FINAL

Assessing Emission Reductions from Potential Climate Policies in the Northwest Territories:

Sector-specific "wedge diagrams"

May, 2011

Prepared for:
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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 inform its targets, M. K. Jaccard and Associates, Inc. (MKJA) was selected to perform a decomposition analysis of potential abatement over the next two decades. The analysis will assist the GNWT in setting targets that are both realistic and achievable.

A decomposition analysis, also known as "wedge diagram analysis," identifies the key actions that are likely to generate emissions reductions when stimulated by policy. For example, building codes and subsidies for solar hot water heaters are likely to generate emissions reductions from improved building shell efficiency and substitution of carbon-intensive fuel oil with zero-emissions solar energy.

A wide range of policies and initiatives can encourage abatement in all sectors of the Northwest Territories (NWT) economy. In its last greenhouse gas strategy, the GNWT identified a list of policies to reduce territorial emissions. Since its release that list has grown, as the GNWT continues to expand the breadth and scope of abatement initiatives in the territories.

The Analysis

This analysis builds on a previous MKJA study of the NWT. The study, *An Exploration into the Impact of Carbon Pricing in the Northwest Territories*, completed in March 2011, forecasted territorial emissions without climate policy and assessed the magnitude of future emissions reductions achieved by different strengths of carbon pricing. The present study expands on this analysis by assessing the full range of current and proposed GNWT policies.

In preparation for setting greenhouse gas emissions targets, the GNWT is interested in investigating the effectiveness of current, proposed, and future energy and climate initiatives. In particular, the GNWT would like to understand the potential emission reductions that could be achieved with these policies. Using wedge diagrams, this report identifies the key abatement actions stimulated by a suite of GNWT policies (see Table 11 for an overview of the policies). Two distinct methodologies are used to estimate policy effectiveness (i.e., territorial and sectoral abatement). Combined, the following two approaches produce a comprehensive review of mid-term (2030) abatement in the region:

- The first approach uses the CIMS model, which estimates policy effectiveness in light of differences in consumer/firm preference, risk perception, and policy interaction.
- The second approach is developed in conjunction with the GNWT and estimates policy effectiveness in light of regional variation.

Sectoral wedge diagrams are produced with each approach. The result is an economy-wide wedge diagram that illustrates the effectiveness of announced, proposed and future policy implementation over the next two decades. In this study, abatement illustrated with the wedge diagrams refers to emission reductions relative to a future where no energy and climate policies are pursued, "the reference case".

The report is structured as follows. First, the reference case forecast is described in terms of both key assumptions and model outputs. Second, we detailed the results of the policy analysis, and highlight key abatement actions with wedge diagrams. Third we contrast emissions growth in the NWT to other regions in Canada. Finally, we conclude with a discussion of study findings.

A Future with No Policy

This section presents the assumptions and outputs that define the reference case developed in the CIMS energy-economy model. A reference case forecast describes how the economy may evolve in the absence of any policies aimed at reducing energy consumption or greenhouse gas emissions. It is also a benchmark for assessing policy effectiveness (i.e., effective policy generates energy and emissions reductions from levels described in the reference case).

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 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.

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), including outputs from anticipated or planned developments (i.e., the Mackenzie Gas Project (MGP)). Assumptions in this report were developed in conjunction with the GNWT, and reflect a combination of GNWT and publically available data sources.

The reference case presented in this study differs from previous analysis (MKJA, 2011)[1] primarily in its treatment of future renewable power capacity and the MGP development. In this reference case we assume that no additional renewable electricity capacity is constructed, and we assume that the MGP is developed (in the previous analysis the reference case excluded its development). Construction of the MGP begins in 2015 with

[1] MKJA, 2011, An Exploration into the Impact of Carbon Pricing in the Northwest Territories: Reference Case & Quantitative Policy Analysis, prepared for the Government of the Northwest Territories March, 2011.

production levels of 34 million cubic metres per day starting in 2020.[2] Table 1 summarizes the sector forecasts used in the reference case. 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. The following discussion summarizes the reference case economic output forecast used in this report. To accommodate project timelines, material from the previous analysis is used where assumptions are consistent.

Table 1: Reference case output forecast

	Units	*2010*	*2015*	*2020*	*2025*	*2030*
Macroeconomic						
Population	*thousands of people*	43.7	45.3	46.6	47.5	48.2
GDP	*basic prices ($2005 million)*	3,692	4,193	5,563	6,253	7,099
Demand Sectors						
Residential	*thousands of households*	14.6	15.5	16.2	16.8	17.2
Commercial	*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	1,629	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	34,002	34,002	34,002
Crude Oil	*thousand barrels / day*	14.6	11.3	8.7	6.7	5.2

Note: Generally, assumptions related to the effects of the MGP were derived from the Conference Board of Canada[3] and the Wright Mansell report.[4]

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 2 summarizes the estimated share of floor space occupied by subsector, as well as the forecasted growth rate of floor space. Based on trends in physical building footprints, commercial floor space grows by approximately 37% between 2010 and 2030, 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

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[2] Wright Mansell Research Ltd., 2007, An evaluation of the economic impacts associated with the Mackenzie Valley gas pipeline and Mackenzie Delta gas development.

