenhouse gas emission in the reference case. Emissions rise steadily over the forecast period, with greater growth experienced in the first half of the simulation period. By 2030, emissions reach 2,587 Kt CO_2e, an increase of 50% above 2010 levels. Note that emissions from the mining, oil and gas sectors include emissions from combustion and process emissions, but do not include emissions from power generation (these are accounted for in the electricity generation sector) or off-road vehicles. Emissions from the transportation sector include emissions from personal, freight and off-road transportation.

Table 11: Reference case greenhouse gas emissions

	Units	*2010*	*2015*	*2020*	*2025*	*2030*
Demand Sectors						
Residential	*Kt CO2e*	81	79	78	77	74
Commercial	*Kt CO2e*	228	222	221	215	219
Transportation	*Kt CO2e*	764	1,031	1,022	1,089	1,178
Mining Sector	*Kt CO2e*	94	126	192	221	252
Supply Sectors						
Electricity Generation	*Kt CO2e*	442	498	556	694	835
Oil and Gas	*Kt CO2e*	115	87	63	41	28
Total	***Kt CO2e***	**1,725**	**2,043**	**2,133**	**2,337**	**2,587**

Note: CIMS emissions do not include land use changes or emissions of halocarbon and SF_6.

Discussion

Despite anticipated growth in the building sector, energy consumption remains fairly stable over the simulation period due to improvements in energy intensity. Energy intensity (measured as GJ Space Heating / m^2 floor space) improves by 18% and 21% in the residential and commercial sectors over the simulation period, respectively. Similarly, the emissions intensity of the sector (measured as tCO_2e Space Heating / m^2 floor space) improves as well – by 22% and 21%, in the residential and commercial sectors, respectively.

In the personal transportation sector, energy consumption and emissions do not vary substantially, growing only 8% and 4% respectively, over the forecast period. Between 2010 and 2030, vehicle energy and emissions intensity in the sector improve substantially as households respond to the vehicle emissions standard and purchase more efficient vehicles. As a result, emissions in the sector grow an average of 0.2% a year, in contrast to the average annual growth of travel demand which is 2.0%. Unlike personal transportation, energy consumption and emissions in the freight transportation sector almost double (65%) over the forecast period in response to anticipated demand for off-road transportation in the mining sector.

Mining production is projected to increase substantially in the first half of the simulation period as new projects are anticipated to come online, increasing energy consumption and emissions. Emissions growth is the greatest between 2010 and 2015 − approximately 34%. After 2015, emissions growth slows as production stabilizes.

The region's electricity sector has fairly high GHG emissions intensity because of its extensive use of diesel power – 0.57 t CO_2e/MWh in 2010. Due to increased renewable capacity (mainly hydroelectricity), the GHG intensity of the sector falls slightly over the simulation period to 0.53 t CO_2e/MWh in 2030.

Energy consumption and GHG emissions in the oil and gas sector are linked to the number of fields in operation and the activity in those fields. Production in the natural gas sector is expected to drop significantly after 2015. Consequently, sectoral energy and emissions forecasts for 2020 to 2030 largely reflect activity in the crude extraction sector.

Discussion of Reference Case Emissions Forecast

According to Environment Canada's National Inventory Report (2008), GHG emissions in the NWT in 2005 were 1,372kt CO_2e (excluding the waste, agriculture and other manufacturing sectors). Table 12 summarizes these emissions in each sector, and compares them with the emissions forecast by CIMS in that year. Emissions from CIMS are 244kt CO_2e, or 18% higher. This difference is predominantly due to variation in the commercial/institutional and electricity sectors, which is discussed below.

Table 12: Comparison of 2005 greenhouse gas emissions by sector (kt CO2e)

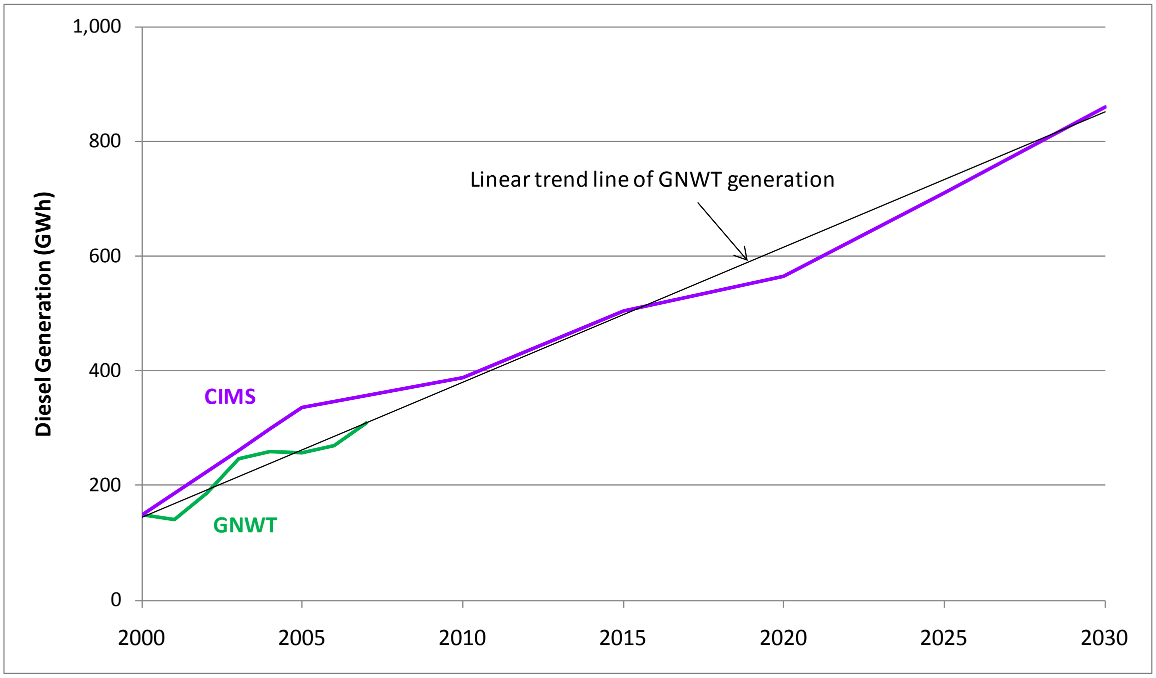
	NIR	*CIMS*
Residential	83	84
Commercial & Institutional	147	237
Transportation	662	671
Electricity Generation	260	393
Mining, oil & gas	220	230
Mining		*71*
Crude and Natural Gas Extraction		*159*

Notes: NIR- Environment Canada's National Inventory Report. Non utility electricity generation is included in the electricity generation sector. Off-road transportation associated with mining is included in the transportation sector.

First, a discrepancy exists between the emissions data of the NIR and Statistics Canada's Report on Energy Supply and Demand for the commercial/institutional sector in the NWT. Applying standard emission coefficients to the Statistics Canada energy consumption data implies that GHG emissions for the commercial sector should be around 272 kt CO_2e in 2005, 125 kt higher than that reported by the NIR. Given this discrepancy and the greater accuracy of the fuel consumption data, the commercial sector in CIMS is calibrated to Statistics Canada data.

Second, a discrepancy exists between emissions reported by the NIR and emissions produced with the CIMS model for the electricity sector in 2005. However, emissions fluctuate over time and comparing emissions in a single year is not always the best indicator of a model's robustness. In the NWT, emissions in the electricity sector vary substantially over time and are influenced to a large extent by diesel power demanded by major resource extraction activities that can begin or cease operations over a short period of time. Our analysis is focused on long term trends (5+ years) and does not fully capture shorter term fluctuations (<5 years) in both emissions and generation. As such, it is more important to ensure that the direction and magnitude of the trend aligns with historic data rather than necessarily matching up a specific year. As illustrated in Figure 5 the CIMS model aligns with the long term trends in diesel generation despite being somewhat higher in 2005.

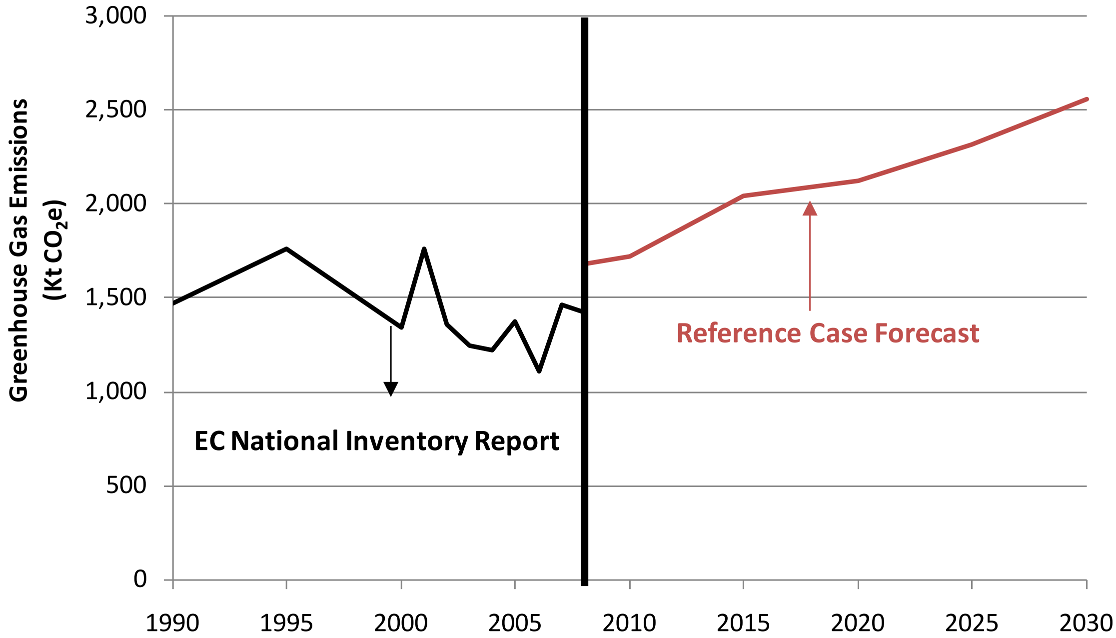
Figure 5: Historical and forecasted diesel generation



Note: Generation data provided to MKJA by the GNWT.

Figure 6 displays historic − from the NIR− and forecast reference case GHG emissions − from CIMS − in the NWT. As shown in this figure, the anticipated trend is for emissions to increase over the entire forecast period, which is largely driven by anticipated expansion of the mining sector.

Figure 6: Northwest Territories reference case greenhouse gas emissions



Policies Included in the Reference Case

The following existing and proposed policy measures have been included in the reference case:

- **Revision to the residential building code.** After 2010, all new residential buildings must achieve EnerGuide 80. (Note: This regulation only applies to new buildings within the City of Yellowknife and new GNWT Housing Corporation buildings.**)**
- **Revision to the commercial building code.** After 2010, all new commercial buildings must be 25% more energy efficient than buildings built to the current specifications of the Model National Energy Code of Canada for Buildings. (Note: This regulation only applies to GNWT facilities.)
- **National vehicle emission standard.** Model year 2012 to 2016 passenger vehicles must meet an average GHG target of 250 grams CO_2/mile (equivalent to 35.5 miles per gallon) by 2016.
- **The Energy Efficiency Incentive Program (EEIP).** The EEIP offers rebates to NWT residents, businesses and non-profit organizations for the purchase of high efficiency equipment/appliances (e.g., oil furnace 92% efficiency).

Regional Variation

Communities in the NWT vary widely in terms of energy infrastructure, access to energy sources and energy prices. MKJA has undertaken a number of measures to ensure that important regional variations are accounted for in the analysis while using a single-region modelling framework. Representing this variation is not only important for developing the reference case, but also for measuring the responsiveness of households and firms to climate policy. In particular, we have included a number of constraints in each sector to reflect regional limits in terms of infrastructure and availability of energy carriers. This is reflected both in the reference case and the policy analysis. Although the policy analysis does not describe the policy response for particular communities or facilities, it represents the combined response of all communities and facilities in the territories. For example, a carbon tax is likely to increase the cost of energy. Households with access to cheaper clean electricity such as hydro may respond to the tax by replacing fossil fuel consumption with electricity consumption; however, households that do not have access to cheaper clean electricity may respond by to the tax purchasing more energy efficient equipment. In this example, modelled constraints − regional constraints related to energy infrastructure, access and price − are combined to describe the likely responsiveness of households in a heterogeneous market. Future analysis could be conducted to provide regionally-disaggregated data if desired.

Quantitative Policy Analysis

The following analysis explores the magnitude of emissions reductions achieved by carbon price scenarios combined with regulatory policies. The carbon price scenarios modelled in this analysis simulate territorial emissions under a given strength of a market-based policy. The emissions prices modelled here are roughly equivalent to an economy-wide tax on GHG emissions or the price of permits in an economy-wide cap and trade system. While this study does simulate the impact of carbon prices, it does not address issues related to system design, such as revenue allocation. These issues will be discussed in a subsequent section (the GEEM macroeconomic analysis). To account for the potential development of the Mackenzie Gas Project (MPG), each carbon price is simulated with and without the MGP.

This section begins with an introduction to the general CIMS methodology, and a discussion on the specific methodology and major assumptions used in this study. Following this discussion, we present the results from the quantitative analysis, describing how policy scenarios affect territorial and sector emissions. In this analysis, wedge diagrams are used to identify the key abatement actions taken in each policy scenario. Next, we discuss how the policy scenarios affect key energy and economic indicators. The energy indicators include changes to energy intensity and greenhouse gas emissions by sector and changes to emissions from the electricity sector. The economic indicators include changes to capital costs, household energy costs, transportation energy costs, and electricity cost of production.

Methodology

The CIMS model

This analysis uses the CIMS energy-economy model to estimate the impacts of carbon pricing in the NWT. The CIMS model is a technologically explicit energy-economy model that captures equilibrium feedbacks for the supply and demand of energy. As mentioned in the reference case section, CIMS requires external inputs – forecasted demand for products, services and energy prices. These drivers determine the processes, technologies and energy required to meet demand, enabling CIMS to produce territorial and sector emissions forecasts.

The CIMS model is well suited for this analysis because of its disaggregated sector structure and technologically explicit framework. CIMS models all the major energy supply and demand sectors in the economy as well as the main processes within those sectors (where demand for each process is satisfied by current and emerging technologies). The model captures virtually all emissions, energy consumption and energy production in the economy; thus, it is well positioned to provide a realistic forecast of abatement opportunities in the Territories.[19] The following discussion

[19] This excludes non-vehicle energy consumption and emissions in the construction, forestry and agriculture sectors as well as energy commodities used as refinery or chemical feedstock.

highlights the strengths and limitations of the CIMS model. A more detailed description of the model is provided as an appendix to this report (Appendix B: CIMS and GEEM).

The main advantages of CIMS are:

- **CIMS accounts for non-linearities in emissions abatement.** Many models simulate abatement using elasticities of substitution or linear functions that represent how firms can change their inputs while maintaining a given level of production. For example, computable general equilibrium models use elasticities to show how firms may switch from refined petroleum products to electricity, or how they can increase capital consumption to reduce energy consumption. The result is that the abatement from these models is relatively linear as a function of an emissions price. Rather than using elasticities or linear functions to represent abatement, CIMS simulates a competition between technologies (e.g., an oil furnace vs. a ground source heat pump) that provide the same service (i.e., space heating). The result is that some abatement technologies may be uncompetitive until an emissions price reaches a specific threshold (e.g., plug-in electric vehicles), at which point the sector undertakes a significant amount of abatement.
- **CIMS is technologically detailed.** Every sector requires several services and processes to function. For example, natural gas extraction requires a combination of drilling, extraction, and processing services to produce natural gas. For each service and process required, CIMS allows a suite of technologies to compete to fulfil the particular service or process needs of the sector. For example, low efficiency diesel, high efficiency diesel and biodiesel trucks may compete to provide freight trucking services to the freight transportation sector. CIMS represents each of the major processes/services and associated technologies, whereas the other modelling approaches represent the sector as a single production unit.
- **CIMS produces detailed policy impacts.** Because of the level of detail in the CIMS model it is possible to separate the impacts of policies on each sector. For example, CIMS describes the changes in energy intensity of space heating in the commercial sector (GJ / m2 floor space), or the changes in average vehicle fuel price (2005¢ / L gasoline eq.) that are produced when policies are implemented.

The limitations of CIMS are:

- **CIMS does not account for economic activity unrelated to energy consumption or greenhouse gas emissions.** The CIMS model accounts for the energy and emissions intensive portion of the economy, but does not account for other economic activity. For example, the CIMS model accounts for a household's costs related to energy consumption (e.g., light bulbs), but does not account for other household expenses. Therefore, CIMS does not estimate how a change in expenditures on energy or capital related to energy consumption might affect other household expenditures. However, supplemental analysis with our in-house general equilibrium model, GEEM, provides an estimate of policy impacts on these broader economic structures.

- **This modelling analysis provides an integrated forecast showing how archetypical sectors are likely to respond to carbon pricing but does not contain data obtained from consultation with individual industries or communities**. As such, the results may not reflect abatement opportunities at specific facilities or in specific communities.
- **CIMS includes all utility and industry generation in the electricity sector in the NWT.** By combining all generation, supply mix changes in either utility or industry generation affect total generation in the electricity sector (cost of production and electricity prices). Any change to the average cost of electricity generation, resulting from the policy scenarios, influence abatement choices throughout the entire economy. Also, because CIMS NWT is a one region model, results reflect regional averages. For the purposes of this study, average electricity prices are assumed to be insensitive to the development scenario.

Modelling scenarios

The goal of this study is to examine how various strengths of carbon pricing will reduce emissions and impact households and firms in the NWT. This analysis explores a variety of potential carbon price paths and two future development scenarios, and examines how these two development scenarios interact with climate policy.

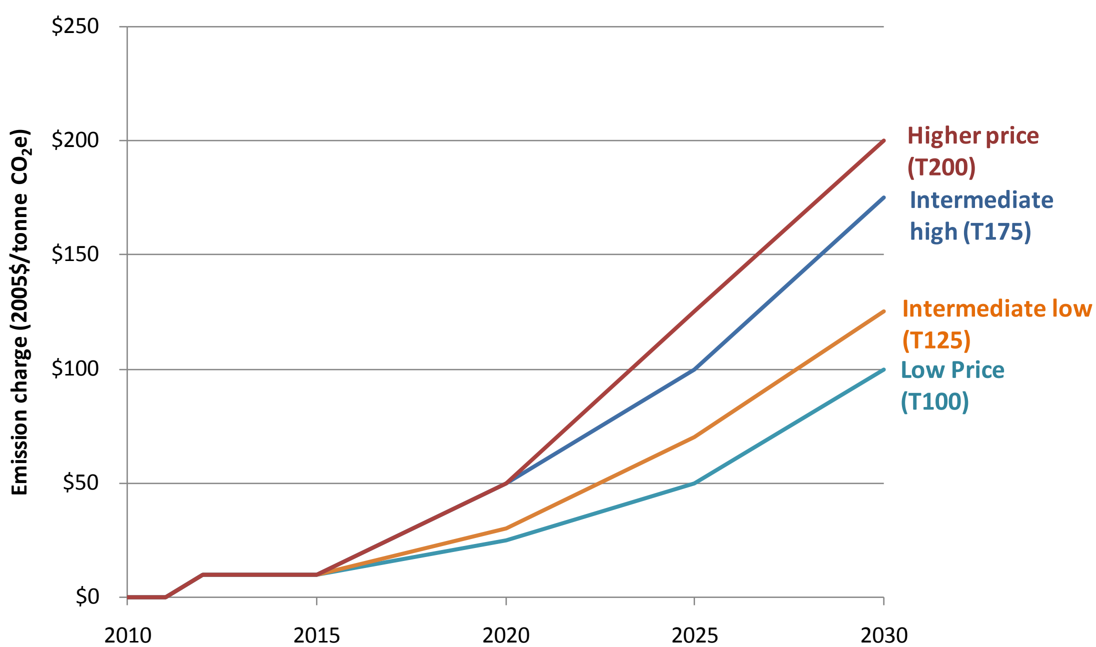
The carbon pricing scenarios selected for this study were determined through consultation with the GNWT. However, the price paths presented below do not represent the Government's policy position on future carbon pricing in the region. Carbon pricing scenarios begin in 2012 and increase over the simulation period, ending in 2030. Four carbon price pathways (lower, intermediate-low, intermediate-high, higher) and two development scenarios (MPG is not developed and MGP is developed) are modelled (Table 13). In all scenarios the carbon price starts at \$10/t CO_2e, rising slowly between 2012 and 2020 and increasing more rapidly between 2020 and 2030 (Figure 7). Exploring several carbon pricing and development scenarios reveals the range of emissions reductions that can be achieved as the strength of climate policies change.