[3] Conference Board of Canada, July 2010, Territorial Outlook: Economic Forecast.

[4] Wright Mansell Research Ltd., 2007, An evaluation of the economic impacts associated with the Mackenzie Valley gas pipeline and Mackenzie Delta gas development.

British Columbia and the Territories, and energy consumption data from Statistics Canada.

Table 2: Share of total floor space and annual growth in the commercial sector, by subsector

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%. 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. By 2030 demand for freight transportation is boosted substantially, reaching 1.88 billion tonne-kilometres in 2020 and 2.12 billion in 2030, from 1.53 in 2010. Average annual growth of tonne-kilometres over the forecast period is 1.3%.

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

[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.

presently undergoing environmental assessment. The production assumptions for these mines are summarised in Table 3.

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.

Table 3: 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.

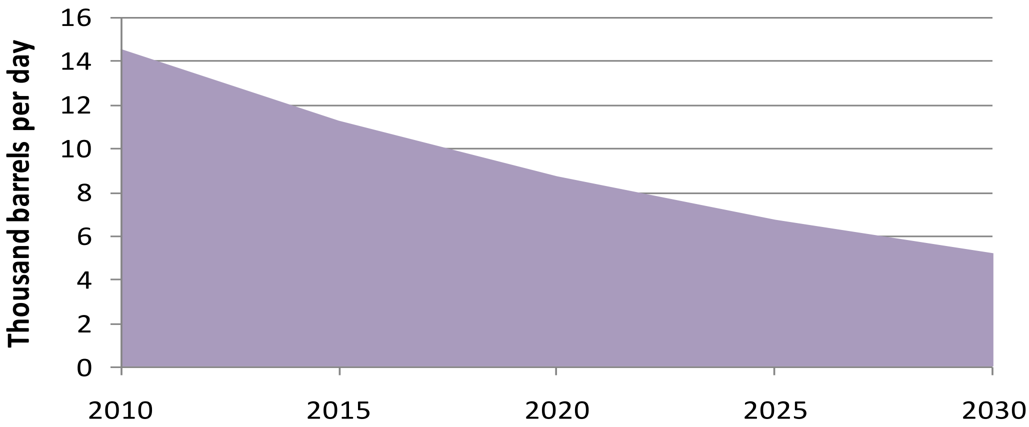
We have taken a conservative approach to modeling future mining development. Therefore the assumptions used to develop the mining forecast can be considered an aggressive or optimistic forecast. If future production is lower than what is forecasted in this analysis, it is likely that projected emissions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

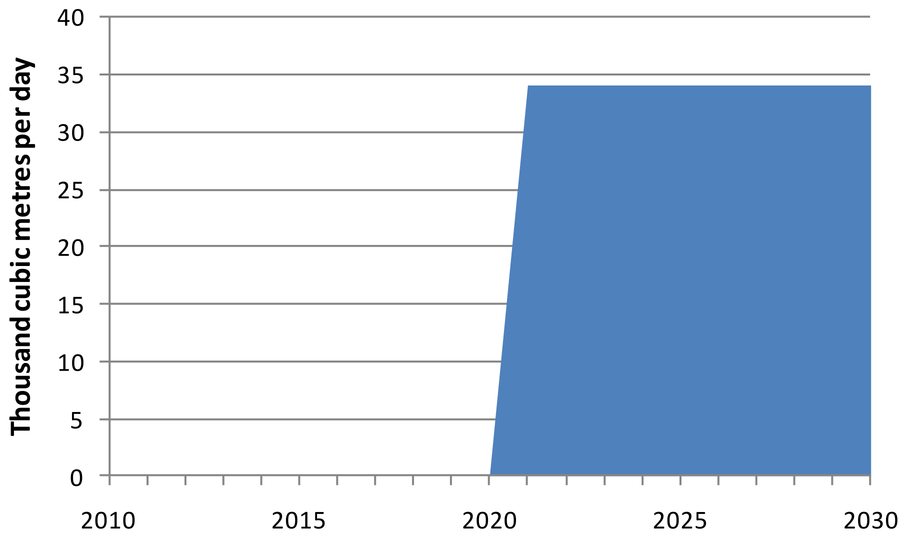


Total discovered recoverable natural gas resources in the NWT total 32,727 billion cubic feet.[8] Developed gas reserves are located at Cameron Hills, Fort Liard, Normal Wells and Ikhil, near Inuvik. Natural gas production is also based on the NEB 2009 reference case scenario from 2010 to 2020, and then 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). Production from the MGP 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).

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

[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 facilitates modeling expansions of the hydro grid (with policy) for use in mining, oil and gas extraction activities.

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).