Note: *Table 13 indicates the policy code associated with each policy scenario modelled in this analysis. Reference to policy scenarios hereafter will refer to policy codes only (i.e., T125).*

Table 13: Carbon price paths of the policy scenarios

		2012-2015	2016-2020	2021-2025	2026-2030
Policy Scenario	*Policy Code*	*Emissions Charges 2005$ / tonne*			
MGP is NOT developed					
Lower price	T100	$10	$25	$50	$100
Intermediate price Low	T125	$10	$30	$70	$125
Intermediate price High	T175	$10	$50	$100	$175
Higher price	T200	$10	$50	$125	$200
MGP is developed					
Lower price	MGP_T100	$10	$25	$50	$100
Intermediate price Low	MGP_T125	$10	$30	$70	$125
Intermediate price High	MGP_T175	$10	$50	$100	$175
Higher price	MGP_T200	$10	$50	$125	$200

Figure 7: Carbon Price Pathways



Policy analysis modelling assumptions

The analysis is carried out under several key assumptions, including:

- Carbon pricing scenarios are simulated by applying 'shadow prices' to all technology choice decisions in the CIMS model. Shadow prices are equivalent to the value of a carbon tax. A shadow price reveals the strength of the carbon price policy necessary to reach a given level of emissions.
- The analysis in this report is aimed at understanding the potential for reducing territorial greenhouse gas emissions. As a result, we restrict the analysis to

domestic greenhouse gas reductions. We assume all other regions in North America have implemented similar policy signals and we allow no purchases of carbon offsets between sectors and regions of Canada or internationally.

- The sectors modelled in this study are representative of the economy of the NWT. This study identifies potential abatement opportunities in the economy, but does not reflect current or future abatement activity at the project level or community level (i.e., abatement from a specific mining development or crude extraction operation). While we strive for accuracy, a model of an archetypical sector can never be as accurate as a techno-economic assessment of the abatement potential at a specific facility or in a specific community.
- Due to economic and technical constraints, abatement from carbon capture and storage technologies is not included in this analysis.
- Carbon pricing does not change the world price for natural gas or crude oil (Canada is assumed to be a price taker), nor does it impact output and production in the NWT.
- Biodiesel has been made available as an abatement option in the transportation and mining sectors. However, constraints have been established to ensure that large-scale adoption of the fuel does not occur, reflecting the feasibility of bio-fuels in the regions (i.e., harsh winter temperatures and limited access to fuels are likely to limit biodiesel use in the region).
- Electricity sector supply options are constrained based on the geography, remoteness and size of many communities in the NWT. The primary supply options include diesel, hydroelectricity (which is further constrained by assumptions related feasibility) and natural gas (supply largely depends on the development of the MGP). Renewable generation from wind, geothermal and biomass is also considered.

Mackenzie Gas Project Modelling assumptions – Scenario Analysis

The scenario analysis is carried out under several key assumptions (a more detailed description of MGP scenario assumptions is provided in Appendix A), including:

- Production from the MGP is assumed to start in 2020 at 34 million cubic metres per day (based on the National Energy Board (NEB) 2009 reference case scenario to 2020 and Scenario 2 of the Wright Mansell Report[20]) and remain constant over the simulation period.[21] Although the development of the MGP will likely spur further exploration and drilling of new wells (beyond that considered by the

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[20] NEB, 2009, 2009 Reference Case Scenario: Canadian Energy Demand and Supply to 2020 - An Energy Market Assessment. Wright Mansell Research Ltd, 2007, An evaluation of the economic impacts associated with the Mackenzie Valley gas pipeline and Mackenzie Delta gas development.

[21] Note: Our analysis assumes the production levels presented in the NEB (2009) reference case, 34 Mm3/d (1.2bcf), which is equal to the capacity of the pipeline. It assumes that other known and discovered reserves will contribute to production over the lifetime of the MGP.

NEB), we assume production from any such wells will not begin prior to 2030 (the end of our forecast period).

- Upstream emissions are calibrated to data from the 2007 Pembina analysis[22] – approximately 1.6 Mt CO_2e per year with production at 34 million cubic metres per day.[23]
- Based on analysis from the Wright Mansell report, we assume GDP increases by $ 1.9 million annually (2005$) − 53% greater than the non MPG scenario. GDP impacts are based on a long-run price of natural gas of $6 (2006$ USD).[24]
- This analysis excludes short-term activity impacts (<5 years) associated with the project's construction (e.g., temporary increases in employment and construction freight activity).
- Three communities (Tulita, Fort Good Hope and Fort Simpson) are assumed to convert to natural gas for electricity generation and heating. Conversion rates and technological assumptions are based on the Encore *McKenzie Valley Gas Conversion Feasibility Study* (2008).[25] Installation of natural gas generation capacity is assumed to occur immediately upon opening of the MGP in 2020, while installation of heating technologies is assumed to occur when existing units meet the end of their lifespan.
- Downstream impacts of the MGP (i.e., natural gas conversion for electricity generation in the three communities noted above) is restricted to domestic impacts only. While we acknowledge that the development of the MGP is likely to have downstream impacts (i.e., potential emissions reductions benefits) in other North American regions, it is beyond the scope of this study.

Quantitative Analysis of Carbon Pricing Scenarios

This section contains the quantitative analysis of eight carbon pricing scenarios, showing how they affect emissions in the NWT. The analysis identifies the specific impacts policies have on each sector in the economy, namely how carbon pricing changes the energy intensity and emissions of each sector, and how it changes energy related costs for households, transportation and electricity production, as well as mining, oil and gas production.

Effect of carbon pricing on territorial emissions

In total, eight policy scenarios – two sets of carbon pricing scenarios under two different development scenarios – are modelled in CIMS. For this analysis all policies are compared to a reference case (REF) that assumes the MGP is not developed. The MGP

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[22] Pembina, 2007, Mackenzie Gas Project Greenhouse Gas Analysis.
[23] Note: Emissions associated with the MGP scenario include all combustion and process emissions in the natural gas sector, as well as a portion of emissions from the electricity sector.
[24] The Wright Mansell Report (2007) Case #2 assumes that the price of natural gas remains constant (in real terms) at $6/Mcf.
[25] Encore, 2008, McKenzie Valley Gas Conversion Feasibility Study.

development is likely to have a significant impact on the economy, energy use, fuel availability and emissions of the region. Production from the MGP and its impacts – demand changes in the commercial and freight transportation sector, and natural gas conversions in the buildings and electricity sectors – are modelled as a policy scenario. Modelling the MGP as policy scenario facilitates the evaluation the project's impact on the territories. As illustrated in Figure 8, the development of the MGP could have a substantial affect on emissions in the Territories. In the absence of climate policy, emissions are projected to rise steadily after 2020 reaching 4.4 Mt CO_2e in 2030 with the development of the MGP, approximately 72% greater than reference case emissions in that year. While a portion of this growth can be attributed to increased demand from the commercial and freight sectors due to indirect economic impacts, the majority is directly linked to natural gas production from the MGP – an average of 1.6 Mt CO_2e annually when operating at full capacity.[26]

Figure 8: Greenhouse gas emissions in the absence of climate policy

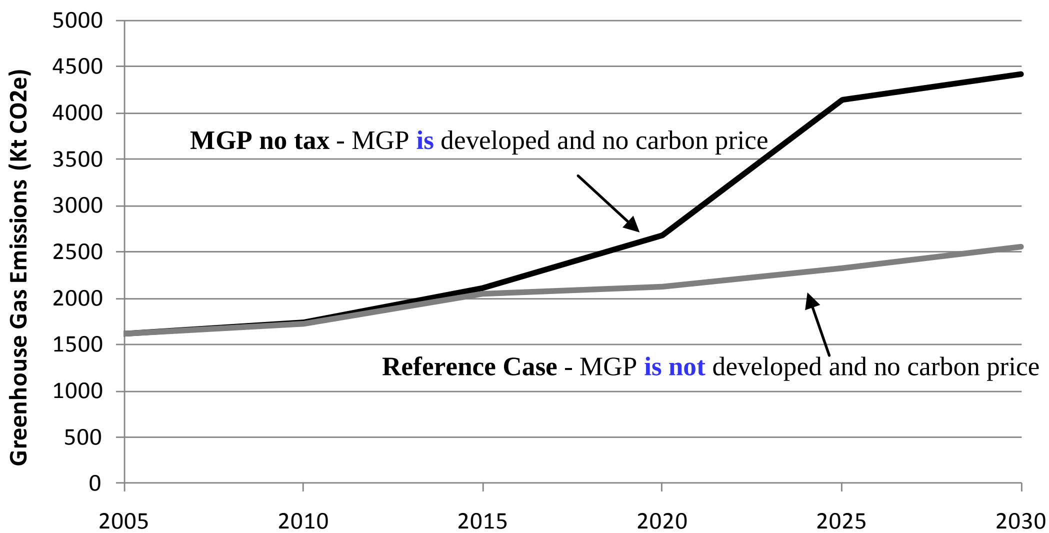


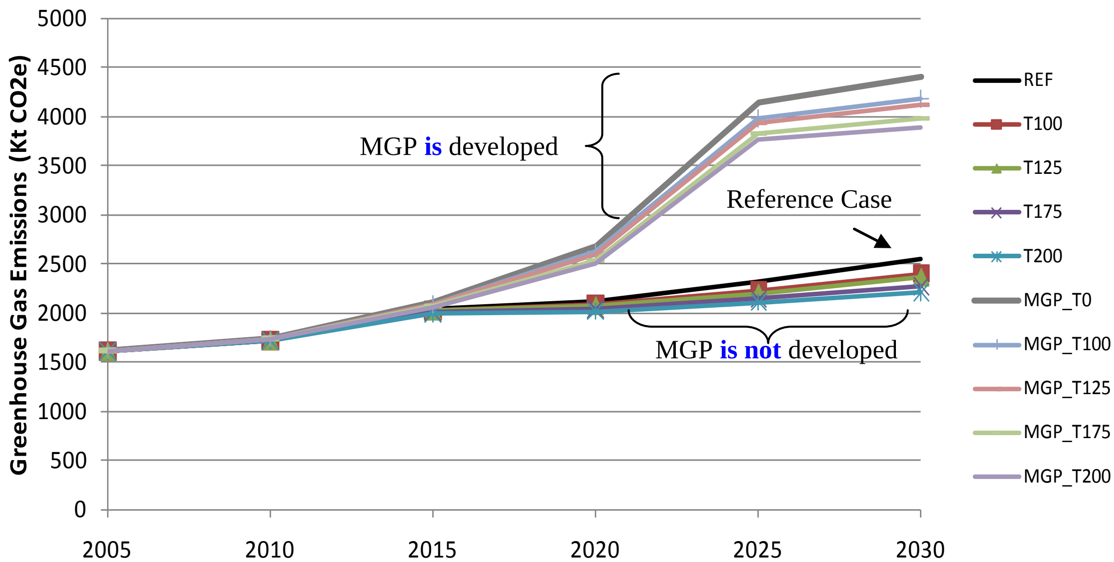
Figure 9 shows the forecasted greenhouse gas emissions in each policy scenario. The effect of the policies modelled in scenarios where the MGP is assumed to not be developed range from emissions reductions of approximately 6% to 13% relative to the reference case by 2030. In scenarios where MPG is developed and an emissions charge is in place, emissions increase by approximately 52% to 63%, relative to the reference case in 2030. Projected emissions are significantly lower at each carbon price level in simulations that do not include the development of the MGP. While the MGP increases emissions, carbon pricing is likely to mitigate some of the potential impacts of the project (relative to a scenario with no carbon pricing). In scenarios with the MGP, emissions are approximately 5% to 12% lower with carbon pricing.

[26] Includes all combustion and process emissions in the natural gas sector, as well as a portion of emissions produced in the electricity sector.

This analysis reveals that emissions are significantly lower and total abatement is considerably greater under the assumption that the MGP is not developed, but that carbon pricing could reduce the magnitude of increase in total emissions in the MGP scenario.

Note: Due to the timing of the MGP development (assumed to begin in 2020) and the modeled carbon charges (starting in 2012 at $10/t and rising over time); carbon policy will likely affect technology choice at the onset of the project's development. In a carbon constrained environment it is likely that abatement technologies such as high efficiency equipment would be considered "base case" technologies. However for this analysis we compare all policy scenarios to a reference case that assumes no MGP; therefore, any deviation from that is considered a policy effect.

Figure 9: Greenhouse gas emissions in each policy scenario



Note: In this graph and those that follow, the reference case scenario will be referred to as REF, and the no carbon price MGP scenario will be referred to as MGP_T0.

Table 14 shows total emissions by sector for the eight policy scenarios. In the no-MPG scenario, the majority of reductions are concentrated in the electricity and transportation sectors. In 2030, these sectors account for approximately 78% of territorial greenhouse gas emissions in the reference case and in carbon pricing scenarios that assume no MGP. In the MGP development scenarios, emissions from these sectors account for approximately 61% of territorial emissions, while emissions from the natural gas sector are 25%.[27]

With the exception of the commercial, freight and natural gas sectors, abatement potential in all sectors of the economy is not greatly affected by the MGP development assumption. In fact, abatement in the residential sector is slightly greater in the MGP scenario due to natural gas availability (at lower emission charges). While emissions

[27] This does not include emissions from power generation associated with the MGP.

from the commercial, freight and transportation sector increase relative to the reference case, emissions growth is slowed with carbon policy.

In both development scenarios, abatement in the economy is partially constrained by access to fuel, as fuel options in certain communities (mainly for electricity generation and space heating) are limited − often to only refined petroleum products − even when faced with fairly high carbon prices. However, in communities where access to a wider range of fuels such as natural gas, wood, or hydroelectricity, possible abatement from fuel switching is significant (e.g. replacing diesel generation with hydro electricity or wind).

Table 14: Greenhouse gas emissions, by sector in 2030

	No MGP				
	Reference	***T100***	***T125***	***T175***	***T200***
Demand Sectors		*Kt CO_2e*			
Residential	74	68	66	62	59
Commercial	219	210	207	198	194
Transportation Personal	141	134	132	128	126
Transportation Freight	1,037	1,016	1,005	966	936
Mineral Mining	252	223	215	199	191
Total Demand Sectors	1,723	1,652	1,625	1,554	1,506
Supply Sectors					
Electricity	835	754	740	719	710
Oil and Gas	28	28	28	27	27
Total Supply Sectors	863	782	767	746	737
Total Territories	**2,587**	**2,434**	**2,392**	**2,300**	**2,243**

	MGP				
	MGP_T0	***MGP_T100***	***MGP_T125***	***MGP_T175***	***MGP_T200***
Demand Sectors		*Kt CO_2e*			
Residential	73	67	65	61	59
Commercial	269	260	256	247	242
Transportation Personal	141	134	132	128	126
Transportation Freight	1,279	1,248	1,229	1,170	1,125
Mineral Mining	252	223	215	199	191
Total Demand Sectors	2,015	1,932	1,898	1,806	1,743
Supply Sectors					
Electricity	1,305	1,203	1,185	1,159	1,148
Oil and Gas	1,122	1,075	1,064	1,041	1,030
Total Supply Sectors	2,427	2,278	2,249	2,199	2,178
Total Territory	**4,443**	**4,210**	**4,146**	**4,005**	**3,922**

Greenhouse gas reduction "wedge" diagrams

A wedge diagram is a graphical representation of the relative contribution of different actions towards reducing total GHG emissions from their business as usual trend, or reference case. Wedge diagrams show the abatement actions that result from the implementation of policies, such as a carbon tax, reflecting abatement activity over the time (in this study the period covered is 2010 to 2030).

The wedge diagrams generated with CIMS estimate the response of households and firms to each of the carbon pricing scenarios that are modelled. Because CIMS is an integrated model in which firm and consumer behaviour has an empirical basis, the results account for preferences and behaviour, the relative cost of different actions, and the interaction of actions (e.g., the interaction of a building code with residential appliance subsidies).

Figure 10 illustrates a standard wedge diagram and shows abatement with a carbon price that starts off at \$10/tCO_2e in 2012 and rises to \$175/tCO_2e by 2030, scenario T175. The top of the stack of wedges reflects the reference case greenhouse gas emissions. Each wedge below corresponds to reductions of greenhouse gas emissions that result from abatement activity in the economy, with the exception of the policy emissions wedge. The policy emissions wedge represents the emissions that remain after the policies are implemented. Abatement activity is classified into two main categories: fuel switching and energy efficiency. Fuel switching can be further broken down into emissions reductions from replacing emissions intensive fuels like heating oil and diesel, with renewables (e.g., biomass and hydro), electricity and lower emissions fuels (e.g., natural gas).

Figure 10: Wedge diagram for T175

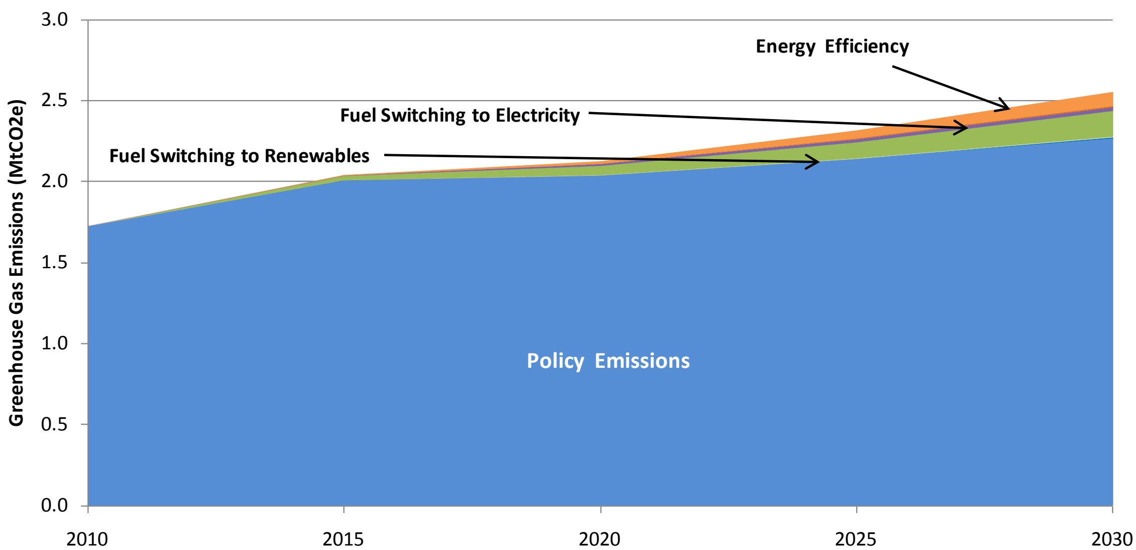
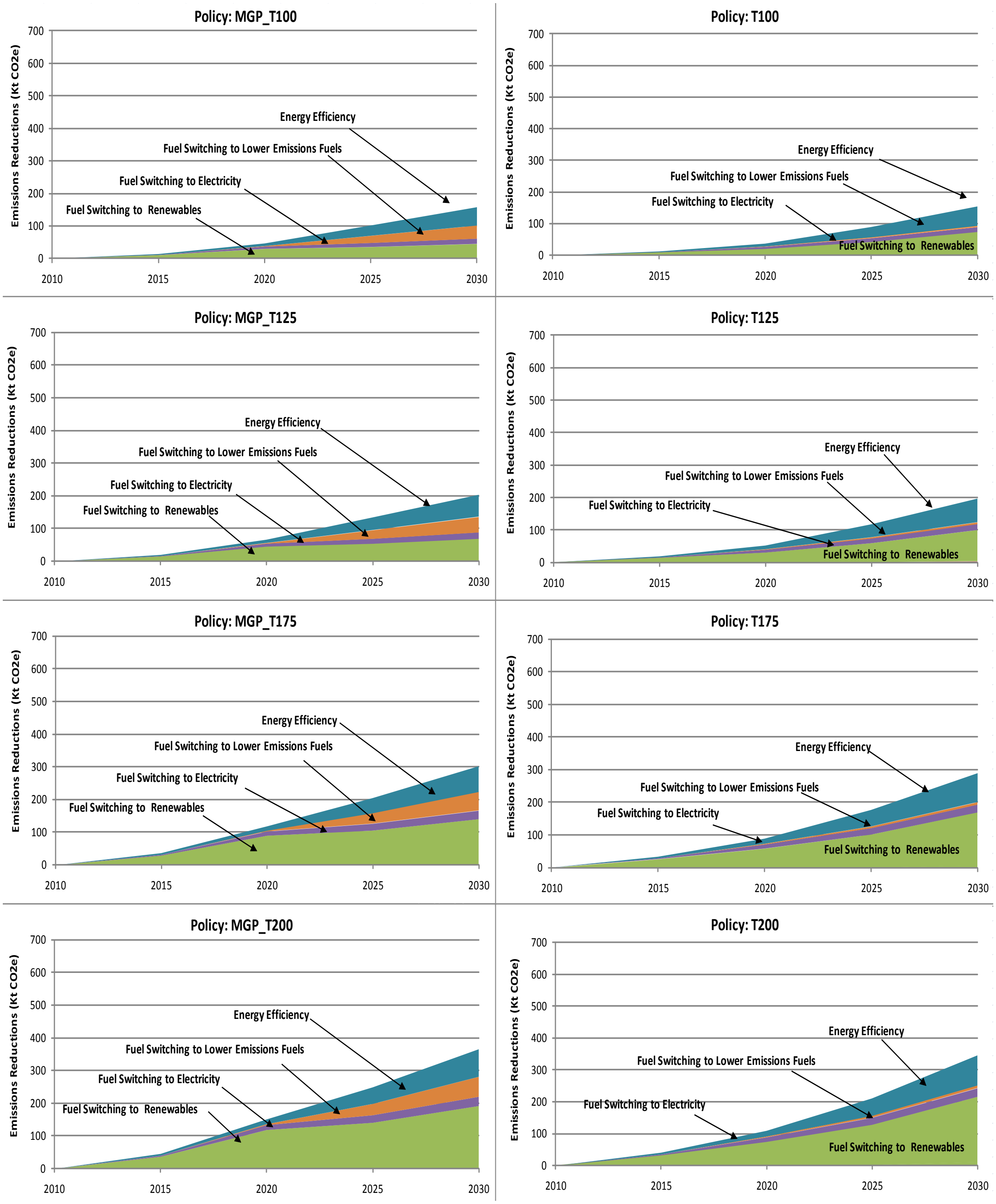


Figure 11 illustrates the wedges corresponding only to abatement actions in each policy scenario and omits the final greenhouse gas emissions after the policy has been applied (policy emissions wedge). The size of each wedge reflects the amount of abatement achieved in each scenario, which is a function of the policy strength and development assumption. To illustrate the relative abatement potential of each development scenario, we present two distinct analyses below: an analysis with the no MGP policy scenarios and an analysis with the MGP policy scenarios (see Appendix C: Reference Case Wedge Diagrams for wedge diagrams of T0). Wedge diagrams in the no MGP analysis reflect abatement relative to the reference case, and wedge diagrams in the MGP scenario reflect abatement relative to a scenario that assumes MGP and no carbon policy (MGP_T0). For each carbon price, the sizes of the wedge diagrams are fairly similar in both development scenarios indicating the effectiveness of the carbon policy. However the relative contributions of each wedge to the total are not similar, as levels of abatement and action taken in each sector differ greatly. For example, in the no MGP scenarios energy efficiency and fuel switching to renewables generate the majority of abatement in the economy mainly from activity in the electricity and transportation sectors; fuel switching to electricity and lower emissions fuels contributing very little. However, in the MGP scenario fuel switching to lower emissions fuels becomes a fairly significant abatement action in the electricity and natural gas sectors.

Note: Because the analysis compares the MGP scenarios with carbon policies against a MGP scenario that assumes no policy, MGP_T0, the emissions impact from changes in output (i.e., increased natural gas production, and commercial and freight demand associated the MGP) relative to the reference case have been netted out. When compared to the reference case, changes in output induce negative abatement, meaning that emissions in the MGP scenarios are higher because of increases in output.

Figure 11: Greenhouse gas reduction wedge diagrams for all policy scenarios



Effect of carbon pricing on energy and emissions indicators

To achieve abatement similar to that illustrated above, a variety of actions in each sector can be taken to reduce emissions. Consumers and firms will make different decisions depending on the carbon price they face. Likewise, in this quantitative policy analysis, varying abatement actions are used in response to each policy scenario. The effect of the policy scenarios can be further understood by exploring how they change key energy and emissions indicators. Specifically, this section highlights how the policy scenarios change the energy and emissions intensity of residential space heating, commercial space heating, personal vehicles, and freight travel. This section also covers the mining, oil and gas, and electricity sectors. However, because of the diverse nature of the industrial and energy supply sectors, we primarily discuss changes to total energy consumption and emissions rather than changes to intensities.

Residential and commercial

In the residential and commercial sectors, space heating technologies account for over 50% of total energy consumption. Thus, changes to the energy and greenhouse gas emissions intensities of space heating are likely to have a significant impact on total sector energy consumption and emissions.

Figure 12 and Figure 13 compare the energy and emissions intensity of space heating in the residential sector from the present to 2030 for all policy scenarios.

Figure 12: Energy intensity of residential space heating

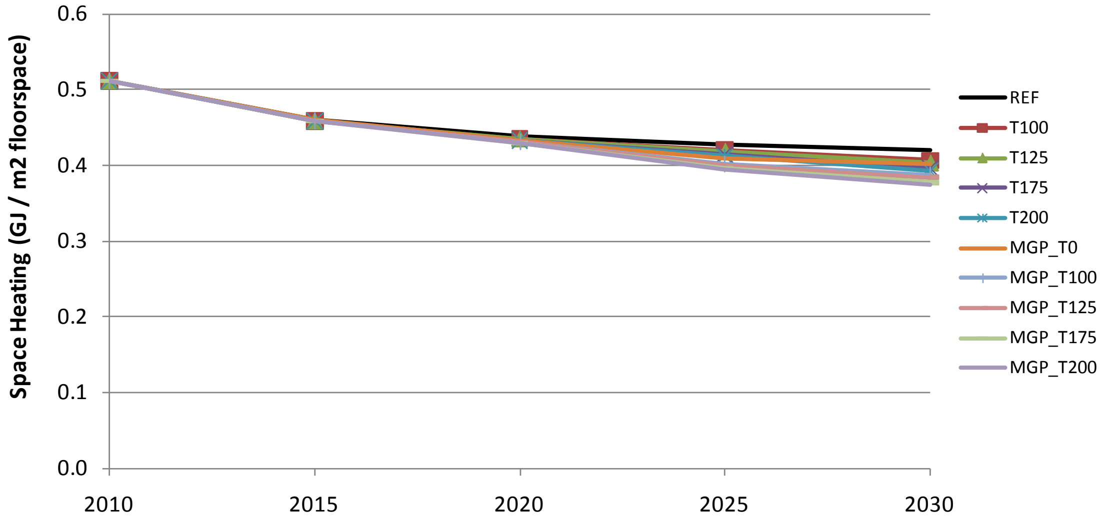
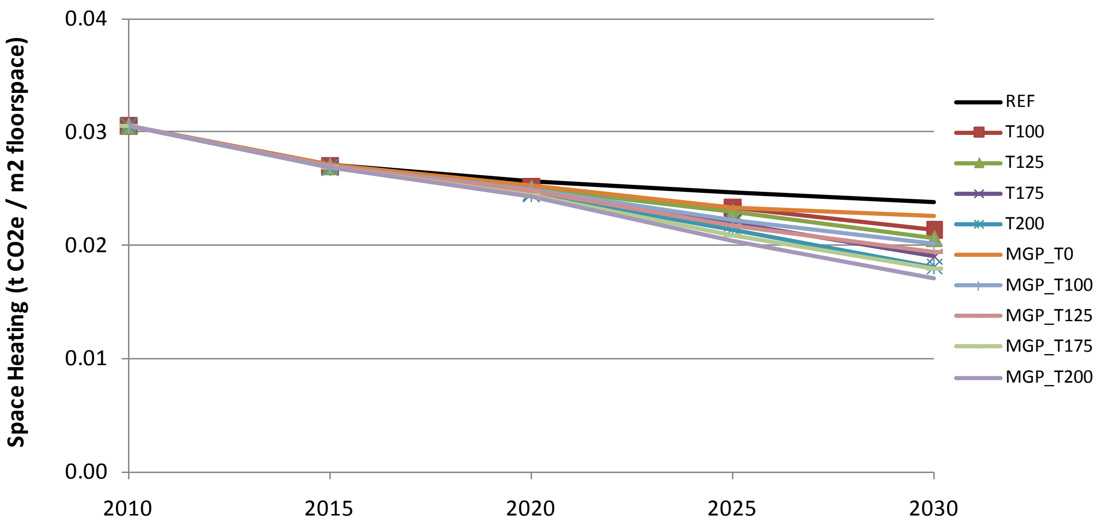


Figure 13: Greenhouse gas intensity of residential space heating



By 2030, improvements in energy intensity (measured as GJ/m^2 floor space per year) are modest – 5% and 9% on average relative to the reference case in the no MGP and MGP scenarios respectively. Figure 12 shows that energy intensity in the residential sector is not highly sensitive to carbon pricing: a result of intensity improvements in the reference case. In many NWT communities access to fuels for heating is constrained to expensive heating oil. In the reference case, energy intensity decreases 18% over the simulation period as households replace older furnaces with higher efficiency furnaces to reduce energy costs, leaving less room for additional gains in intensity in policy scenarios. Thus, further improvements in energy intensity are difficult to achieve. Due to high penetration of higher efficiency technologies in the reference case, abatement in the sector is primarily achieved by fuel switching. Figure 13 shows that by 2030 emissions intensity decreases an average of 17% − ranging from 10% in T100 to 24% in T200 − in the no

MGP scenario, and 22% − ranging from 15% in T100 to 28% in T200 − in the MGP scenario. Emissions intensity is slightly lower – 5% with each carbon price – in scenarios that assume the MGP is developed due to natural gas conversion. In the MGP scenarios, it is assumed that the communities of Tulita, Fort Good Hope and Fort Simpson switch from fuel oil to natural gas to for heating services. Overall, increased adoption of wood fuelled furnaces, followed by heat pumps are the primary abatement actions in the sector. Table 15 shows how the penetration of furnace technologies changes in response to policy. With higher carbon prices the percentage of total floor space heated with wood furnaces and heat pumps rises from 12% and 5%, respectively in the reference case scenario, to roughly 20% and 13% in 2030. While a fair amount of fuel switching occurs in response to the policy, some communities in the NWT continue to consume fuel oil for space heating in 2030 because their abatement options are limited (constrained access to alternative fuels).

Table 15: Furnace technology adoption − % of total heated residential floor space

	2020				2030			
	NG & Propane	Fuel Oil	Wood/ Pellet	Heat pump	NG & Propane	Fuel Oil	Wood/ Pellet	Heat pump
No MGP Scenario								
T0	16%	72%	11%	1%	10%	73%	12%	5%
T100	17%	71%	11%	1%	11%	65%	16%	9%
T125	17%	70%	11%	2%	11%	62%	17%	10%
T175	17%	69%	12%	2%	11%	57%	20%	13%
T200	17%	69%	12%	2%	11%	54%	21%	14%
MGP Scenario								
MGP_T0	17%	71%	11%	1%	14%	69%	12%	4%
MGP_T100	18%	70%	11%	1%	15%	61%	15%	9%
MGP_T125	18%	69%	11%	1%	15%	59%	16%	10%
MGP_T175	18%	68%	12%	2%	15%	53%	19%	12%
MGP_T200	18%	68%	12%	2%	15%	51%	20%	13%

Figure 14 and Figure 15 compare the energy and emissions intensity of space heating in the commercial sector for all scenarios.

Figure 14: Energy intensity of commercial space heating

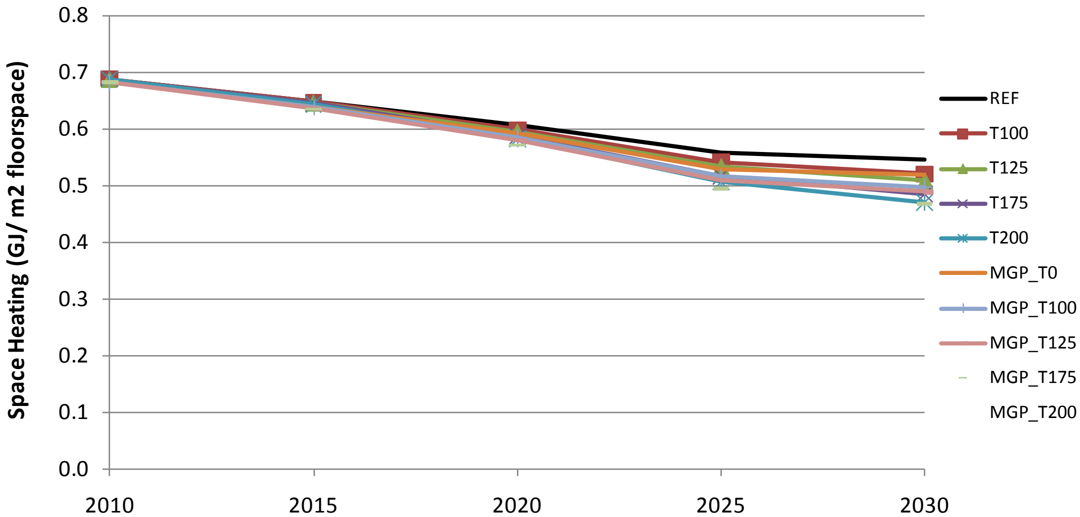
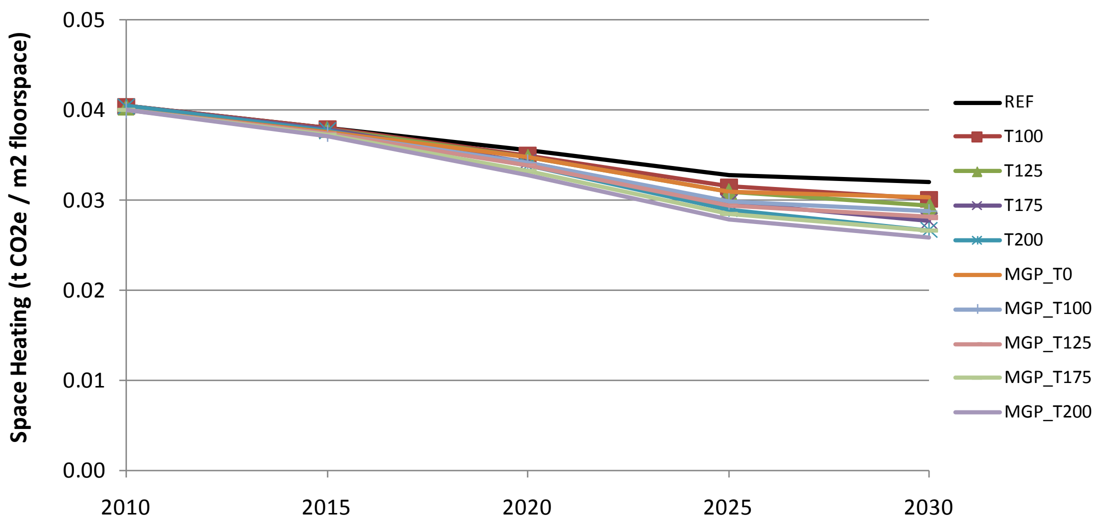


Figure 15: Greenhouse gas intensity of commercial space heating



In the reference case, the energy and emissions intensity of the commercial sector decline over the simulation period due to increased adoption of more efficient boilers and improved shell energy efficiency (encouraged in part by the building code). When carbon policies are implemented, energy and emissions intensity decrease further. On average, energy intensity in 2030 falls approximately 9% from the reference case in all policy scenarios that assume the MGP is not developed. In scenarios that assume that the MGP is developed, energy intensity improves slightly more and average intensity drops 13% relative to the reference case with carbon pricing because of natural gas conversion in the sector. In the no MGP scenario, abatement from fuel switching to natural gas (e.g., replacing oil boilers with natural gas boilers) is restricted and abatement from energy efficiency is limited.

In line with energy intensity, emissions intensity in the sector varies only slightly − 3% on average − between development scenarios. By 2030 emissions intensities are on average 11% and 14% lower than the reference case for the no MGP and MGP scenarios, respectively. Abatement options in the commercial sector are limited to fuel switching to renewables (e.g., wood pellets) and electricity (e.g., heatpumps) and a small amount of energy efficiency. Table 16 shows the how shares of heating technologies change in response to policy. As illustrated in the table, increased adoption of wood fuelled technologies increases significantly with policy from 2% in the reference case to 12% and 14% with a carbon price that rises to $200 in 2030, for the no MGP and MGP scenario respectively. Consequent, shares of oil fuelled boilers drop − average share for oil boilers is 56% with an equivalent carbon price (compared with a share of 72% in the reference case in 2030).

In general, intensities in the residential and commercial sector vary more among pricing scenario than development scenario: in other words, sectoral intensities are more sensitive to carbon pricing assumptions than development scenario. For example, emissions intensity in the residential sector falls between 10% with T100 and 24% with T200, a difference of 14%, while with MGP_T200 intensity falls 28%, a difference of only 4% when compared to T200, an equivalent carbon price.

Table 16: Space heating technology adoption − % of total heated commercial floor space

	2020				2030			
	NG & Propane	Fuel Oil	Wood/ Pellet	Heat pump	NG & Propane	Fuel Oil	Wood/ Pellet	Heat pump
No MGP Scenario								
T0	31%	68%	1%	0%	26%	72%	2%	1%
T100	31%	67%	2%	0%	26%	67%	6%	1%
T125	31%	66%	3%	1%	26%	65%	8%	2%
T175	31%	64%	4%	1%	26%	60%	12%	2%
T200	31%	63%	5%	1%	26%	57%	14%	3%
MGP Scenario								
MGP_T0	30%	69%	1%	0%	30%	68%	2%	0%
MGP_T100	30%	67%	2%	1%	30%	63%	5%	1%
MGP_T125	30%	66%	3%	1%	30%	61%	7%	1%
MGP_T175	30%	64%	5%	1%	30%	58%	10%	2%
MGP_T200	30%	63%	6%	1%	30%	55%	12%	2%

Transportation

Figure 16 and Figure 17 compare the energy and GHG emissions intensity of passenger vehicles. In the reference case, both the energy and emissions intensity of passenger vehicles decrease over time as older vehicles are replaced with more efficient gasoline and hybrid vehicles. The high fuel prices and the vehicle emissions standard are a significant driver of this change, with carbon pricing moderately accelerating this trend.

In the reference case, energy and emissions intensity improve approximately 30%, over the simulation period. In the policy scenarios, energy intensity falls by an extra 5% to 9% relative to the reference case by 2030. Conversely, emissions intensity is more sensitive to carbon pricing. In initial simulation periods, the impact of pricing is low relative to the impact of high fuel prices and the vehicle emissions standard, and do not induce much additional abatement from the reference case. However, as the strength of carbon pricing increases after 2020, the emissions intensity of the sector declines more rapidly. By 2030, reductions in emissions intensity range from 10% with an emissions price of $100/t CO_2e to 23% with an emissions price of $200/t CO_2e. Increased penetration of alternative fuels, hybrids and zero emissions vehicles (e.g., plug-in electric) generate the majority of this abatement. In general, neither energy or emission intensity are greatly affected by the development scenario.

Figure 16: Personal vehicle energy intensity

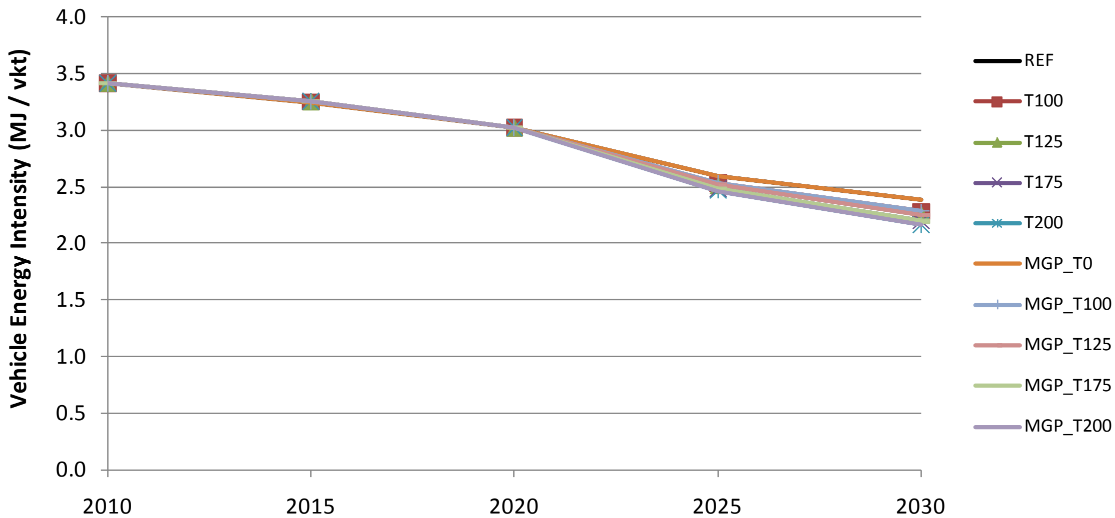


Figure 17: Personal vehicle greenhouse gas intensity

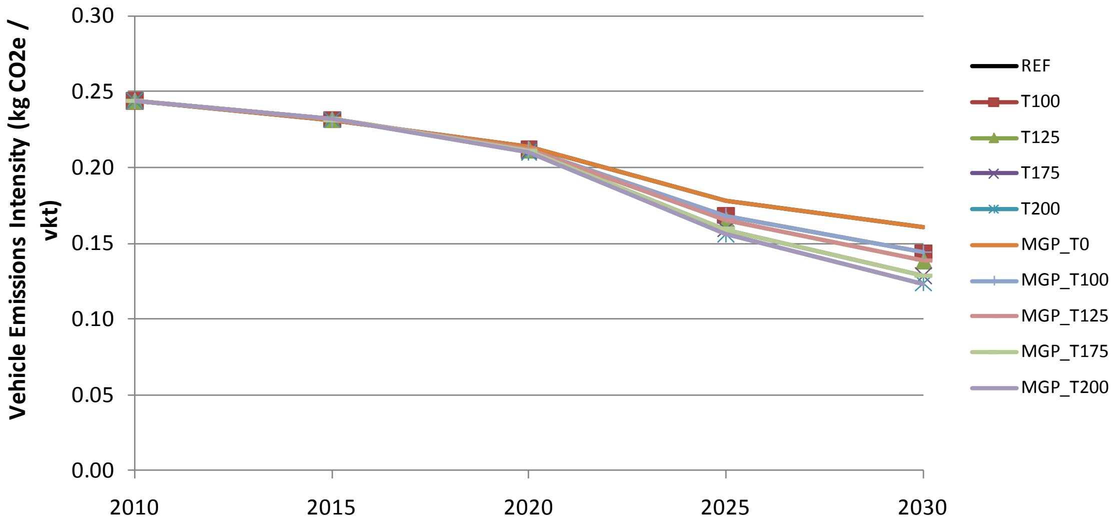


Figure 18 and Figure 19 show the energy and emissions intensity of the freight sector. While these intensities decline in response to the policy scenarios, the magnitude of the decline is less than in the personal transportation sector. The absence of a vehicle emissions standard and a lack of emerging abatement options (e.g., plug-in electric or ethanol vehicles) are the reasons for this difference. Freight activity in the region, especially from heavy truck and off-road mining vehicles, often occurs in parts of the region where access to alternative fuel is limited. Moreover, harsh climates (average winter temperatures can range from -20^{o}C to up to -40^{o}C) create an inhospitable environment for the effective compression of biodiesel (a major abatement technology for freight activity). To account for these technical issues, we assume a conservative price for biodiesel. If technological advances succeed in producing biodiesel more suitable to conditions in the NWT, it is likely that fuel costs would be lower and penetration of biodiesel technologies higher.