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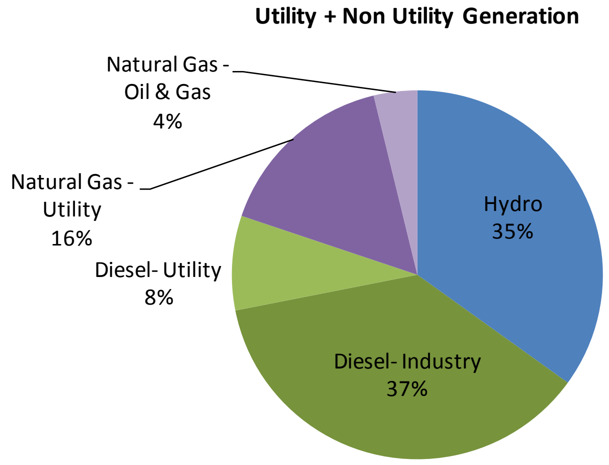
[9] In addition to natural gas, Inuvik has approximately 6MW of diesel capacity.

[10] GNWT, *Generation Stats 2008-2010.xls*, email communication, received November 10th, 2010.

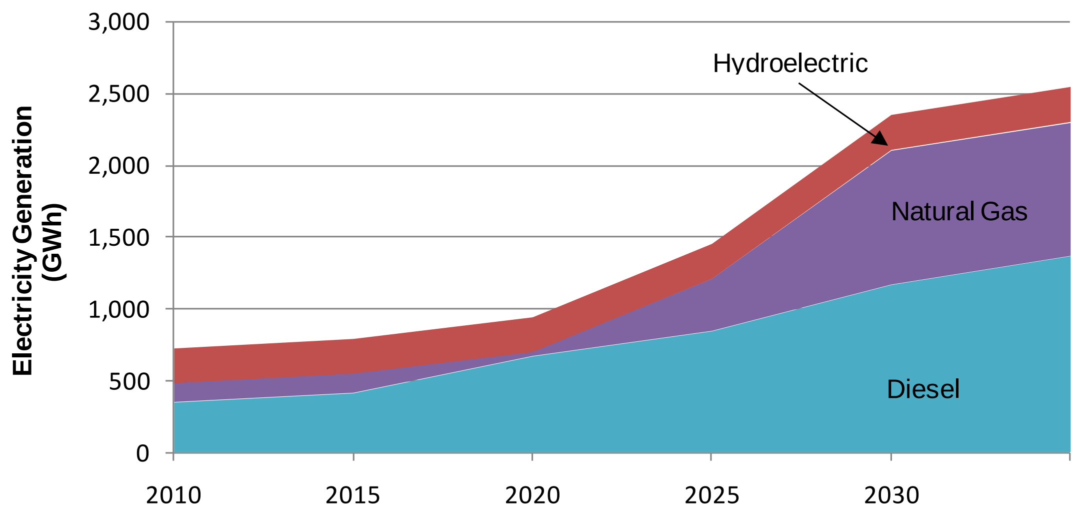
Figure 3: Electricity generation by fuel, 2009[11]



Given anticipated growth in the mining, residential and commercial sectors, as well as the development of the MGP, electricity demand is projected to almost double between 2010 and 2030; almost half of this growth attributed to demand from the MGP. 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. Generation grows substantially from 792 GWh in 2010 to 2,545 GWh in 2030. As noted above, projected renewable development differs from the previous analysis; this study assumes no additional investment in renewable capacity (i.e., hydro, geothermal, biomass, wind and solar) beyond what is currently installed. Future development (and investments) in additional renewable supply is considered a policy result as it is a component of the GNWT's alternative energy development strategies (Table 11). All additional demand, with the exception of the MGP which is supplied by natural gas generation, is met with diesel generation.

[11]GNWT, *Generation Stats 2008-2010.xls*, email communication, received November 10th, 2010.

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.

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 4 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.[12] Average fuel prices for both residential and commercial consumers reflect regional prices weighted by population and sales data (where 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

[12] 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.

higher costs of these fuels in the NWT.[13] 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.[14] 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.[15]

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

[14] 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

[15] 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 4: 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.[16]

The reference case forecast for total primary[17] and secondary energy consumption (i.e., electricity) is shown in Table 5, while Table 6, Table 7 and Table 8 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 section, but is available in the appendices.

[16] 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.

[17] Primary energy represents all energy consumption less electricity consumption.