While Figure 18 shows that carbon pricing stimulates few gains in energy efficiency relative to the reference case, Figure 19 shows that emissions intensity is sensitive to carbon pricing. Reductions in emissions intensity are driven by only a small amount efficiency improvements − older trucks and off-road vehicles are replaced with higher efficiency ones − and fuel switching − a small amount of the vehicle stock is converted to biodiesel (3% to 13% of total fuel consumption in the sector, with lowest and highest carbon prices respectively). Improvements in emissions intensity range from 2% to 12%. Like personal transportation, the energy and emissions intensity of the sector are fairly insensitive to the development scenario.

Figure 18: Freight energy intensity

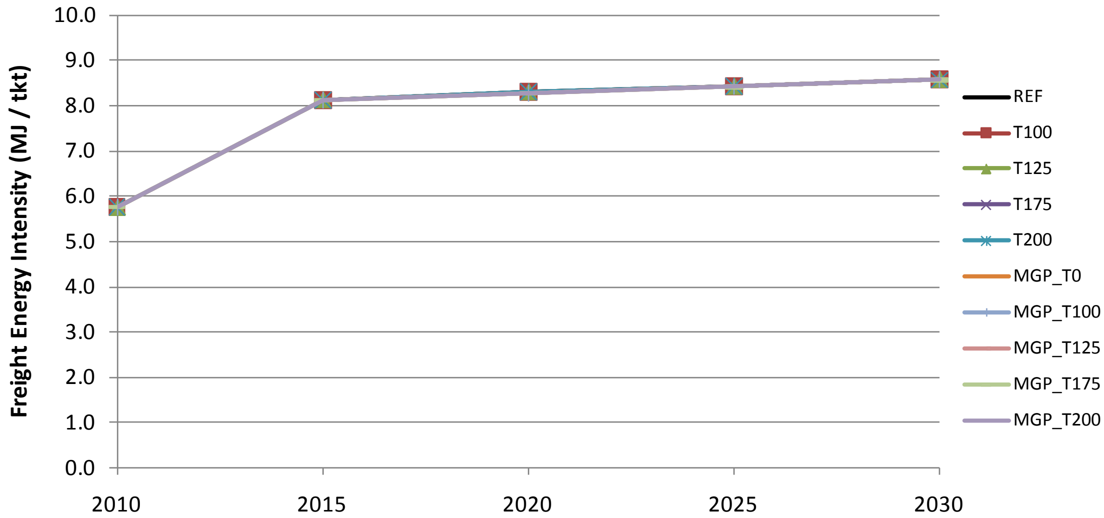
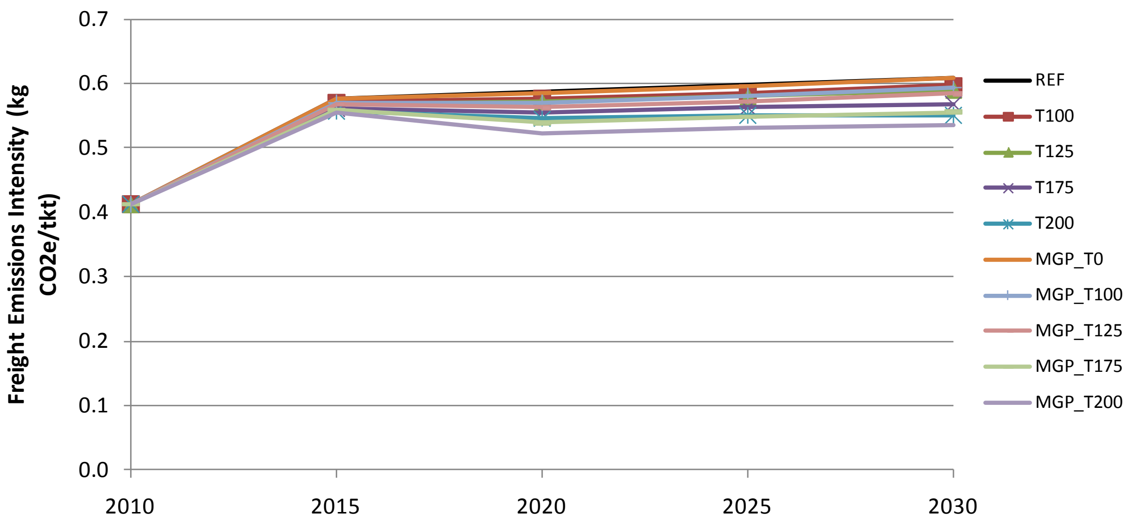


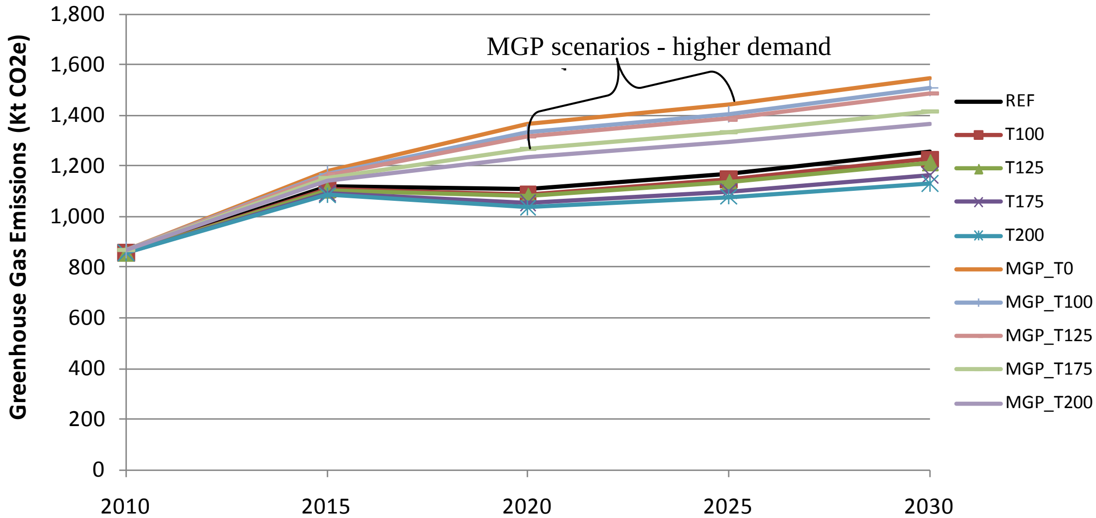
Figure 19: Freight greenhouse gas intensity



Indirect impact of MGP on demand sectors

As noted in previous sections, the development of the MGP is likely to induce demand shifts in other sectors of the economy. In this study, it is assumed that demand from the commercial and freight transportation sectors increase with the development of the MGP (see Table 1 for demand assumptions). Therefore, total energy consumption and emissions are higher in the MGP scenario. Despite improvement in emissions intensity (see Figure 15 and Figure 19) induced by policies in both sectors, absolute emissions continue to be greater than the reference case scenario. Figure 20 shows the absolute emissions from the commercial and freight sectors over the simulation period. At each price level emissions in the MGP scenario are roughly 20% greater than the in the no MGP scenario. Although carbon prices reduce emissions in the MGP scenario relative to a scenario with no policy (MGP_T0), emissions are consistently higher in all MGP scenarios because of anticipated growth in demand.

Figure 20: Greenhouse gas emissions in the commercial and freight sectors



Mining, oil and gas

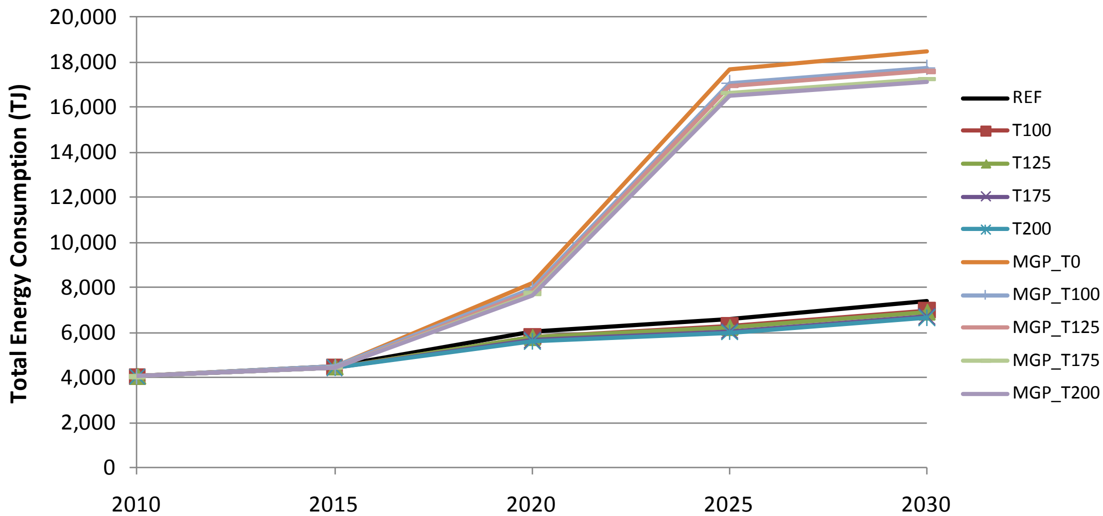
Figure 21 and Figure 22 show energy consumption and GHG emissions of the mining, oil and gas sectors. Both Figure 21 and Figure 22 show that trends are strongly influenced by the emissions from the mining sector in the no MGP scenario, and the natural gas extraction sector in the MGP scenario. In 2030, activity in the mining and natural gas sectors account for approximately 90% and 80%, respectively, of total sector emissions in the no MGP and MGP scenarios.

In the reference case, energy consumption and emissions in the sector increase over time in response to anticipated mining development. However, the introduction of carbon policy sees energy consumption and emissions in the sector drop. In policy scenarios that assume the MGP is not developed, emissions reductions are driven by activity in the mining sector. In 2030 emissions fall between 11% and 22%, primarily from increased penetration of electric and high efficiency equipment for extraction and processing activities. In the no MGP scenario, the oil and natural gas sectors are fairly insensitive to carbon policy because abatement options in these sectors are constrained by cost (i.e., declining production in the oil and natural gas sectors do not warrant large investment in abatement equipment) and technical feasibility (i.e., for this analysis carbon capture and storage and large scale adoption of biodiesel was deemed not suitable in the Territories). The change in energy consumption is slightly less than the change in emissions − between 5% and 10% − since a portion of the abatement comes from fuel switching.

In scenarios that assume the MGP is developed, energy consumption and emissions rise significantly. As discussed in previous sections, energy consumption and emissions growth is driven by activity associated with natural gas extraction from the MGP (~1.1

Mt CO_2e/year with no policy).[28] At lower carbon prices, emissions in the sector more than triple and energy consumptions almost doubles relative to reference case values. With higher carbon charges (MGP_T175 and MGP_T200) emissions growth is slowed considerably and by 2030 emissions are approximately 7% lower than what they would likely be if no policies were implemented. Consistent with the wedge diagram analysis, improved efficiency in the sector and greater usage of electric equipment result in lower sector emissions with rising carbon prices. Despite the MGP development, energy consumption and emissions in the crude and mining sector decline (to the same scale as in the no MGP scenario), showing that activity in these sectors is insensitive to the development assumption.

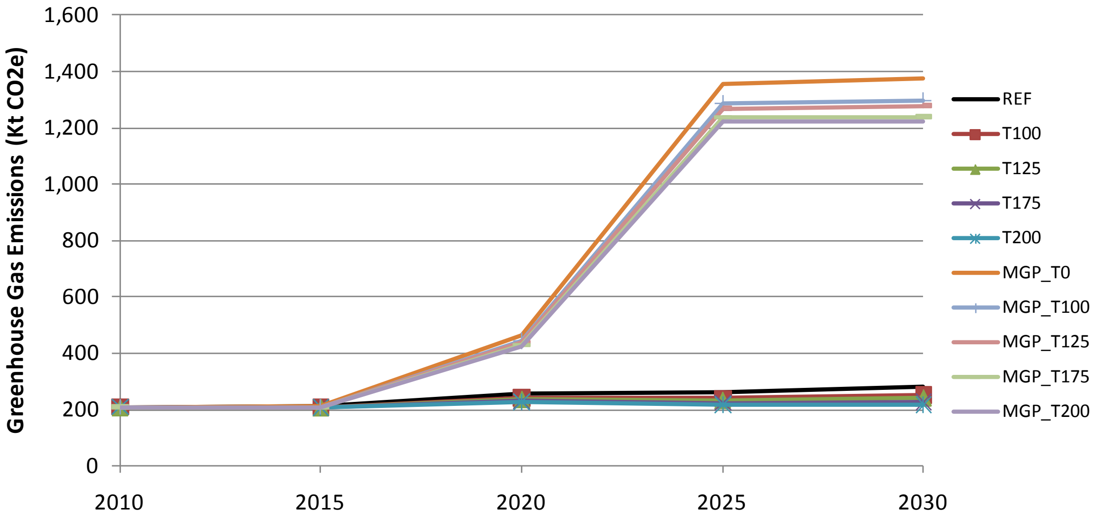
Figure 21: Mining, oil and gas energy consumption



Note: Includes energy consumption from the mining, oil and gas. Values include own consumption of natural gas for non motive activity, and exclude consumption of diesel and natural gas for transportation and power generation.

[28] This value does not include emissions from power generation associated with the MGP development, which is accounted for separately in the electricity generation sector.

Figure 22: Mining, oil and gas greenhouse gas emissions



Note: Values exclude emissions from transportation and power generation.

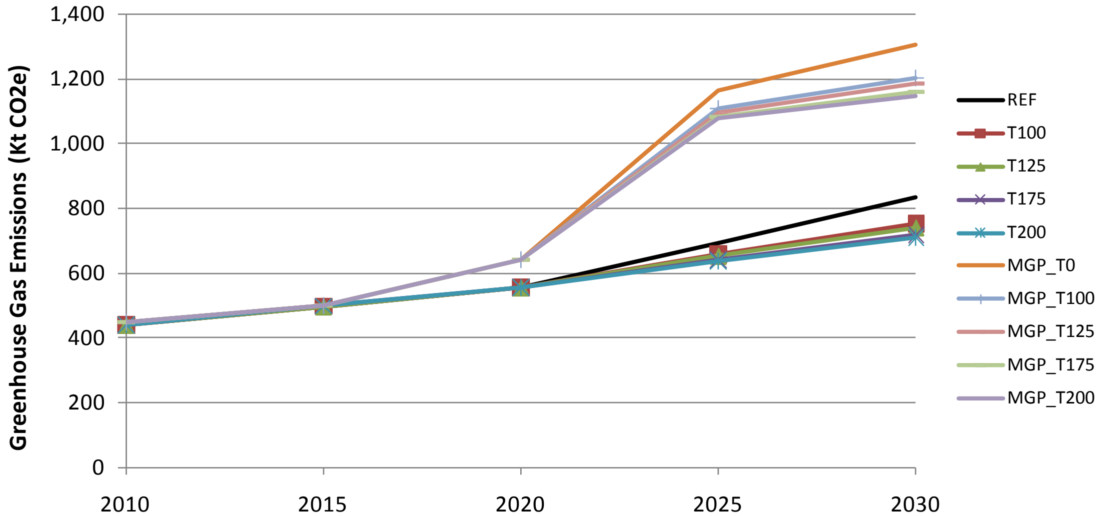
Electricity

As noted in the reference case section above, generation from the electricity sector in CIMS includes all generation from utility and industry. Emissions therefore vary substantially with the development assumption, because of both (1) increased industry generation requirements of the natural gas sector in the MGP scenario and (2) rising demand for electricity from the commercial sector as it grows in response to indirect effects of the MGP.

Figure 23 shows GHG emissions in the electricity sector in the reference and policy scenarios. In the reference case, emissions reach 835kt CO_2e in 2030, up from 442kt CO_2e in 2010. Expanding output from the mining sector is a key driver of this growth, with electricity demand from mining rising by 2.4PJ over the period. Emissions grow more quickly in the MGP scenario, reaching 1,305kt CO_2e in 2030, close to double the reference projection. In this case, growth is driven by substantial electricity requirements from the natural gas sector (almost 3PJ annually, accounting for 35% of electricity consumption in 2030) as well as higher demand from the commercial sector.

In the no MGP scenarios, the carbon price reduces emissions by between 10% (in the low price scenario) to 15% (in the high price scenario) relative to the reference case in 2030. In the MGP scenarios, the carbon price is unable to reduce emissions relative to the reference case due to greater electricity demanded by the natural gas sector (and to a lesser extent the commercial sector), although emissions intensity falls relative to the reference case.

Figure 23: Utility and industry electricity sector greenhouse gas emissions



In the reference case, hydroelectric and diesel generation each make up slightly less than half of utility and industry electricity generation in 2030. This forecast assumes the Taltson hydro project gets developed and that there is modest growth of hydro after 2020 (i.e., Wha ti development in 2025). Diesel generation also increases substantially in the reference case due in particular to projected growth in the mining sector. Natural gas supplies about 2% of generation (in Inuvik) while wind accounts for the remainder. Wind generation is assumed to be developed initially in the Beaufort region; with additional capacity installed after 2020 (output reaches 1.8GWh in 2030).

Total generation does not change markedly in response to the policy. Although the carbon policies do induce efficiency gains in demand sectors, thereby reducing electricity demand, the policies also induce some electrification which offsets the drop in demand. The carbon price does stimulate a shift in the generation mix, reducing reliance on diesel while slightly increasing the share of hydroelectric, wind and other renewable generation (see Table 17). The share of diesel declines from 55% in the reference case scenario to 47% in the T200 scenario, while that of hydroelectricity increases from 43% to 51%. Wind generation increases, as does other renewable generation (including a limited amount of geothermal and biomass) however in total these sources only supply about 0.3% of power in 2030 in the higher carbon price scenarios. Lastly, the share of natural gas remains constant in response to carbon policy because it is assumed that supplies are constrained.

In the MGP scenario, the share of natural gas generation is much higher, and that of all other fuels correspondingly lower. However, the fuel mix response to carbon pricing is largely similar, with a switch away from diesel toward hydro and other renewable generation. Although total generation is higher, mostly from natural gas generation associated with the MGP itself, this generation is unable to displace more diesel generation because opportunities for community conversion are assumed to be maximized in the MGP no policy scenario. Therefore, higher carbon prices do not induce greater natural gas generation.

Note: In the reference case, additional hydro capacity is limited to the Taltson and Wha ti projects. With policy we do show additional hydro growth, a function of the relative costs of different generation technologies adjusted for feasibility constraints in the North (reflective of generation choices in the reference case). However, it is possible that with an aggressive hydro development policy, greater capacity could be developed and emissions further reduced.

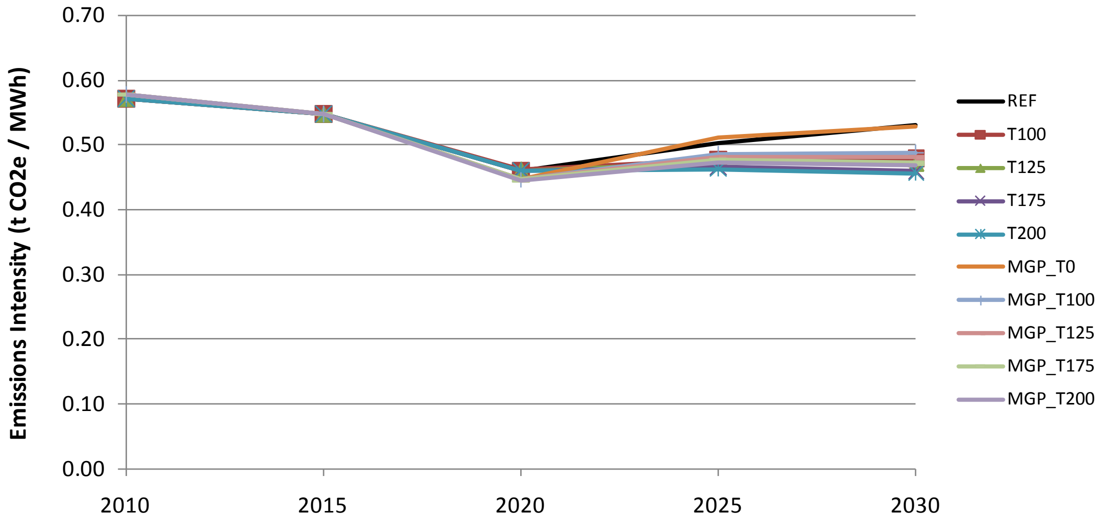
Table 17: Utility and industry electricity generation by fuel, 2030

Generation (% of total power)	*No MGP*				
	T0	*T100*	*T125*	*T175*	*T200*
Hydroelectric Generation	43%	49%	50%	51%	51%
Wind Generation	0.1%	0.1%	0.1%	0.2%	0.2%
Other Renewable Generation	0.0%	0.1%	0.1%	0.1%	0.1%
Diesel Generation	55%	49%	48%	47%	47%
Natural Gas Generation	2%	2%	2%	2%	2%
Generation (% of total power)	*MGP*				
	MGP_T0	*MGP_T100*	*MGP_T125*	*MGP_T175*	*MGP_T200*
Hydroelectric Generation	29%	33%	34%	35%	35%
Wind Generation	0.1%	0.2%	0.2%	0.2%	0.2%
Other Renewable Generation	0.0%	0.1%	0.1%	0.1%	0.1%
Diesel Generation	36%	31%	30%	30%	29%
Natural Gas Generation	36%	36%	36%	36%	36%

Note: Other renewables includes biomass and geothermal power.

In the reference case, the emissions intensity of electricity generation declines from 0.57t CO_2e/MWh in 2010 to 0.53t CO_2e/MWh in 2030 (see Figure 24). The fuel shifts induced by the carbon pricing lower the intensity of electricity generation further to between 0.48 and 0.46t CO_2e/MWh in the no MGP scenarios. In the MGP scenario, emissions intensity decreases due to the rising share of natural gas generation from conversion in Tulita, Fort Good Hope and Fort Simpson and own generation from the MGP, reaching between 0.49 and 0.47t CO_2e depending on the magnitude of the carbon price. In all scenarios, emissions intensity increases slightly after 2020 because of constrained capacity for renewable technologies, primarily hydroelectricity. Consequently, supply is produced with diesel generation.

Figure 24: Utility and industry electricity generation greenhouse gas emissions intensity



In all scenarios, the choice of electricity generation technologies is assumed to be severely constrained due to the geography, remoteness and small size of many communities in the NWT. For these reasons, a carbon price alone is somewhat limited in its ability to reduce emissions from the electricity sector. However, the results presented here are highly dependent on the manner in which individual technologies are constrained, and the abatement options available. This analysis attempts to be conservative in its assessment of the ability of alternative fuels (e.g., hydroelectricity) and technologies to meet electricity needs in the NWT. However if these assumptions were relaxed to include a wider scope of projects, emissions in the sector would fall in both the reference case, and the policy case – in a policy scenario such abatement options have the potential to significantly reduce emissions from the sector, although this potential is highly dependent on the availability (i.e., the availability of hydro resources) and technical feasibility in the NWT (i.e., the productivity and scale of hydro resources).

Financial analysis

In this section, we discuss the economic impact of the policy and the development scenarios. This discussion covers only the energy and GHG intensive portions of the economy.[29] The economic indicators generated by CIMS are as follows:

- **Changes to capital investment by sector**, which shows how capital investments change in response to policy scenarios.
- **Changes to household energy costs**, which shows how household energy costs (e.g., heating cost) change in response to policy scenarios.
- **Changes to transportation energy costs**, which shows how annual vehicle fuel costs and average vehicle fuel prices change in response to policy scenarios.
- **Changes to electricity generation costs**, which shows how cost of production in the electricity sector changes in response to policy scenarios.

Changes to capital investment by sector

Table 18 presents the projected cumulative change in capital investment for each sector from 2010 to 2030, relative to the reference case. In CIMS, capital investment includes the cost of new or retrofit equipment, which is based on archetypal technologies for each sector. As such, these values do not relate to firm-specific investments in the region. In response to the carbon pricing, net changes in capital investment are expected to range from $47.0 to $68.6 million (2005$) between 2010 and 2030 in the no MGP scenarios. In the MGP scenarios, investment increases substantially due to greater expenditures in the natural gas, electricity, commercial and freight transportation sectors, by between $9.25 and $9.29 billion (2005$). In both the MGP and no MGP scenarios, total capital investment increases in response to higher carbon prices.

In the no MGP scenarios, the electricity sector is projected to experience the greatest increase in capital investment, between $31.0 and $39.7 million (2005$). Investment varies depending on the carbon price, as diesel generation is replaced with more costly hydro generation as well as other renewable sources. Note that some of this investment would be borne by the mining industry, because electricity generation by industry is included in the electricity sector.

Excluding electricity generation, the mining sector invests an additional $9.0 to $16.5 million in capital expenses between 2010 and 2030. While this analysis is focused on those portions of the mining sector related to energy consumption, expenditures values produced with the CIMS model only represent a fraction of total expenses (other areas being labor, financial, etc.). As such, the impact of carbon pricing on competitiveness and output depend on the marginal impact of the carbon price on total costs. These issues are discussed further in the subsequent Macroeconomic Analysis.

Additional investment in the residential sector ranges from $4.6 to $10.0 million (2005$), while investment in the commercial sector increases by $1.8 to $4.2 million. These

[29] In the subsequent analysis using GEEM we forecast how climate policy might affect GDP, economic structure, employment, savings and investment.

increases are largely associated with investment in more efficient building shells and space and water heating technologies.

Investment in the freight sector increases by $3.4 to $6.6 million over the period, while investment in the personal transportation sector actually decreases by $2.7 to $8.5 million. Reductions occur in the personal transport sector because consumers shift to smaller and higher occupancy vehicles, higher efficiency vehicles, as well as transit.

Capital investment does not change substantially in the oil and gas sectors in the no MGP scenario, due to generally declining output. In the MGP scenario however, capital costs increase substantially relative to the reference forecast, by $8.2 to $8.3 billion (2005$). Note that any additional investment caused by rising carbon prices would depend on specific abatement technologies incorporated into the project's design.

The MGP scenario also affects investment in other sectors, due to changes in output (in the commercial, freight and electricity sectors) and fuel mix (for example, natural gas electricity generation and space heating). Investment in the residential sector is lower in the MGP scenarios due to the lower capital cost of natural gas technologies, while investment is higher in the commercial, freight and electricity sectors due to greater output.

Table 18: Cumulative changes to capital investment by sector, relative to the reference case (2010-2030)

	No MGP			
(2005$ Millions)	***T100***	***T125***	***T175***	***T200***
Demand Sectors				
Residential	4.6	5.9	8.7	10.0
Commercial	1.8	2.4	3.6	4.2
Transportation Personal	-2.7	-4.3	-7.2	-8.5
Transportation Freight	3.4	4.3	5.8	6.6
Mineral Mining	9.0	11.1	14.8	16.5
Total Demand Sectors	*16.0*	*19.3*	*25.8*	*28.8*
Supply Sectors				
Electricity	31.0	35.7	39.2	39.7
Oil and Gas	0.0	0.0	0.1	0.1
Total Supply Sectors	*31.0*	*35.8*	*39.3*	*39.8*
Total Territories	**47.0**	**55.1**	**65.1**	**68.6**

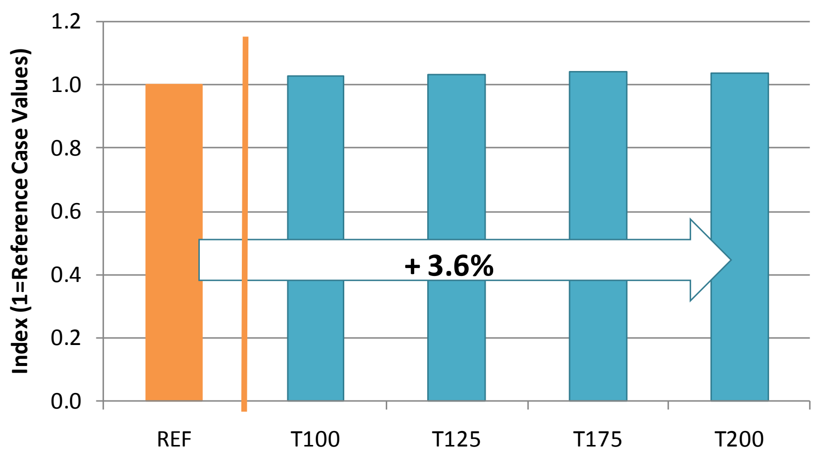
	MGP			
(2005$ Millions)	MGP_T100	MGP_T125	MGP_T175	MGP_T200
Demand Sectors				
Residential	4.1	5.3	7.9	9.2
Commercial	309.4	310.1	311.5	312.2
Transportation Personal	-2.7	-4.3	-7.2	-8.5
Transportation Freight	438.4	439.4	441.3	442.3
Mineral Mining	9.0	11.1	14.9	16.5
Total Demand Sectors	*758.2*	*761.6*	*768.4*	*771.7*
Supply Sectors				
Electricity	250.0	255.7	261.2	262.2
Oil and Gas	8,243.9	8,246.7	8,252.3	8,254.7
Total Supply Sectors	*8,493.8*	*8,502.4*	*8,513.5*	*8,516.9*
Total Territories	**9,252.0**	**9,264.0**	**9,281.9**	**9,288.6**

Note: The capital costs used in this analysis reflect the investment costs associated with archetypical sectors and do not reflect the investment cost of any specific facility in the region.

Changes to household energy costs

Figure 25 depicts the change in average household energy costs over the simulation period, relative to the reference case. Relative changes are shown because of the substantial variation of costs within the NWT. Energy costs generally increase in response to the carbon pricing, reaching about 3.6% in the scenarios with a carbon price that rises to $200/t CO_2e in 2030. However, the increase in energy cost generally lessens after 2020, as capital stock is replaced by more efficient technologies, both over time as stock reaches the end of its natural lifespan and in response to rising carbon prices. In the MGP scenario, the rise in energy costs is lower due to the availability of natural gas in several communities. In the MGP_T0 scenario, average energy costs are actually lower than the reference case by about 2%, and an average of about 1.6% lower with policy.

Figure 25: Average household energy costs in 2030



Changes to transportation energy costs

Figure 26 and Figure 27 show how average vehicle fuel prices and annual vehicle fuel costs change in response to policy over the simulation period. In all policy scenarios, the average fuel price rises, increasing incrementally with higher carbon prices. Average fuel price increases in part because higher priced bio-fuels replace gasoline and diesel, and in part because the carbon charge makes conventional fuels more expensive. Across all scenarios (all carbon prices and development scenarios) average fuel prices increase approximately 20%.

Average annual fuel costs also increase in the policy scenarios, although to a lesser extent than fuel prices, peaking at 15% in 2030 in the T200 scenario, relative to the reference case. In the reference case, annual fuel costs are projected to decline after 2020 with the increased adoption of high efficiency and hybrid vehicles (due in part to the vehicle emissions standard). In the policy scenarios, higher fuel prices cause an increase in the market penetration of more efficient and alternative-fuelled vehicles over the reference case.

Figure 26: Average personal vehicle fuel prices

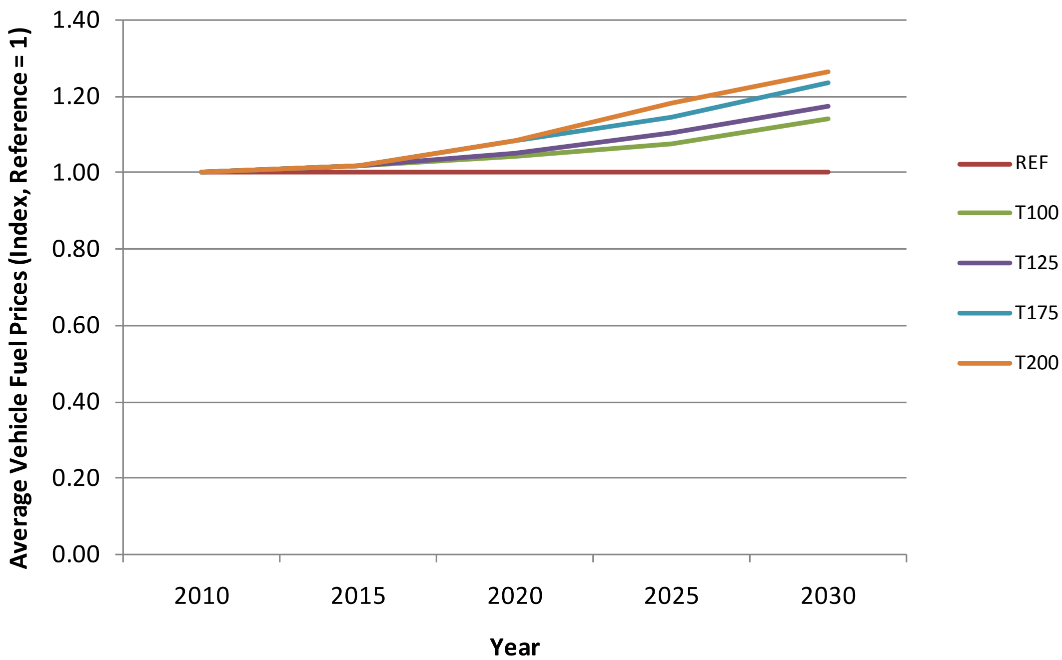
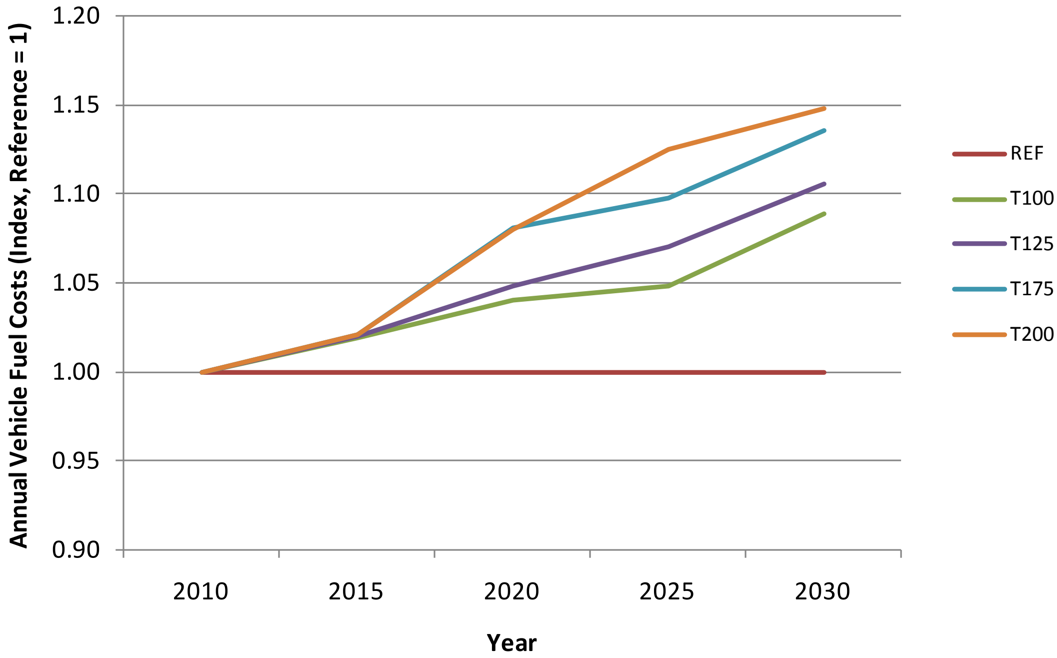


Figure 27: Average annual personal vehicle fuel costs



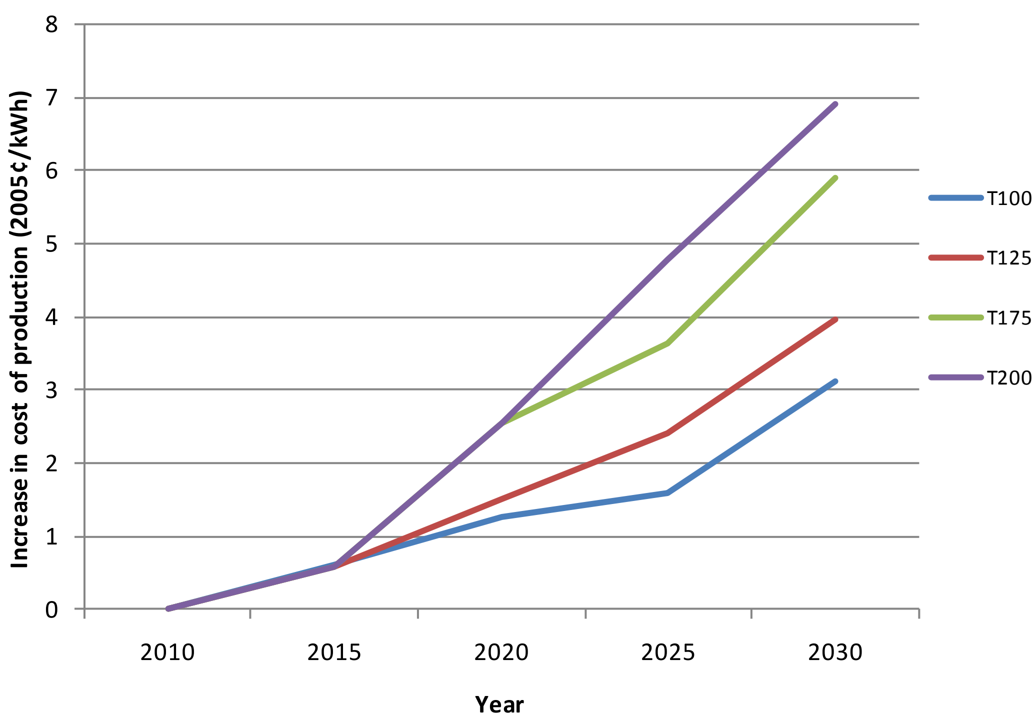
Changes to electricity costs of production

Figure 28 shows the forecasted increase in the cost of electricity generation for each carbon price scenario. Note that these changes reflect the average cost of electricity generation in the NWT and that actual production costs vary significantly throughout the Territories and will be affected to differing degrees by carbon pricing. Costs increase as the sector bears the cost of the carbon policy and responds by adopting abatement technologies. In 2030, average generation costs increase by between about 3 and 7c/kWh, depending on the carbon price. The greatest increase (7c/kWh) occurs in the T200 scenario, representing a 22% increase relative to the reference case.

In our analysis, electricity prices are assumed to rise in proportion with increases to average generation costs. As discussed earlier in the report, reference electricity prices are subsidized in the residential sector. Rising electricity prices influence a variety of abatement actions (such as fuel switching and energy efficiency), which in the future will be influenced by whether and to what degree electricity prices reflect increases in generation costs.

In the MGP scenario, average electricity generation costs decrease substantially due to the large amount of natural gas generation associated with the MGP. We do not present these results because in reality, this change would only directly affect the communities connected to new gas supply. As mentioned earlier, a limitation of this analysis is the use of a single regional model for the NWT which comprises a heterogeneous and non-integrated electricity sector.

Figure 28: Change in cost of electricity generation (relative to the reference case)



Macroeconomic Analysis

Introduction to model and policy scenarios

The GNWT has commissioned MKJA to examine the environmental and economic effects of potential carbon pricing in the NWT. Earlier in this report we examined the potential direct technological and behavioural responses to carbon pricing in the NWT using the CIMS technology simulation model. CIMS specializes in simulating firm and consumer investment and equipment utilization decisions in response to energy pricing and regulations. The effects of carbon pricing are not wholly confined to energy intensive sectors, however; carbon pricing will affect the net profitability of sectors across the economy, causing a general reallocation of productive labour and capital. In addition, if revenues are generated from carbon pricing, how they are used also has an important general economic effect.

Another type of model is needed to calculate the economy wide GDP, employment and general economic structural effects of energy policies like carbon pricing. To supplement the CIMS analysis we use the North-American (NA)-GEEM computable general equilibrium model. NA-GEEM includes both the US and Canada; before this analysis Canada was regionally disaggregated into British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Québec, and the rest of Canada (which included the Atlantic provinces, territories and Canadian economic activity outside Canada). For this project we separated the Northwest Territories from the rest of Canada and ran it as a separate regional component. A detailed appendix describing NA-GEEM is also included with this report (see Appendix B: CIMS and GEEM).

To analyze the general economic effects of carbon pricing − and policy design − we simulated two separate general scenarios for carbon pricing, one based on carbon taxation, and the other on an emissions cap and trade system. In the first we simulate a sequence of carbon taxes rising from \$10 to \$200 per tonne (rising in \$10 and \$20 increments) by 2020, where one-third of revenues are used to reduce corporate taxes and two-thirds incomes taxes. This is functionally identical to BC's current carbon tax revenue allocation design. In the second sequence, we focus on a North American cap and trade system based on the recently proposed US target of 17% below 2005 emissions levels by 2020, copied by Canada. A cap and trade system is applied to large final emitters (e.g. industrial plants, electricity production); while a direct carbon charge is imposed on households, returned lump sum. Emissions permit revenues are returned to firms using an output based allocation system. Under this system, permit revues are returned to firms based on firms' contributions to sectoral GDP; this is a commonly proposed revenue recycling method because its implicit subsidy to output mitigates competitiveness effects. Table 19 summarizes the policies.

Table 19 Key greenhouse gas policy scenarios

Scenario Name	Notes:
Carbon tax $0-X per tonne CO_2e	GHG prices from $10 to $200 per tonne CO_2e. Revenues are used to reduce other taxes, two thirds to income taxes and one third to corporate taxes.
C&T Value Added Output Based Allocation (VAOBA)	Both the US and Canada impose a target of reducing GHG emissions -17% from 2005 levels by 2020, with 20% achieved through international permits at $50/tonne CO_2e. The system covers all emissions, and is applied to firms through a cap-and-trade system where permits are distributed based on current value added. It is applied to households via a carbon charge on fuel combustion; all revenues are returned lump sum to households. Personal income taxes are further adjusted to maintain "no policy" base case federal government spending.
VAOBA w/ US-Canada trading	VAOBA with permit trading between the US and Canada
VAOBA w/ US BTAs	VAOBA, but the US imposes additional border tax adjustments on all imports based on their US GHG production intensity multiplied by the US carbon price.
VAOBA w/ No offsets	VAOBA with no international offsets purchases.