Table 5: 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*	4.0	4.3	5.0	5.1	5.3
Transportation	*PJ*	10.7	15.1	17.4	18.7	20.2
Mining Sector	*PJ*	1.3	1.7	2.7	3.1	3.5
Supply Sectors						
Electricity Generation	*PJ*	7.3	9.2	14.9	24.8	27.2
Oil and Gas	*PJ*	1.7	1.1	2.3	8.7	8.6
Total	***PJ***	**26.4**	**32.8**	**43.6**	**61.6**	**66.0**
Electricity						
Demand Sectors						
Residential	*PJ*	0.5	0.5	0.6	0.6	0.5
Commercial	*PJ*	0.9	1.1	1.1	1.2	0.9
Transportation	*PJ*	0.0	0.0	0.0	0.0	0.0
Mining Sector	*PJ*	1.5	2.4	2.9	3.4	1.5
Supply Sectors						
Electricity Generation	*PJ*	0.0	0.0	0.0	0.0	0.0
Oil and Gas	*PJ*	0.2	0.8	3.1	3.1	0.2
Total	***PJ***	**3.1**	**4.8**	**7.7**	**8.3**	**3.1**

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 6: Reference case refined petroleum product consumption

	Units	2010	2015	2020	2025	2030
Demand Sectors						
Residential	*PJ*	0.9	0.9	0.9	0.8	0.8
Commercial	*PJ*	1.7	1.4	1.2	0.9	0.9
Transportation	*PJ*	10.7	15.0	17.2	18.4	20.0
Mining Sector	*PJ*	1.3	1.7	2.7	3.1	3.5
Supply Sectors						
Electricity Generation	*PJ*	4.9	8.0	10.1	14.0	16.4
Oil and Gas	*PJ*	1.3	1.0	1.0	1.9	1.7
Total	***PJ***	**20.8**	**28.0**	**33.1**	**39.2**	**43.3**

[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 7: Reference case natural gas and natural gas liquids consumption

	Units	2010	2015	2020	2025	2030
Demand Sectors						
Residential	*PJ*	0.2	0.3	0.3	0.3	0.2
Commercial	*PJ*	2.4	2.9	3.8	4.2	4.4
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*	1.5	0.3	3.9	9.9	9.9
Oil and Gas	*PJ*	0.1	0.1	1.4	6.7	6.8
Total	***PJ***	**4.2**	**3.7**	**9.3**	**21.1**	**21.3**

Note: This includes propane consumption.

Table 8: 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	0.9	1.1	1.1	1.2
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	0.8	3.1	3.1
Total	***PJ***	**2.6**	**3.1**	**4.8**	**7.7**	**8.3**

Table 9 shows greenhouse gas emission in the reference case. Emissions rise steadily over the forecast period, with greater growth experienced in the second half of the simulation period as the MGP comes online. By 2030 emissions reach 5,000 Kt CO_2e, almost tripling from 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 9: Reference case greenhouse gas emissions

	Units	2010	2015	2020	2025	2030
Demand Sectors						
Residential	*Kt CO2e*	81	79	77	74	70
Commercial	*Kt CO2e*	258	275	315	316	328
Transportation	*Kt CO2e*	763	1,070	1,230	1,316	1,425
Mining Sector	*Kt CO2e*	94	126	192	221	252
Supply Sectors						
Electricity Generation	*Kt CO2e*	467	655	1,001	1,615	1,804
Oil and Gas	*Kt CO2e*	115	87	273	1,133	1,122
Total	***Kt CO2e***	**1,778**	**2,292**	**3,089**	**4,675**	**5,000**

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 21% and 6% 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 32% and 10%, in the residential and commercial sectors, respectively.

In the personal transportation sector, energy consumption and emissions do not vary substantially, with energy use growing only 11% and emissions 8%, over the forecast period. Between 2010 and 2030, vehicle energy and emissions intensity in the sector improve substantially as households respond to high fuel costs and purchase more efficient vehicles. As a result, emissions in the sector increase by less than 1% a year − an annual average of 0.04% − which is 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 double (104%) over the forecast period in response to anticipated demand from the commercial, natural gas and mining sector (mainly off-road for gas and mining).

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 – 0.59 t CO_2e/MWh in 2010. Because additional demand is met with diesel and natural gas generation, the GHG intensity of the sector rises over the simulation period to 0.71 t CO_2e/MWh in 2030.

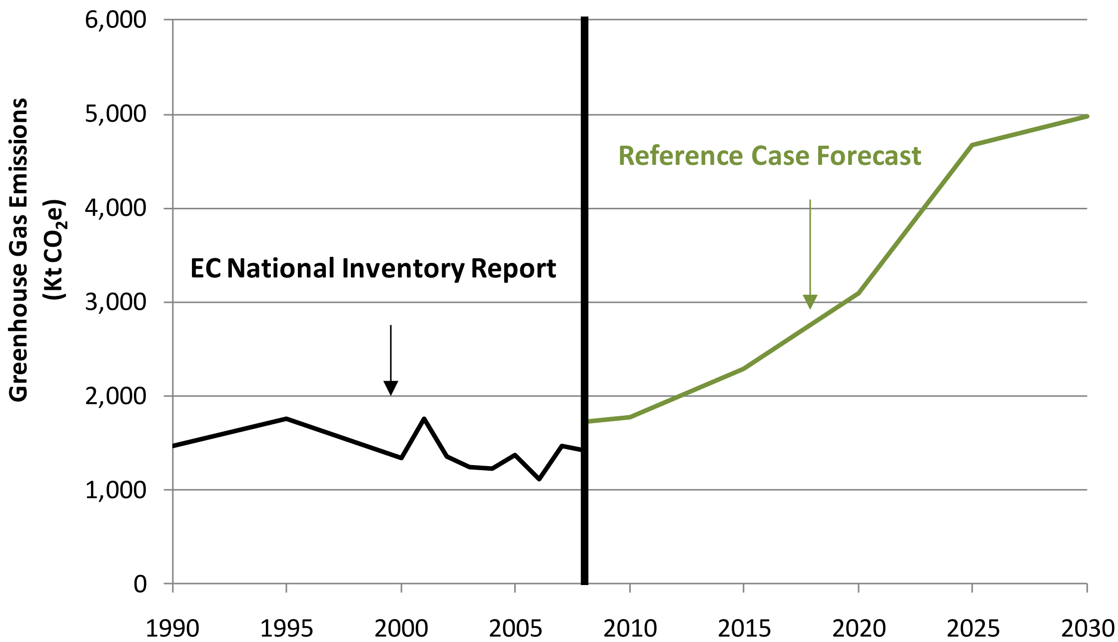
Energy consumption and GHG emissions in the oil and gas sector are linked to the number of fields in operation and the activity in those fields. Production in the natural gas sector increases significantly after 2020 as the MGP comes online with emissions rising to 1,096 Kt CO_2e. Consequently, sectoral energy and emissions forecasts for 2020 to 2030 largely reflect activity in the natural gas sector.

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).[19] 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.

Figure 5 displays historic − from the NIR− and forecast reference case GHG emissions − from CIMS − in the NWT. As can be seen in this Figure, the anticipated trend is for emissions to increase over the entire forecast period, which is largely driven by the development of the MGP.

[19] Encore, 2008, McKenzie Valley Gas Conversion Feasibility Study.

Figure 5: Northwest Territories reference case greenhouse gas emissions



Discussion of reference case emissions forecast

According to Environment Canada's National Inventory Report (2008), GHG emissions in the NWT in 2005 were 1,372 Kt CO_2e (excluding the waste, agriculture and 'other manufacturing' sectors). Table 10 summarizes these emissions by sector, and compares them with the emissions forecast by CIMS in that year. Emissions from CIMS are 263 Kt CO_2e, or 19% higher. This difference is predominantly due to variation in the commercial/institutional and electricity sectors, which is discussed below.

Table 10: Comparison of 2005 greenhouse gas emissions by sector (kt CO2e)

	NIR	*CIMS*
Residential	83	84
Commercial & Institutional	147	245
Transportation	662	671
Electricity Generation	260	404
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 align with historic data rather than necessarily matching up a specific year.

Guidelines for Interpreting Study Results

This study presents an analysis of announced, proposed, and future policy in the NWT, and provides policy makers with key insights into the impact and effectiveness of such policies. The results described below reflect estimates of policy effectiveness relative to a reference case that assumes no policy intervention. While we use credible sources to define the parameters of this analysis (i.e., reference case and policy assumptions), no amount of research allows for perfect foresight into the future of the economy or policy implementation. However, the study presents a robust examination of GNWT policy potential within the following context:

- The study assumes full compliance with all policies (e.g., all new buildings meet code specifications).
- Wood fuel (i.e., biomass) is assumed to produce no net GHGs; we do not explicitly model biomass production because currently the production of pellets occurs outside of the NWT. However, it is likely that local production could be established in the NWT within the timeframe of this study.
- Emissions from freight transportation are not addressed in this study. However, opportunities for abatement in the sector do exist. Future policy initiatives could address these emissions.
- Policies related to emissions captured in the resource extraction sectors, specifically the MGP, are not addressed in this study because a) estimates of emissions capture potential and feasibility are highly project-specific and thus beyond the scope of this analysis, and b) the CO_2 content of gas extracted from the project is ~1.25% (pipeline ready) and is unlikely to require CO_2 removal prior to transport. Depending on the CO_2 content of other fields in the region, there may be potential for emissions capture should additional development occur in the future; however, such an assessment is beyond the scope and timeframe (2030) of this analysis.

- Other opportunities for emission reduction from the MGP are examined in this analysis, including the conversion of compressors and electricity generation from natural gas to hydro. Note that the extent to which this is actually feasible would require review and analysis by project engineers.
- With the exception of combined heat and power initiatives, policies targeted at mining and oil extraction operations are not considered in this analysis.
- Abatement estimates provided by the GNWT do not consider differences in preference and risk (of households and firms), nor do they consider the impact of policy interactions. However, they do consider the local context at the community scale.
- Abatement estimates, and the resulting decomposition, are a product of the policy and reference case assumptions described in this study. If these conditions change in the future, emissions reductions estimates should be reassessed (e.g., should mining development be lower than projected, emissions in the NWT will be lower than forecasted).