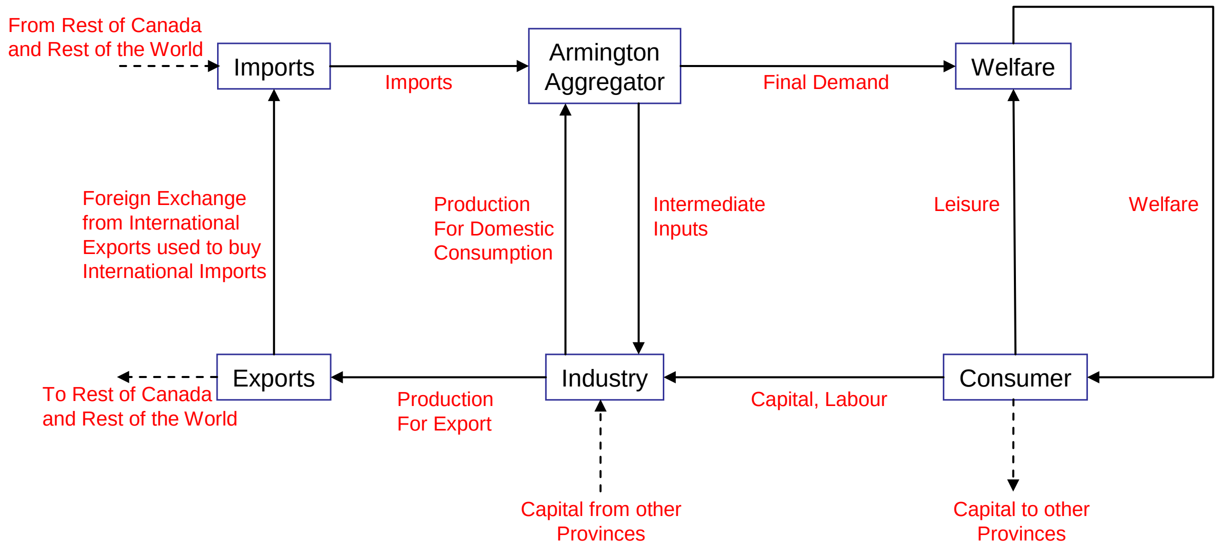
Reference Scenario – BAU

All scenarios are based on Informetrica's January 2011 economic forecast, which was estimated to include recent economic difficulties, and include all usual goods and services trade between the US, Canada and the rest of the world. In this analysis we refer to the reference case or baseline line macroeconomic conditions in 2020 as "BAU". BAU describes projected 2020 economic activity in the absence of carbon pricing policy, in both the no MGP and MGP scenarios.

Method

The North American (NA) version of the GEEM computable general equilibrium model was used to model the scenarios in Table 19. NA-GEEM is a static, multi-sector, open-economy computable general equilibrium (CGE) model that represents the Northwest Territories, British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and Atlantic Canada as separate regions, and the US as a single region. In the model, a representative consumer is the owner of the primary factors (labour and capital). The consumer rents these factors to producers, who combine them with intermediate inputs to create commodities. These commodities can be sold to other producers (as intermediate inputs), to final consumers, or sold to the rest of the world as exports. Commodities can also be imported from the rest of the world. NA-GEEM treats commodities differentially based on whether their prices are set regionally, on North American or world markets. The US and Canada are assumed to be price takers for crude oil, natural gas prices are set at a North American level, electricity prices are set at the provincial/regional level, and all other goods' price are set at the national or provincial/regional level as appropriate. The key economic flows in NA-GEEM are captured schematically in Figure 29.

Figure 29: Overall structure of the NA-GEEM model for a single region (e.g., NWT)



NA-GEEM assumes that all markets clear – prices adjust until supply equals demand. Most markets are assumed to be perfectly competitive, such that producers never make excess profits. However, an exception is made for the upstream oil and gas sectors, which are assumed to earn extra profits due to resource rents, which are shared amongst the producers and provinces/regions. The presence of resource rents makes the oil and gas sector less susceptible to declines in output than other sectors, as the size of rents can decline while the sector remains profitable. However, output from the oil and gas sector may still decline as a function of costs from the sector (i.e., an increase in costs will remove marginal plants from production), and this relationship is based on data from the National Energy Board (2009).

NA-GEEM divides the economy into the following producing sectors. Many sector breakdowns were possible, but the following were chosen as representative of the key differences in greenhouse gas production intensity and the capacity to respond to carbon policy through behavioural and technical change, including changes in output, fuels switching, energy efficiency and direct carbon reduction (e.g., carbon capture and storage).

Table 20 Sectors in NA-GEEM

Primary extraction	Other renewable electricity
Oil production mining and upgrading	Other manufacturing
Oil production insitu	Refining
Oil production light and medium	Chemical production
Oil production heavy	Industrial Minerals
Natural gas extraction and transmission	Primary metal manufacturing
Mining	Transport
Services	Waste
Conventional electricity	Federal government
Hydroelectric electricity	Provincial government

Like most computable general equilibrium models NA-GEEM imposes the restriction of constant returns to scale on producers to make the model more tractable. Likewise, it imposes the assumption that consumer preferences are homogeneous and continuous.

The data underlying the model is derived primarily from the Statistics Canada System of National Accounts. We use the S&M Level Input, Output, and Final Demand tables to populate the model, and aggregate these somewhat to focus on sectors of primary interest.[30] Energy consumption is disaggregated using data from the CIMS model and from the Statistics Canada Report on Supply and Demand of Energy.

NA-GEEM is implemented in GAMS, using the MPSGE substructure. An appendix with more information is provided for NA-GEEM (see Appendix B: CIMS and GEEM).

NA-GEEM Limitations and Uncertainties

NA-GEEM is a representation of the real world, not a perfect copy. It is designed to integrate consumer demand, labour and capital supply, and the markets for all key inputs and outputs between the Canadian regional economies, the US and the rest of the world. This comes at the cost of simplifying assumptions. The main uncertainties and limitations in the model are:

- **Depiction of technological and technology dynamics:** Like most CGE models NA-GEEM makes use of production functions to depict technology and production, which assume a smooth substitution between all inputs at a given rate, depicted as an elasticity. In certain industries, such as services, there does seem to be a relatively smooth substitution frontier between capital, labour, energy and materials. In other industries, such as electricity production or the iron and steel industry, this is not the case, as fundamentally different technologies can produce the final end product. This phenomenon is not confined to industry; natural gas furnaces or electric resistance heaters can both be used to heat buildings, but have completely different capital and operating cost, energy use, and emissions profiles. It is for these reasons that bottom-up models were initially conceived, including the one that evolved into CIMS.

[30] This is the level with the least amount of resolution, and does not allow much differentiation of energy-intensive sectors, but is the only one available at a provincial level because of confidentiality concerns.

- **Calibration of the social accounting matrix: Like all** calibrated as opposed to estimated CGE models, NA-GEEM must be calibrated to a given year's input and output of primary factors, goods and services; 2005 was latest year available with all necessary data.[31] This creates a base structure from which the model adjusts to policy shocks. If the chosen year is unrepresentative or economic or technology structure is changing quickly, the outputs of the model may be biased.
- **Forecasts of output growth and economic structure, population, labour-force participation and labour productivity.** These are all established using Informetrica's latest forecast.
- **Depiction of capital investment.** As a static model, the current version of NA-GEEM models the available North American investment capital in 2020 as a fixed stock. Capital investment can move between different North American sectors or regions in response to a policy, but there are no net inflows or outflows and overall level of investment remains constant. This is a common working assumption in static CGE modeling studies, which constitute the bulk of policy as opposed to academic analyses. Also, the model does not explicitly model the accumulation and depreciation of capital, so it cannot model incentives for more or less total investment; this would require a dynamic model. Our analysis may overestimate the degree to which capital will migrate from the greenhouse gas intense sectors to the less greenhouse gas sectors instead of overseas, and the degree to which North American overall world savings are formed to be transformed into investment capital in an environment where climate policy is applied. However, a review of the capital literature shows that capital is not perfectly liquid (i.e., it does not move across border and between regions with perfect ease in search of higher returns), and savings, the source of investment capital, created in North America will preferentially remain in North America (or any other source region).

Results and Discussion

Table 21 and Table 22 provide changes in market GDP, GDP per capita, labour income, salaries, consumption and welfare for all scenarios, with and without the Mackenzie Gas Pipeline (MGP). Key summary results include:

- In all scenarios GDP, incomes and consumption are significantly higher in 2020 than in 2005 (GDP is 19 to 26% higher in the no MGP scenario, 74 to 93% higher in the MGP scenario). GDP, GDP per capita, overall labour income and salaries are significantly higher in the MGP scenario than in the scenario where the MGP is not built. Conversely, overall emissions are higher and impacts of all climate policy regimes are higher in the MGP scenario.

- When meeting the North American target of -17% from 2005 emissions levels by 2020, from a GDP point of view the NWT is slightly better off with the specified

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[31] Calibrated CGE models operate from a single-year input output matrix, where all inputs and outputs are balanced. Estimated CGE models operate using parameters estimated from historical time series.

carbon tax (~140/tonne $C_{O2}e$) than the cap and trade system in the case where the MGP is not built. This relationship is less clear when the MGP is built.

- Welfare and consumption are substantially higher under the specified carbon tax when the -17% target is met under both the MGP and no MGP scenarios. This is because while the output based recycling system is effective in maintaining GDP, it is not as effective at maintaining household consumption. Reduced income and corporate taxes maintain consumption at higher levels. In the case without the MGP, consumption falls 0.2% with the carbon tax (~140/tonne $C_{O2}e$), and ~0.8% with the cap and trade system (C&TVAOBA). Consumption falls ~1.2% under the carbon tax in the MGP case (~140/tonne $C_{O2}e$), and ~1.9% under the cap and trade system (C&TVAOBA).
- Household incomes, consumption and welfare (a combination of consumption and leisure) are substantially less impacted than GDP, less than 2% in all cases.

Table 21: 2020 Market GDP and GDP per capita for all scenarios

	2020 Market GDP $2005 billions 2005 = 4.247 billion		Market GDP (% of BAU 2020)		Market GDP (% of 2005)		Market GDP per capita (~44000, $2005) 2005 = $96,538	
Policy Code	MGP	No MGP	MGP	No MGP	MGP	No MGP	MGP	No MGP
BAU	8.157	5.335			192%	126%	185,383	121,253
Ctax 0 to 10	8.104	5.318	-0.6%	-0.3%	191%	125%	184,184	120,861
Ctax 0 to 20	8.041	5.299	-1.4%	-0.7%	189%	125%	182,750	120,424
Ctax 0 to 30	7.981	5.277	-2.1%	-1.1%	188%	124%	181,397	119,926
Ctax 0 to 40	7.921	5.252	-2.9%	-1.6%	186%	124%	180,033	119,354
Ctax 0 to 50	7.862	5.225	-3.6%	-2.1%	185%	123%	178,682	118,740
Ctax 0 to 60	7.803	5.202	-4.3%	-2.5%	184%	122%	177,348	118,238
Ctax 0 to 70	7.752	5.181	-5.0%	-2.9%	182%	122%	176,173	117,744
Ctax 0 to 80	7.699	5.159	-5.6%	-3.3%	181%	121%	174,972	117,247
Ctax 0 to 90	7.641	5.135	-6.3%	-3.8%	180%	121%	173,664	116,704
Ctax 0 to 100	7.589	5.114	-7.0%	-4.2%	179%	120%	172,478	116,217
Ctax 0 to 120	7.508	5.083	-8.0%	-4.7%	177%	120%	170,627	115,529
Ctax 0 to 140*	7.485	5.079	-8.2%	-4.8%	176%	120%	170,118	115,423
Ctax 0 to 160*	7.448	5.074	-8.7%	-4.9%	175%	119%	169,264	115,326
Ctax 0 to 180*	7.414	5.073	-9.1%	-4.9%	175%	119%	168,501	115,289
Ctax 0 to 200*	7.386	5.074	-9.4%	-4.9%	174%	119%	167,867	115,323
C&TVAOBA*	7.493	5.056	-8.1%	-5.2%	176%	119%	170,284	114,901
"w/ trading*	7.503	5.057	-8.0%	-5.2%	177%	119%	170,516	114,935
"w/ USBTAs*	7.542	5.049	-7.5%	-5.4%	178%	119%	171,420	114,740
"w/ no offsets*	7.444	5.054	-8.7%	-5.3%	175%	119%	169,181	114,862

* Canadian target of -17% from 2005 levels by 2020 met or exceeded, with 25% international offset purchases

Table 22: 2020 Labour expenditures, average salaries, consumption and welfare

	Labour expenditures $2005 billions 2005 = 1.823 billion		Average Salary $2005 2005 = ~$87,500		Consumption (% of BAU 2020)		Welfare (% of BAU 2020)	
Policy Code	MGP	No MGP	MGP	No MGP	MGP	No MGP	MGP	No MGP
BAU	2.856	2.191	117,059	103,897				
Ctax 0 to 10	2.830	2.174	115,966	103,079	-0.1%	0.0%	-0.1%	0.0%
Ctax 0 to 20	2.802	2.156	114,838	102,243	-0.3%	-0.1%	-0.2%	0.0%
Ctax 0 to 30	2.776	2.137	113,763	101,353	-0.4%	-0.1%	-0.3%	0.0%
Ctax 0 to 40	2.749	2.117	112,672	100,401	-0.5%	-0.1%	-0.4%	0.0%
Ctax 0 to 50	2.723	2.097	111,590	99,419	-0.6%	-0.2%	-0.5%	0.0%
Ctax 0 to 60	2.697	2.082	110,519	98,717	-0.7%	-0.2%	-0.5%	0.0%
Ctax 0 to 70	2.675	2.068	109,634	98,046	-0.8%	-0.2%	-0.6%	-0.1%
Ctax 0 to 80	2.652	2.054	108,702	97,417	-0.9%	-0.2%	-0.7%	-0.1%
Ctax 0 to 90	2.626	2.041	107,633	96,793	-1.0%	-0.3%	-0.7%	-0.1%
Ctax 0 to 100	2.603	2.029	106,680	96,210	-1.1%	-0.3%	-0.8%	-0.1%
Ctax 0 to 120	2.569	2.007	105,283	95,191	-1.2%	-0.3%	-0.8%	0.0%
Ctax 0 to 140*	2.559	1.994	104,893	94,575	-1.2%	-0.2%	-0.8%	0.0%
Ctax 0 to 160*	2.548	1.979	104,425	93,843	-1.2%	-0.1%	-0.8%	0.1%
Ctax 0 to 180*	2.538	1.967	104,036	93,286	-1.2%	0.0%	-0.8%	0.2%
Ctax 0 to 200*	2.531	1.959	103,737	92,879	-1.2%	0.0%	-0.8%	0.3%
C&TVAOBA*	2.695	2.052	110,470	97,330	-1.9%	-0.8%	-1.5%	-0.5%
"w/ trading*	2.664	2.042	109,188	96,858	-1.8%	-0.8%	-1.4%	-0.5%
"w/ USBTAs*	2.697	2.050	110,521	97,220	-1.8%	-0.9%	-1.5%	-0.6%
"w/ no offsets*	2.689	2.050	110,195	97,213	-2.0%	-0.8%	-1.7%	-0.5%

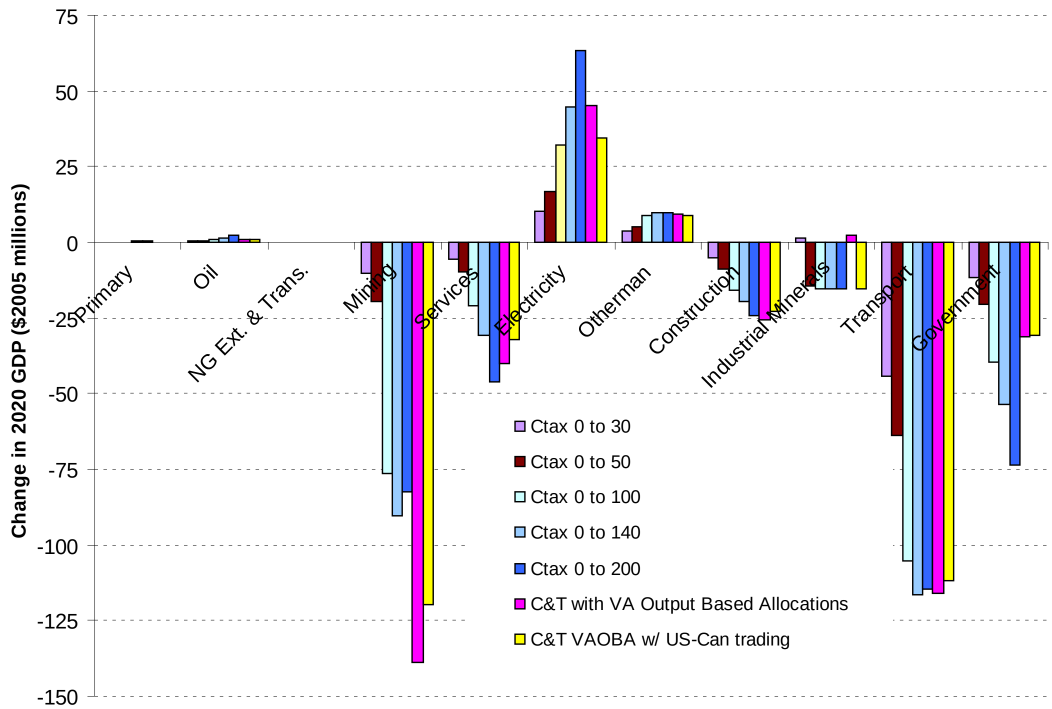
* Canadian target of -17% from 2005 levels by 2020 met or exceeded, with 25% international offset purchases

Figure 30 and Figure 31 show the effects of the carbon tax and cap and trade systems on the NWT's various industries, with and without the MGP. When the MGP is not built, the most affected sectors are the mining and transport sectors. In the mining sector GDP is projected to be about $2 billion by 2020. The cap and trade system reduces mining sector GDP by about $135 million, or 6.8%, while the carbon tax that meets the same target, (~$140/tonne) reduces mining sector GDP by about $80 million, or about 4% − 2.8% less impact than the cap and trade.

If the MGP is built (Figure 31) the natural gas extraction and transmission sector is the most affected by carbon pricing, in absolute terms. Its BAU 2020 GDP is approximately $2 billion; the cap and trade system reduces sector GDP by $434 million, or 22%, while the $140/tonne carbon tax reduces its value by about $385 million, or $19%. If Canadian firms are permitted to buy and sell emissions permits on the US market, then the effects of the carbon tax and cap and trade system are about the same.

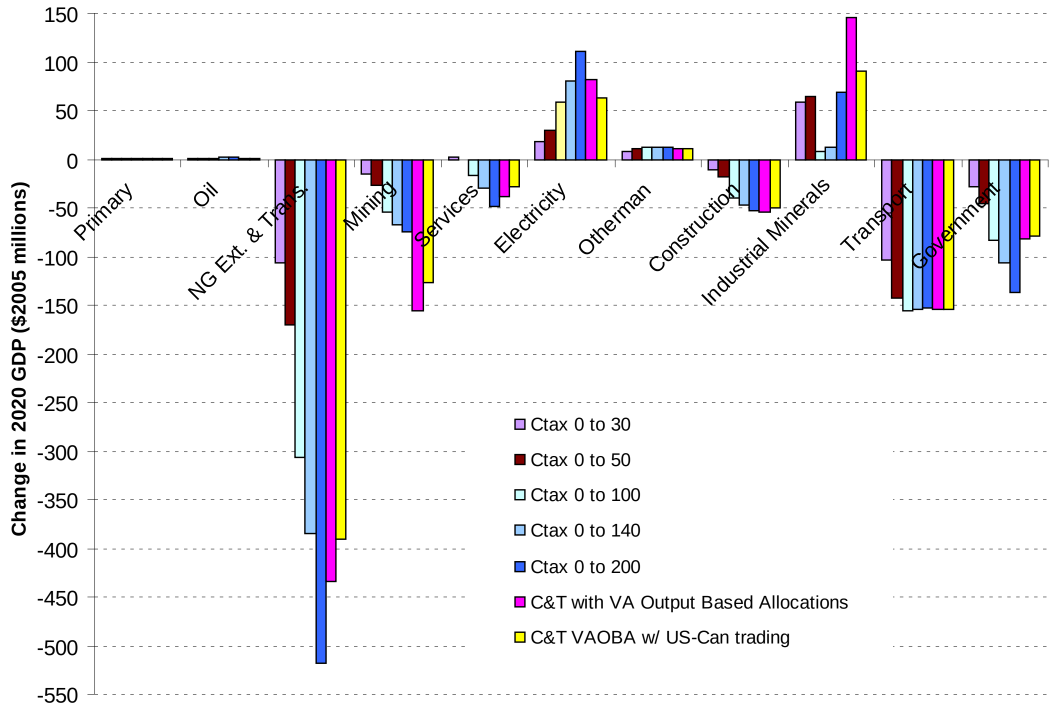
The electricity sector experiences increases in GDP in almost all policy and development scenarios. This is due to increased demand from hydropower facilities, efficiency investments in the fossil fuel driven electricity sector, and a slightly higher electricity price.

Figure 30 Industry impacts: Change in 2020 GDP with no MGP, $2005 billions



*BAU GDP for selected industries= Mining, $2.02 billion; Services, $1.24 billion; Electricity, $120 million; Construction, $480 million; Industrial minerals, $20 million; Transport, $280 million.

Figure 31 Industry impacts: Change in 2020 GDP with the MGP, $2005 billions



Appendix A: MGP Scenario Assumptions

This document describes the key assumptions for the upstream and downstream effects of the Mackenzie Gas Project (MGP) MGP that will be used to generate the MGP reference scenario.

Upstream assumptions

We assume that production from the MGP starts in 2020. Construction activities are not included in our forecast due to their short-term nature. Production volume is assumed to be 34 million cubic metres per day, based on the National Energy Board (NEB) 2009 reference case scenario to 2020.[32] We assume that production remains constant for the rest of the forecast period (to 2030), which aligns with Scenario 2 of the Wright Mansell report. Upstream emissions associated with this level of production are assumed to be 1.6 Mt CO_2e per year, based on the 2007 Pembina analysis.[33] Although the development of the MGP will likely spur further exploration and drilling of new wells (beyond that considered by the NEB) − and increase future emissions – we assume production from any such wells will not begin prior to 2030 (the end of our forecast period).

Note: Our analysis assumes the production levels presented in the NEB (2009) reference case, 34 Mm3/d (1.2bcf), which is equal to the capacity of the pipeline. It assumes that other known and discovered reserves will contribute to production over the lifetime of the MGP.[34] However, we acknowledge that other reports suggest that throughput may be lower in the absence of further field development.[35]

Downstream effects

GDP

- Based on analysis from the Wright Mansell report, we assume that the MGP, when operational, increases GDP by $ 1.9 million annually (2005$).[36]
  - The Wright Mansell report estimates the direct and indirect economic effects of the MGP using the Statistics Canada Interprovincial Input-Output Model (it does not estimate induced effects or the effect of increased income on demand).
  - Estimates from the report are combined with the Conference Board of Canada's[37] forecast for GDP in the NWT (which includes the development of

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[32] NEB, 2009, 2009 Reference Case Scenario: Canadian Energy Demand and Supply to 2020 - An Energy Market Assessment.
[33] Pembina, 2007, Mackenzie Gas Project Greenhouse Gas Analysis & Pacific Analytics Inc, 2006, The Mackenzie Gas Project: A Financial and Economic Assessment.
[34] Wright Mansell Research Ltd, 2007, An evaluation of the economic impacts associated with the Mackenzie Valley gas pipeline and Mackenzie Delta gas development, p.3.
[35] Pembina, 2007, Mackenzie Gas Project Greenhouse Gas Analysis; and
[36] Case 2, $6 natural gas price scenario in: Wright Mansell Research Ltd., 2007, An evaluation of the economic impacts associated with the Mackenzie Valley gas pipeline and Mackenzie Delta gas development.
[37] Conference Board of Canada (CBC), July 2010, Territorial Outlook: Economic Forecast.

MGP), to develop a forecast of territorial GDP with and without the MGP. We use these sources because they use assume similar production volumes as the NEB (reference case production) and allow us to develop two consistent forecasts of GDP with and without development of the MGP.[38]

- During years of full production, territorial GDP is assumed to be 53% higher in the MGP scenario. In our analysis, this increase affects activity in the freight transportation and commercial sectors, which are described later in the document.
- It should be noted that these GDP impacts are highly dependent on the price of natural gas. GDP impact analysis used in this study is based on a long-run price of natural gas of $6 (2006$ USD).[39]

Structural impacts

Population and employment

Development of the MGP will increase employment in the NWT, and although labour constraints in the territory mean that a substantial portion of jobs would be filled by migrants to the region (especially during the construction phase), most of them would likely not claim residency.[40] Much of the employment impact would also be short term (less than 5 years) because it is associated with construction. In this analysis, we do not forecast any increase in demand from the residential or personal transportation sectors resulting from population and/or employment growth associated with the MGP because (1) our analysis is concerned with long term trends and the largest employment impact would occur over the short-term; and (2) we have not found any estimates of long-term activity impacts for these sectors, including induced economic effects. However, this analysis does capture activity impacts in the freight transportation and commercial sector (discussed below).

Natural gas conversion (buildings and electricity generation)

- Encor's 2008 *McKenzie Valley Gas Conversion Feasibility Study* found that it is both technically and economically feasible to convert three communities (Tulita, Fort Good Hope and Fort Simpson) to natural gas with supply from the MGP. For this scenario, we therefore assume that natural gas displaces oil and diesel consumption for space and water heating, as well as electricity generation in these communities.
    - The cost and capacity of the reciprocating natural gas units used to generate electricity in these communities will be informed by data from this study (which

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[38] In particular, we do not base any assumptions on the 2007 Pacific Analytics Inc. report because (1) it is based on lower production volumes (about 24 million cubic meters per day) and is not consistent with our other data sources; and (2) in any case, it uses the input-output results of the Wright Mansell report.
[39] The Wright Mansell Report (2007) Case #2 assumes that the price of natural gas remains constant (in real terms) at $6/Mcf.
[40] CBC, 2010, p. 18.

predicted combined peak load for these communities to be about 3,240kW in 2030).

- Installation of natural gas generation capacity is assumed to occur immediately upon opening of the MGP in 2020, while installation of heating technologies is assumed to occur when existing units meet the end of their lifespan.
    - Avoiding the premature replacement of heating technologies will reduce customer conversion costs; a factor not considered in the Encor study.
    - In the residential sector, we assume the average lifespan of oil-fired water heaters and furnaces to be 9 and 17 years, respectively, while in the commercial sector, the average lifespan is 10 and 25 years respectively.
- Conversion to natural gas will likely lower energy costs for these communities, due in part to an expectation that natural gas delivered from the pipeline to NWT communities will pay a discounted toll.[41]
- Conversion to natural gas is also likely to lower community emissions. For example, generating one GJ of electricity from natural gas produces roughly 47% less greenhouse gas emissions compared to generating an equivalent amount with diesel.[42]

Activity effects

Freight transportation

Demand for freight transport in NWT is closely linked to activity in the mining, oil and gas sector. Off-road, heavy truck, rail and barge transport are particularly sensitive to production in these sectors. In the initial stages of the MGP demand for freight transport is expected to increase significantly for the first three years of development (Figure 32).[43] As the figure shows, impacts from the MGP are acute, producing only a short-term spike in demand that tapers off by the fifth year of development. Based on analysis in *the Logistics Opportunities and Transportation Impacts Report* (2005), we assume that MGP will produce no **direct impacts** on freight demand, as direct impacts are projected to be <5 years.

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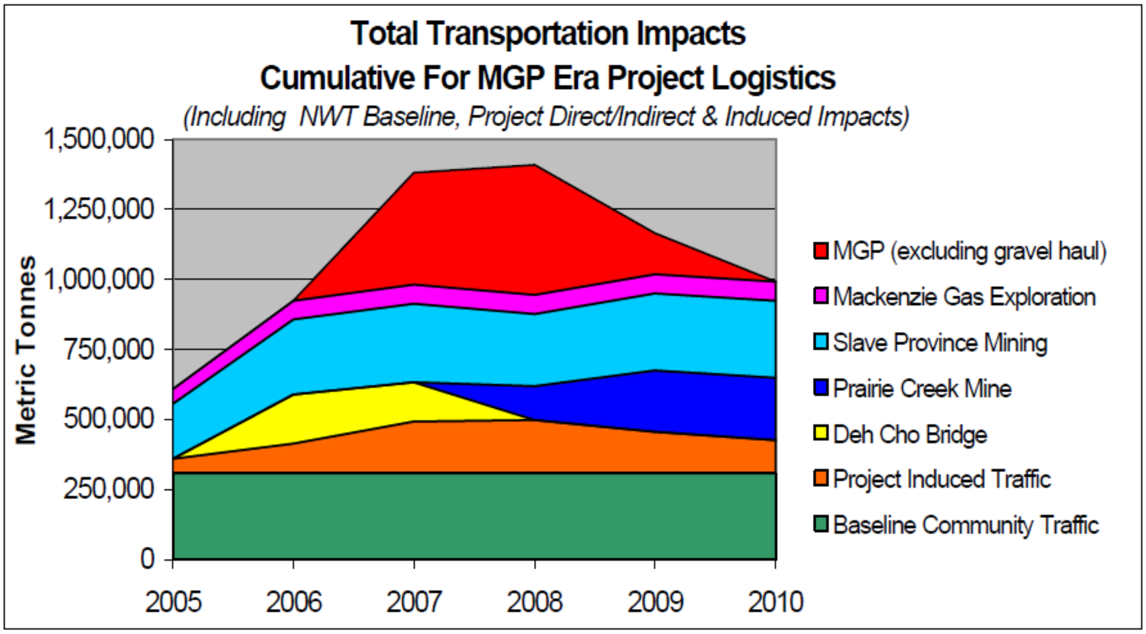
[41] The NWT gas price from the MGP is expected to be equivalent to the "AECO price, less the full TCPL Alberta toll, less half the MGP toll plus fuel for MGP transportation. Equivalently this is the field price plus half the MGP Toll plus fuel (Encor International Inc, 2008, p. 22).

[42] Calculation based on the emissions intensity of a single cycle natural gas turbine and a diesel generation unit.

[43] ProLog Canada, 2005, Logistics opportunities and transportation impacts.

Figure 32: Freight transport impact of MGP − Figure 11 from *Logistic opportunities and transportation impacts (2005), p.58*



While demands from the mining, oil and gas sectors dominate freight activity, a portion of freight demand can also be linked to GDP growth in other sectors of the economy, particularly the commercial sector. As a result of GDP growth, activity in the commercial sector is anticipated to increase with the MGP. In the MGP scenario, freight activity is assumed to increase relative to growth in the commercial sector.[44] Table 23 shows forecasted demand for freight transportation in both scenarios from 2010 to 2030.

Table 23: Freight transportation activity forecast

Scenario	*2010-2015*	*2015-2020*	*2020-2025*	*2025-2030*
Million tkt				
MGP	1,629	1,875	1,986	2,115
No MGP	1,561	1,516	1,607	1,710

[44] Calculation of the MGP impact in the freight sector is a function of GDP impacts on the commercial sector and the relative contributions of GDP from the commercial sector to economy-wide GDP.

Commercial

- Activity in the commercial sector is driven by growth of GDP. In line with GDP growth from the development of the MGP, the commercial sector can also be expected to expand. Table 4 summarizes the forecast growth rates of floor space for the MGP and no MGP scenario. Based on trends in physical building footprints, between 2010 and 2030, commercial floor space grows by approximately 10% in the no MGP scenario, and by 30% in the MGP scenarios. This expansion is driven by growth in the transportation and warehousing, and office subsectors.

Table 24: Annual growth in the commercial sector

Scenario	*2010-2015*	*2015-2020*	*2020-2025*	*2025-2030*
MGP	1.7%	3.1%	0.8%	0.8%
No MGP	0.5%	1.0%	0.8%	0.8%

Appendix B: CIMS and GEEM

The CIMS Model

CIMS has a detailed representation of technologies that produce goods and services throughout the economy and attempts to simulate capital stock turnover and choice between these technologies realistically. It also includes a representation of equilibrium feedbacks, such that supply and demand for energy intensive goods and services adjusts to reflect policy.

CIMS simulations reflect the energy, economic and physical output, GHG emissions, and CAC emissions from its sub-models as shown in Table 25. CIMS does not include adipic and nitric acid, solvents or hydrofluorocarbon (HFC) emissions. CIMS covers nearly all CAC emissions except those from open sources (e.g., forest fires, soils, and road dust).

Table 25: Sector Sub-models in CIMS

Sector	BC	Alberta	Sask.	Manitoba	Ontario	Quebec	Atlantic
Residential	■	■	■	■	■	■	■
Commercial/Institutional	■	■	■	■	■	■	■
Personal Transportation	■	■	■	■	■	■	■
Freight Transportation	■	■	■	■	■	■	■
Industry							
Chemical Products	■	■			■	■	
Industrial Minerals	■	■			■	■	■
Iron and Steel					■	■	
Non-Ferrous Metal Smelting*	■			■	■	■	■
Metals and Mineral Mining	■		■	■	■	■	■
Other Manufacturing	■	■	■	■	■	■	■
Pulp and Paper	■	■			■	■	■
Energy Supply							
Coal Mining	■	■	■				■
Electricity Generation	■	■	■	■	■	■	■
Natural Gas Extraction	■	■	■	■	■	■	■
Petroleum Crude Extraction	■	■	■		■		■
Petroleum Refining	■	■	■		■	■	■
Agriculture & Waste	■	■	■	■	■	■	■

* Metal smelting includes Aluminium.

Model structure and simulation of capital stock turnover

As a technology vintage model, CIMS tracks the evolution of capital stocks over time through retirements, retrofits, and new purchases, in which consumers and businesses make sequential acquisitions with limited foresight about the future. This is particularly important for understanding the implications of alternative time paths for emissions reductions. The model calculates energy costs (and emissions) for each energy service in the economy, such as heated commercial floor space or person kilometres travelled. In each time period, capital stocks are retired according to an age-dependent function (although retrofit of un-retired stocks is possible if warranted by changing economic conditions), and demand for new stocks grows or declines depending on the initial exogenous forecast of economic output, and then the subsequent interplay of energy supply-demand with the macroeconomic module. A model simulation iterates between energy supply-demand and the macroeconomic module until energy price changes fall below a threshold value, and repeats this convergence procedure in each subsequent five-year period of a complete run.

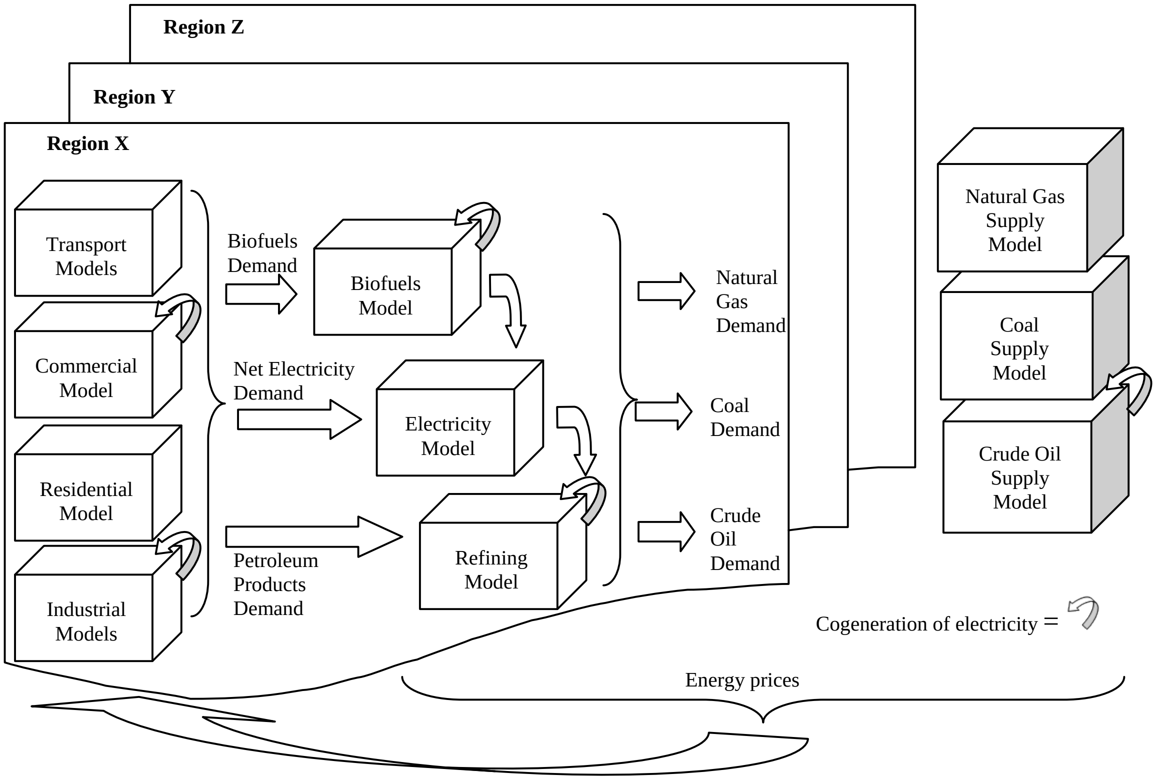
CIMS simulates the competition of technologies at each energy service node in the economy based on a comparison of their life cycle cost (LCC) and some technology-specific controls, such as a maximum market share limit in the cases where a technology is constrained by physical, technical or regulatory means from capturing all of a market. Instead of basing its simulation of technology choices only on financial costs and social discount rates, CIMS applies a definition of LCC that differs from that of bottom-up analysis by including intangible costs that reflect consumer and business preferences and the implicit discount rates revealed by real-world technology acquisition behaviour.

Equilibrium feedbacks in CIMS

CIMS is an integrated, energy-economy equilibrium model that simulates the interaction of energy supply-demand and the macroeconomic performance of key sectors of the economy, including trade effects. Unlike most computable general equilibrium models, however, the current version of CIMS does not equilibrate government budgets and the markets for employment and investment. Also, its representation of the economy's inputs and outputs is skewed toward energy supply, energy intensive industries, and key energy end-uses in the residential, commercial/institutional and transportation sectors.

CIMS estimates the effect of a policy by comparing a business-as-usual forecast to one where the policy is added to the simulation. The model solves for the policy effect in two phases in each run period. In the first phase, an energy policy (e.g., ranging from a national emissions price to a technology specific constraint or subsidy, or some combination thereof) is first applied to the final goods and services production side of the economy, where goods and services producers and consumers choose capital stocks based on CIMS' technological choice functions. Based on this initial run, the model then calculates the demand for electricity, refined petroleum products and primary energy commodities, and calculates their cost of production. If the price of any of these commodities has changed by a threshold amount from the business-as-usual case, then supply and demand are considered to be out of equilibrium, and the model is re-run based on prices calculated from the new costs of production. The model will re-run until a new equilibrium set of energy prices and demands is reached. Figure 33 provides a schematic of this process. For this project, while the quantities produced of all energy commodities were set endogenously using demand and supply balancing, endogenous pricing was used only for electricity and refined petroleum products; natural gas, crude oil and coal prices remained at exogenously forecast levels (described later in this section), since Canada is assumed to be a price-taker for these fuels.

Figure 33: CIMS energy supply and demand flow model



In the second phase, once a new set of energy prices and demands under policy has been found, the model measures how the cost of producing traded goods and services has changed given the new energy prices and other effects of the policy. For internationally traded goods, such as lumber and passenger vehicles, CIMS adjusts demand using price elasticities that provide a long-run demand response that blends domestic and international demand for these goods (the "Armington" specification).[45] Freight transportation is driven by changes in the combined value added of the industrial sectors, while personal transportation is adjusted using a personal kilometres-travelled elasticity (-0.02). Residential and commercial floor space is adjusted by a sequential substitution of home energy consumption vs. other goods (0.5), consumption vs. savings (1.29) and goods vs. leisure (0.82). If demand for any good or service has shifted more than a threshold amount, supply and demand are considered to be out of balance and the model re-runs using these new demands. The model continues re-running until both energy and goods and services supply and demand come into balance, and repeats this balancing procedure in each subsequent five-year period of a complete run.

Empirical basis of parameter values

Technical and market literature provide the conventional bottom-up data on the costs and energy efficiency of new technologies. Because there are few detailed surveys of the annual energy consumption of the individual capital stocks tracked by the model

[45] CIMS' Armington elasticities are econometrically estimated from 1960-1990 data. If price changes fall outside of these historic ranges, the elasticities offer less certainty.

(especially smaller units), these must be estimated from surveys at different levels of technological detail and by calibrating the model's simulated energy consumption to real-world aggregate data for a base year.

Fuel-based GHGs emissions are calculated directly from CIMS' estimates of fuel consumption and the GHG coefficient of the fuel type. Process-based GHGs emissions are estimated based on technological performance or chemical stoichiometric proportions. CIMS tracks the emissions of all types of GHGs, and reports these emissions in terms of carbon dioxide equivalents.[46]

Both process-based and fuel-based CAC emissions are estimated in CIMS. Emissions factors come from the US Environmental Protection Agency's FIRE 6.23 and AP-42 databases, the MOBIL 6 database, calculations based on Canada's National Pollutant Release Inventory, emissions data from Transport Canada, and the California Air Resources Board.

Estimation of behavioural parameters is through a combination of literature review and judgment, supplemented with the use of discrete choice surveys for estimating models whose parameters can be transposed into CIMS behavioural parameters.

Simulating endogenous technological change with CIMS

CIMS includes two functions for simulating endogenous change in individual technologies' characteristics in response to policy: a declining capital cost function and a declining intangible cost function. The declining capital cost function links a technology's financial cost in future periods to its cumulative production, reflecting economies-of-learning and scale (e.g., the observed decline in the cost of wind turbines as their global cumulative production has risen). The declining capital cost function is composed of two additive components: one that captures Canadian cumulative production and one that captures global cumulative production. The declining intangible cost function links the intangible costs of a technology in a given period with its market share in the previous period, reflecting improved availability of information and decreased perceptions of risk as new technologies become increasingly integrated into the wider economy (e.g., the "champion effect" in markets for new technologies); if a popular and well respected community member adopts a new technology, the rest of the community becomes more likely to adopt the technology.