A Future with Policy

The GNWT understands the threats posed by its current dependence on fossil fuels and is taking action to reduce fossil fuel use and territorial emissions. This commitment is echoed in its 2007 *Greenhouse Gas Strategy* document.[20] To date, a wide range of policies have been implemented, including subsidies to encourage the use of alternative energy, energy conservation, energy efficiency in homes and business across the territory, and the installation of biomass heating equipment in GNWT buildings. The GNWT has reported success with these policies, and is currently pursuing additional measures to ensure significant and sustained emissions reductions are realized. Given the region's reliance on expensive fossil fuels, any shift away from its current energy structure is likely to yield benefits to residences and businesses in the region.

As noted above, the GNWT has reported success with previous policy implementation. Moving forward, however, the impacts of recently announced (and other policies that may be implemented in the future) are unknown. In this section we estimate the effectiveness of current, recently announced and potential policies on future emissions. Policy impacts are assessed for the period of 2010 to 2030; a time when territorial emissions are anticipated to grow substantially.

A priori analysis gives policy makers key insight into policy design and abatement potential. This study will provide the GNWT with information to assess its current policy design and emissions strategy, set mid-term targets and adjust policy measures to align with its energy and emissions goals.

[20] Government of the Northwest Territories. 2007. Greenhouse gas strategy. Available from http://www.enr.gov.nt.ca/_live/documents/content/Greenhouse_Gas_Strategy_FINAL.pdf.

Table 11 lists the policies considered in the analysis and indicates the methodology used to estimate policy impacts (i.e., emission reductions). The table also identifies a group of "other programs" that were not modelled (program impacts, in terms of energy and emissions reductions are not easily quantifiable), but are included because they provide momentum and support for the policies modelled in this analysis. Two methodologies are employed in this analysis. The first uses the CIMS technology-simulation model, which considers consumer preference, perceived risk and policy interaction in its estimation of emission reductions. The second uses a methodology developed by the GNWT, which considers regional variation and community constraints in its estimation of emission reductions. The two methodologies are compliments, with individual strength associated with each approach. Combined, they provide a powerful and comprehensive analysis of future policy effectiveness.

Table 11: Study policies and estimation methodology, by sector

Sector	*Program Name*	*Estimation Methodology*
Electricity Generation		
	GNWT Hydro Strategy	CIMS
	GNWT Solar Strategy	CIMS
	GNWT Biomass Strategy	CIMS
	GNWT Geothermal Strategy	CIMS
	GNWT Wind Strategy	CIMS
	Territorial Power Subsidy program	CIMS
Transportation		
	National vehicle emissions standard	CIMS
	National renewable fuel standard for gasoline	CIMS
Households and Businesses		
	Enhanced capacity−Alternative Energy Development	GNWT
	Alternative Energy Emerging Technologies	GNWT
	Energy Conservation Program	GNWT
	Energy Efficiency Incentive Programs	CIMS
	EnerGuide for houses	CIMS
	Commercial Building Codes	CIMS
	Biomass Strategy - heating conversions	CIMS
	Solar strategy - solar hot water heater conversions	CIMS
GNWT Buildings		
	Fort Smith Electrification Project	GNWT
	Wood pellet boiler – Kalemi Dene School	CIMS
	Wood pellet boiler – CJB School Behchoko	CIMS
	Wood pellet boiler – Ft. Simpson	CIMS
	Wood pellet boiler – Leg Assembly	CIMS
	Energy Efficiency for Public Housing	CIMS
Other programs (not estimated)		
	Community Energy Plans	N/A
	Support Community Presence AEA	N/A
	Business Support Program	N/A
	CARE Program	N/A
	Energy Information Awareness	N/A
	Commercial Energy Efficiency Audits	N/A
	Capital Assets Retrofit Funds	N/A
	Electricity Review	N/A
	NTPC Review	N/A
	Energy Plan Renewal	N/A
	Community Pricing Survey	N/A
	Public Housing Energy Coordinator	N/A
	Asset Management Energy Specialist	N/A

Greenhouse gas reductions "wedge" diagrams

A thorough a priori policy analysis involves decomposing or deconstructing emissions reduction estimates by key actions (e.g., switching from heating oil to biomass to power a furnace). This type of analysis reveals what actions are stimulated by policy and how these actions reduce emissions. Such information is important to policy makers because it provides insight into policy impacts (e.g., subsidies that support alternative energy development for buildings may result in higher adoption of solar roofs) and also identifies design flaws or unintended policy effects. Thus, this type of analysis is used widely by governments (specifically policy makers) to assess energy and emissions goals. For example, the Government of Alberta uses a priori wedge diagram analysis to illustrate the actions and policies that accompany its greenhouse gas emissions target.[21]

A common approach to decomposition is wedge diagram analysis. 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 over time (in this study the period covered is 2010 to 2030).