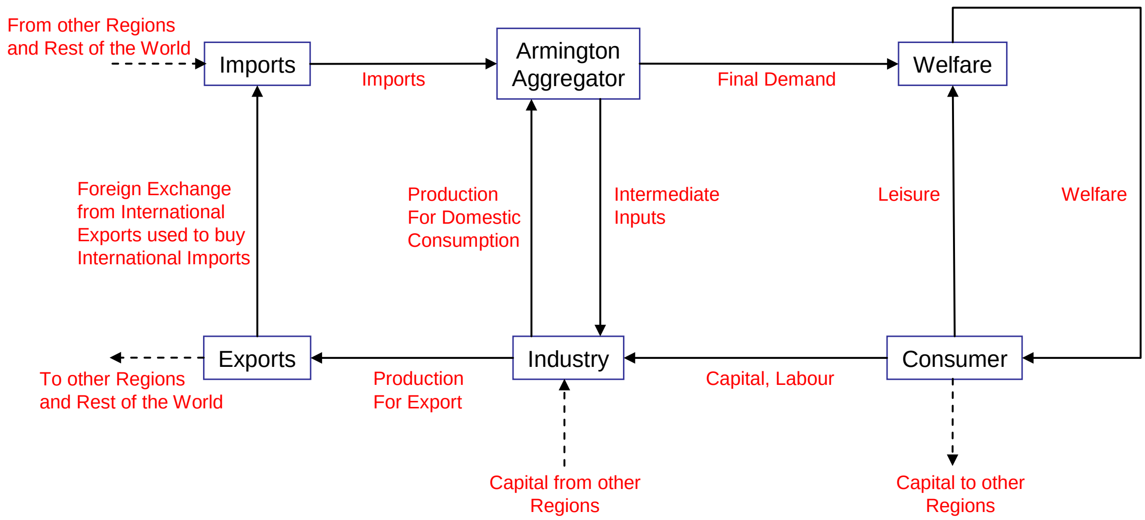
The GEEM Model

This model is essentially a sophisticated input-output economic model that balances supply and demand for commodities and services in all markets by solving for prices. Our current GEEM model represents British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Atlantic Canada and the United States as separate regions, and each of these regions interact through trade of commodities and services. Capital is

[46] CIMS uses the 2001 100-year global warming potential estimates from Intergovernmental Panel on Climate Change, 2001, "Climate Change 2001: The Scientific Basis", Cambridge, UK, Cambridge University Press.

assumed to be mobile among regions within North America, while labour is assumed to be mobile within Territorys or states. In the model, a representative household in each region is the owner of primary factors (labour, capital and natural resources) which they rent to producers who combine them with intermediate inputs to create commodities. Commodities can be sold to other producers (as intermediate inputs), to final consumers, or to other regions and the rest of the world as exports. Commodities can also be imported from other regions or the rest of the world. The key economic flows in GEEM are captured schematically in Figure 34.

Figure 34: Overall structure of the GEEM model



The current version of GEEM is dynamic and solves in annual increments from 2005 to 2020. One of the benefits of using a dynamic model is it can simulate policies that change over time as well as producing results for multiple years. For example, it can simulate carbon taxes that rise over time, or regulatory policies (e.g., requirements for carbon capture and storage) implemented in a certain year. Although the model currently solves to 2020, it can be updated to simulate to a future period (e.g., 2050). Furthermore, the model simulates capital accumulation over time, and adjusts savings (and therefore investment) based on the rate of return to capital.

The data underlying the model is derived primarily from the Statistics Canada System of National Accounts. We use the S-Level Input, Output, and Final Demand tables to populate the model, and aggregate these somewhat to focus on sectors of primary interest. One of the challenges with the S-Level data is its lack of disaggregation for energy and emissions intensive sectors. We disaggregate these sectors using the M- and L-Level data from Statistics Canada, Statistics Canada's Report on Energy Supply and Demand, CAPP's production data for oil and gas production, MKJA's CIMS energy economy model, among other sources.

The following sections describe our representation of industry, consumers and trade between Territory's and countries.

Industry

The GEEM model represents 21 industries. Alternative aggregations may be available upon request. The table also shows the data from Statistics Canada’s input-output tables on which the sectors are based.

Table 35: Industries in GEEM

GEEM Code	***GEEM Sector Description***	***Data Available for AB at the S-Level***
PEXT	Crop and animal production	Crop and animal production
	Forestry and logging	Forestry and logging
	Fishing, hunting and trapping	Fishing, hunting and trapping
	Support activities for agriculture and forestry	Support activities for agriculture and forestry
OSMU	Oil Sands Upgraded	Mining and oil and gas extraction
OSIS	Oil Sands In-situ	
OCLM	Oil Light Medium	
OCHY	Oil Heavy	
CNGAS	Conventional Natural Gas Extraction	
TNGAS	Tight Natural Gas Extraction	
SNGAS	Shale Natural Gas Extraction	
MINING	Coal and Mineral Mining	
SOGM	Support activities for mining and oil and gas extraction	
CELEC	Conventional electric power generation	Utilities
RELEC	Hydroelectric and other renewable electric power generation	
PAPER	Paper manufacturing	Manufacturing
REFINE	Petroleum and coal products manufacturing	
CHEM	Chemical manufacturing	
INDMIN	Non-metallic mineral product manufacturing	
METAL	Primary metal manufacturing	
OMAN	Miscellaneous manufacturing	
TRANSIT	Transit and ground passenger transportation	Transportation and warehousing
TRANS	Other Transportation	
	Transportation margins	Transportation margins

GEEM Code	*GEEM Sector Description*	*Data Available for AB at the S-Level*
SERV	Natural gas distribution, water and other systems	Utilities
	Construction	Construction
	Wholesale trade	Wholesale trade
	Retail trade	Retail trade
	Information and cultural industries	Information and cultural industries
	Finance, insurance, real estate and rental and leasing	Finance, insurance, real estate and rental and leasing
	Professional, scientific and technical services	Professional, scientific and technical services
	Administrative and support, waste management and remediation services	Administrative and support, waste management and remediation services
	Educational services	Educational services
	Health care and social assistance	Health care and social assistance
	Arts, entertainment and recreation	Arts, entertainment and recreation
	Accommodation and food services	Accommodation and food services
	Other services (except public administration)	Other services (except public administration)
	Operating, office, cafeteria, and laboratory supplies	Operating, office, cafeteria, and laboratory supplies
	Travel and entertainment, advertising and promotion	Travel and entertainment, advertising and promotion
	Non-profit institutions serving households	Non-profit institutions serving households
GOVT	Government sector	Government sector

All industrial sectors in the GEEM model are represented by constant elasticity of substitution (CES) functions, which represent the technologies industry can use to produce goods and services. Central to this function are the elasticity of substitution parameters which represent how easily a sector can substitute between different inputs while maintaining a given level of production. For example, the model simulates a tradeoff between energy consumption and value added (i.e., capital and labour) through the elasticity parameter labelled σ_{vae} in Figure 2: **Structure of industrial sectors in GEEM**

. A low value for σ_{vae} indicates that the value added bundle is not very substitutable for energy; and the energy intensity of the sector is largely unaffected by new economic conditions or policies. A high value for σ_{vae} indicates greater substitution possibilities; and economic conditions or policies that raise the price for energy relative to the price for the value-added bundle induce improvements in energy efficiency.

To model resource extraction sectors, we introduce the concept of "resource rent", which is profit earned by resource sectors that exceeds a normal rate of return on investment. Resource extraction sectors earn extra profits (some of which is collected by government in the form of royalties) because the resource they extract is scarce and resource plays have different costs of extraction. In other words, unlike manufactured commodities there is a finite amount resource to extract, such that buyers pay a premium that reflects the scarcity of the commodity. In addition, resource plays differ in their costs of extraction (quality), such that owners of easy to extract (high quality) resources earn additional profits relative to owners of resources that are more difficult to extract. For example, oil extraction from a conventional well would yield greater resource rent per unit of oil production than oil sands mining and upgrading (which has higher costs of extraction).

We use the concept of resource rent to characterize the supply curve for resources. As illustrated in Figure 2, we simulate the ability of a resource sector to substitute between the amount of a fixed resource and other inputs into production, which is represented by the elasticity value σ_{rr}. If the price for the resource increases, the value of the resource rent (extra profits) for a given level of production increases. Assuming the price for other inputs into production stays constant, the model will simulate an increase in production by shifting away from the fixed resource towards greater inputs. This reflects industry moving towards more marginal resources. In an alternative scenario where the costs of extraction increase (due to the adoption of carbon capture and storage for example), the cost of inputs becomes more costly in comparison to the resource and the model simulates that the marginal resources will not be developed.

The value of all elasticity values used to parameterize the model are illustrated in Table 2: **Elasticities of substitution by sector**

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Figure 2: Structure of industrial sectors in GEEM

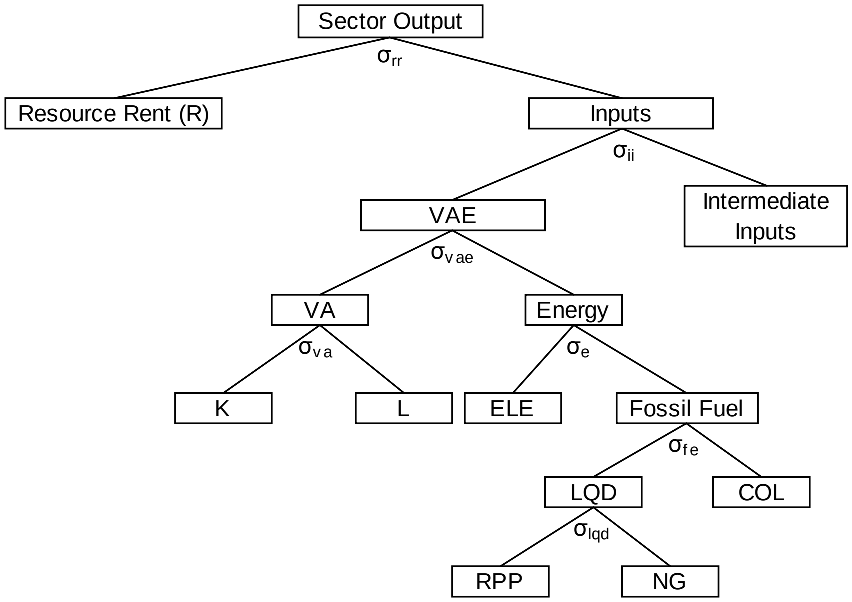

Table 2: Elasticities of substitution by sector

	σ_{rr}	σ_{ii}	σ_{vae}	σ_{va}	σ_{e}	σ_{fe}	σ_{lqd}
PEXT	0.6	0.2	0.5	0.55	1.08	0	1.17
OSMU	0.6	0.2	0.1	0.55	0.2	0.3	1.01
OSIS	0.6	0.2	0.1	0.55	0.2	0.3	1.01
OCLM	0.6	0.2	0.1	0.55	0.2	0.3	1.01
OCHY	0.6	0.2	0.1	0.55	0.2	0.3	1.01
CNGAS	0.6	0.2	0.1	0.55	0.2	0.3	1.01
TNGAS	0.6	0.2	0.1	0.55	0.2	0.3	1.01
SNGAS	0.6	0.2	0.1	0.55	0.2	0.3	1.01
MINING	0.6	0.2	0.1	0.55	0.2	0.3	1.01
CELEC	0	0.2	1.25	0.55	0.4	1	0.1
RELEC	0.6	0.2	0	0.55	0	0	0
PAPER	0	0.2	0.26	0.55	0.2	0.3	1.2
REFINE	0	0.2	0.26	0.55	0.2	0.3	1.2
CHEM	0	0.2	0.26	0.55	0.2	0.3	1.2
INDMIN	0	0.2	0.26	0.55	0.2	0.3	1.2
METAL	0	0.2	0.26	0.55	0.2	0.3	1.2
OMAN	0	0.2	0.45	1.1	0.4	0.3	1.2

	σ_{rr}	σ_{ii}	σ_{vae}	σ_{va}	σ_{e}	σ_{fe}	σ_{lqd}
TRANSIT	0	0.2	0.27	1.1	0.49	0.8	1
TRANS	0	0.2	0.27	1.1	0.49	0.8	1
SERV	0	0.2	0.35	1.1	0.2	0.5	1
GOVT	0	0.2	0.35	1.1	0.2	0.5	2.5

Source: CIMS, 2009 and Paltsev, 2005

An additional feature of the GEEM model is we include "alternative" methods of producing goods and services from sectors with specific abatement technologies (e.g., carbon capture and storage and enhanced oil recovery). These technologies are unprofitable in the reference case and only become active under certain economic or policy conditions (e.g., carbon pricing or high prices for oil that warrant the adoption of EOR). Table 3 shows the key sectors and processes in which carbon capture and storage is available.

Table 3: Sectors and process which include a CCS option

Sector	*Process*
Oil Sands Mining and Upgrading	Hydrogen production
	Heat production
Oil Sands In-situ	Heat production
Natural Gas Processing	Formation CO_2 removal
	Heat production
Electricity Generation	Baseload Coal
	Baseload NG
	Shoulderload Coal
	Shoulderload NG
Non-metallic minerals	Kiln operations
Petroleum Refining	Hydrogen production
	Heat production

In the GEEM model, all industries maximize profits (i.e., revenue minus costs of production) subject to technology constraints through Lagrangian optimization.

Consumers

GEEM uses a representative agent framework, where all households are represented by a single representative agent. In this framework, the representative agent maximizes his/her welfare, where welfare is a function of consumption of various commodities and leisure (see Figure 25 for the tree structure and Table 26 for the associated elasticity values). Note that the tree representing space heating, appliances and other goods is similar to the tree representing transportation, and therefore are not shown in. Most of the elasticity values have been econometrically estimated from MKJA's CIMS energy-economy model, while the values representing the substitutability between an end-use and other goods ($\sigma_{transit}$) are from Paltsev (2005).

Figure 36: Structure of household welfare

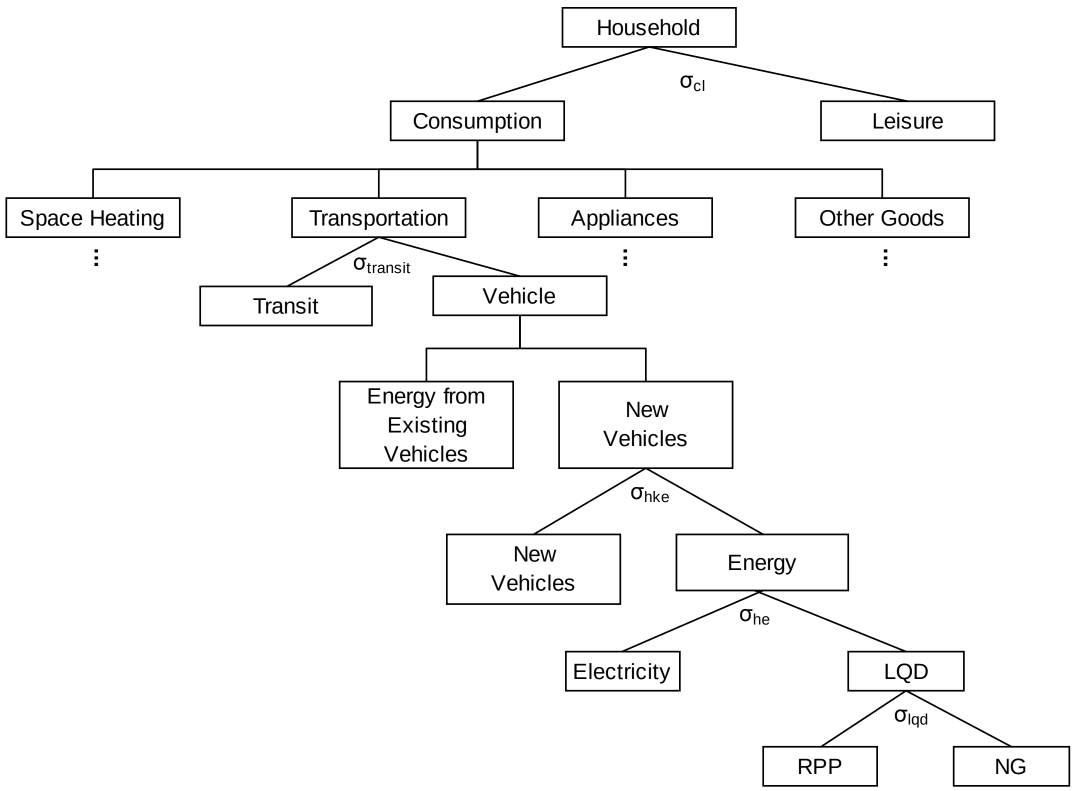

Table 26: Elasticities of substitution for households

<table>
<tr><th></th><th>σ_{cl}</th><th>$\sigma_{transit}$</th><th>σ_{hke}</th><th>σ_{he}</th><th>σ_{lqd}</th></tr>
<tr><td>Space Heating</td><td rowspan="4">0.6</td><td>0</td><td>3.3</td><td>7.0</td><td>3.4</td></tr>
<tr><td>Transportation</td><td>0.2</td><td>2.0</td><td>7.5</td><td>0</td></tr>
<tr><td>Appliances</td><td>0</td><td>0.1</td><td>0</td><td>0</td></tr>
<tr><td>Other Goods</td><td>0.25</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Source: CIMS, 2009 and Paltsev, 2005

The representative agent in GEEM maximizes his/her welfare subject to available income through Lagrangian optimization.

Trade

The substitutability between domestically produced and imported goods is represented by an Armington formulation (see Figure 37 for the structure of imports and Table 27 for the corresponding elasticity values). An elasticity of infinity indicates that a commodity is homogeneous and Alberta is complete price taker. This is important to represent crude oil in international markets and natural gas in North American markets.

Figure 37: Structure of imports

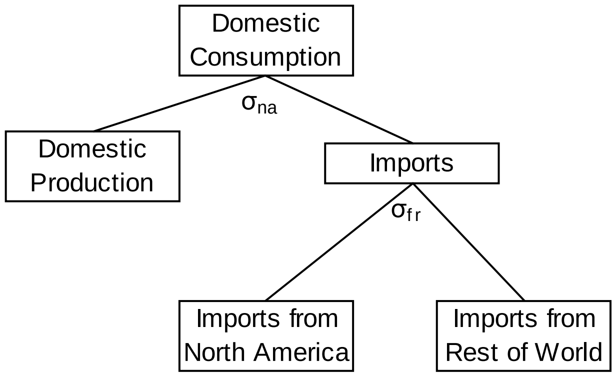

Table 27: Armington elasticities

	σ_{na}	σ_{fr}
Crude Oil	∞	∞
Natural Gas	∞	4.0
Other Energy	4.0	4.0
Other Goods	2.5	2.5

Source: Bohringer and Rutherford (2002)

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Appendix C: Reference Case Wedge Diagrams

Figure 38: Reference case wedge diagram (T0)

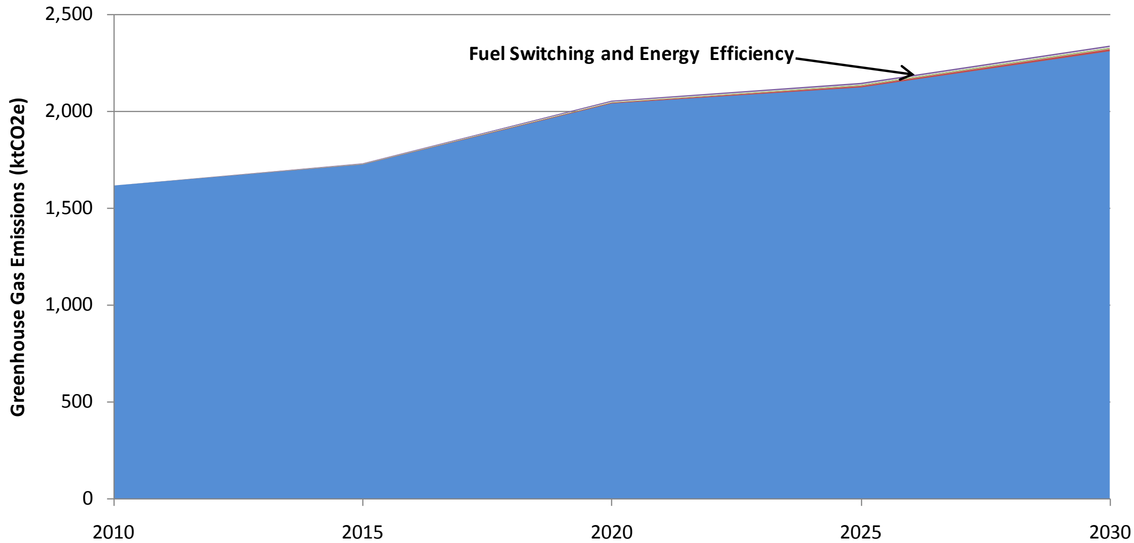

Figure 38 shows the wedge diagram for the reference case scenario. The wedge diagram shows the emissions reductions achieved through reference case policies (i.e., building codes, vehicle emissions standard, and efficiency subsidies − see section "Policies Included in the Reference Case" for addition detail). The impact of the reference case are modest because a) building codes only impact a portion of new stock, and b) because the vehicle emissions standard is assumed to be held constant after 2016, and by 2030 reference case policies reduce emissions approximately 9 Kt CO2e lower than business as usual (a scenario where no policies, including proposed policies are implemented). Fuel switching to renewables and energy efficiency are responsible for the majority of abatement from the reference case policies.