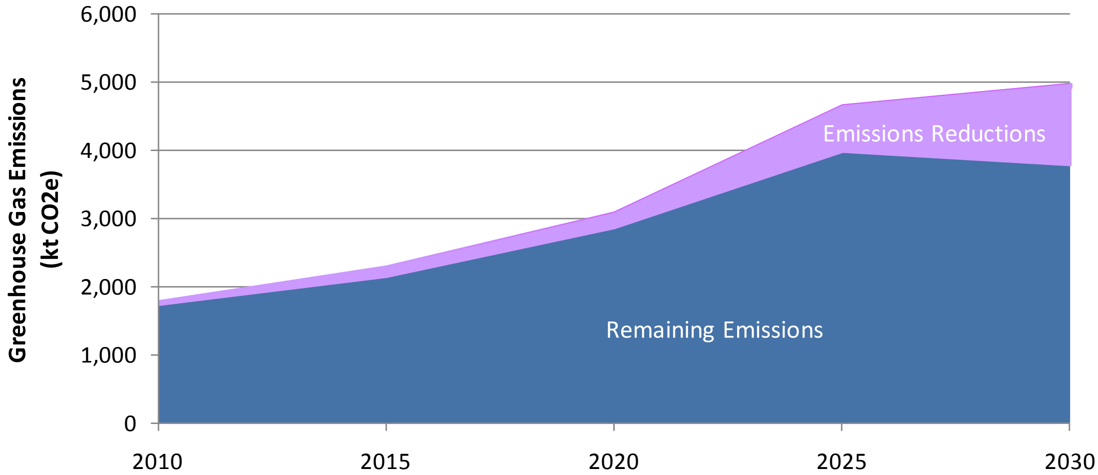
Wedge diagrams can be generated with a variety of methodologies. The diagrams in this analysis use the CIMS methodology, supplemented with abatement estimates from the GNWT. Policies estimated by the GNWT are policies that could not be modeled directly in CIMS. Three distinct sets of wedge diagrams are presented in subsequent sections (using CIMS, GNWT, and a combination of both approaches, respectively).

The two estimation methodologies each have advantages and complement one another. Wedge diagrams generated with CIMS estimate the response of households and firms to each of the policies that are modelled. Because CIMS is an integrated model in which firm and consumer behaviour has an empirical basis, the results account for household and firm 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). Wedge diagrams generated from GNWT estimates assess policy potential from past policy experience, local capacity and energy access constraints.

Figure 6 illustrates a wedge diagram that shows abatement in the NWT resulting from the various policies described in Table 11. The top wedge, "emissions reductions," corresponds to reductions of greenhouse gas emissions that result from abatement activity estimated by CIMS and the GNWT. The bottom wedge, or the "remaining emissions" wedge, represents the emissions that remain after the policies are implemented. This analysis therefore shows that the NWT could reduce its emissions by 23% in 2030, relative to the reference case, if all of the policies described in Table 11 were implemented.

[21] Government of Alberta. 2008. Alberta's climate change strategy. Available from: http://environment.gov.ab.ca/info/library/7894.pdf.

Figure 6: CIMS wedge diagram for whole NWT economy



Decomposition analysis

In the next section we describe emission reduction estimates and policies at the sector level (for the two methodologies noted above). To facilitate a detailed analysis of sector abatement actions, emissions remaining after policies are implemented are not reflected in the wedge diagrams; only total abatement is shown. Abatement activity is classified into three main categories: fuel switching, energy efficiency, and changes in output. 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).

For each sector affected by policy, we describe the policies analyzed and their estimated effectiveness, first using results from CIMS and then using results from the GNWT methodology.

CIMS Decomposition

Buildings − households, business and GNWT facilities

Policy Package

A variety of policies are assessed to reduce emissions from households, business and GNWT facilities, including:

1. **Policy:** EnerGuide for households
   Description: After 2011, all new residential buildings must achieve EnerGuide 80.
2. **Policy:** Commercial building code
   Description: After 2011, 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.

3. **Policy:** The Energy Efficiency Incentive Program (EEIP)
   Description: The program offers rebates to NWT residents, businesses and non-profit organizations for the purchase of high efficiency equipment/appliances (e.g., an oil furnace with 92% efficiency).
4. **Policy:** Solar hot water heating initiative
   Description: One thousand five hundred NWT buildings are to be retrofitted with solar thermal water systems over the next twenty years, reducing the need for oil and gas water heating. Total installed capacity is estimated to be 3.0 MW by 2030.
5. **Policy:** Geothermal energy and biomass strategies (for combined heat and power development in buildings)
   Description: The strategy supports the development and retrofit of conventional heating systems to combined heat and power systems powered by geothermal or biomass (wood pellet) energy. The GNWT estimates that this initiative will result in 4.3 MW of geothermal and 7.5 MW of biomass combined heat and power capacity by 2030.
6. **Policy:** Biomass strategy (for space heating)
   Policy Action: The program facilitates the conversion of furnaces and boilers in households, business and GNWT facilities to cord wood and wood pellets. It is estimated that by 2030 39% of total space heating demand will be generated from biomass.

Note: Estimates of "policy action" above are developed by the GNWT

Policy Analysis

In the reference case, energy intensity in the buildings sector decreases because of natural improvements in energy efficiency driven by high fuel costs. These improvements − 21% and 6% for households and commercial buildings (businesses and GNWT facilities), respectively, between 2010 and 2030 − results in slow emissions growth over the next two decades, at about 1% per year. These trends are more pronounced for households than commercial buildings.

With the policies described above, it is estimated that energy intensity and emissions growth could decline even further. Over the next twenty years, household and commercial building energy intensity could fall by an additional 3% and 10%, respectively, and emissions growth could fall by an additional 1.5% a year. By 2030 emissions in the building sector are 68 Kt CO_2e below 2010 reference case emissions.

Overall, policies are expected to reduce energy use and emissions associated with buildings in the NWT. Figure 7 shows the wedge diagram for the sector. The solar, geothermal and biomass initiatives have the greatest impact on sectoral emissions. The policies stimulate greater adoption of alternative heating technologies. For example, by 2030 it is estimated that:

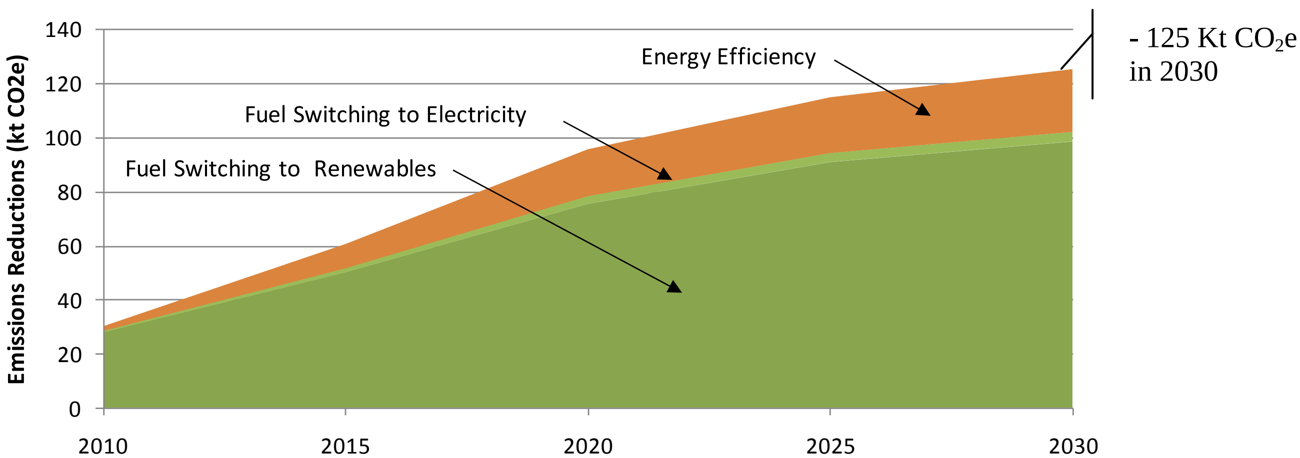
- Wood pellets could supply heat for 42% of total heated floor space in the residential sector, up from roughly 10% in 2010;

- solar hot water heaters could supply water heating in 10% of all buildings in the NWT and;
- combined heat and power from geothermal and biomass systems could produce 11.8 MW of electricity, approximately 15% of total electricity demand from buildings.

In total, fuel switching to renewables for space and water heating (i.e., replacing old fuel oil systems with solar, geothermal and biomass systems) results in cumulative reductions of 344 Kt CO_2e over the study period.

The policy package also encourages energy efficiency through application of building codes and energy efficiency rebates (i.e., EEIP). The efficiency rebates also encourage a small amount of fuel switching from fuel oil to electricity, mainly for water heating − 4 Kt CO_2e in 2030. Combined, these programs produce cumulative emission reductions of 84 Kt CO_2e. Efficiency improvements in the reference case somewhat reduce additional gains from policy.

Figure 7: CIMS wedge diagram for households, businesses and GNWT buildings



Note: Projections for biomass CHP are based on the assumption that there is successful demonstration of best available technology and biomass supply chain development by 2020.

Personal transportation

Policy Package

Two policies are assessed for the personal transportation sector, both of which have been proposed by the federal government:

1. **Policy:** National vehicle emission standard (VES)
   Descriptions: All 2012 to 2016 model year passenger vehicles must meet an average GHG intensity target which rises to 250 grams CO_2/mile (equivalent to 35.5 miles per gallon) in 2016.

2. **Policy:** Renewable fuel standard
   Description: A 5% renewable content is required in gasoline used for personal transportation.[22]

Policy Analysis

Similar to the buildings sector, high fuel costs drive energy efficiency improvements and emission reductions in the personal transportation sector under the reference case. Between 2010 and 2030 it is expected that average energy and emissions intensity of vehicles will improve 25% and 28%, respectively. Nonetheless, policies still induce additional emission reductions. By 2030 energy and emissions intensity fall 31% and 38%, respectively, from today's values − an additional decline of 6% and 10%, respectively, relative to the reference case.

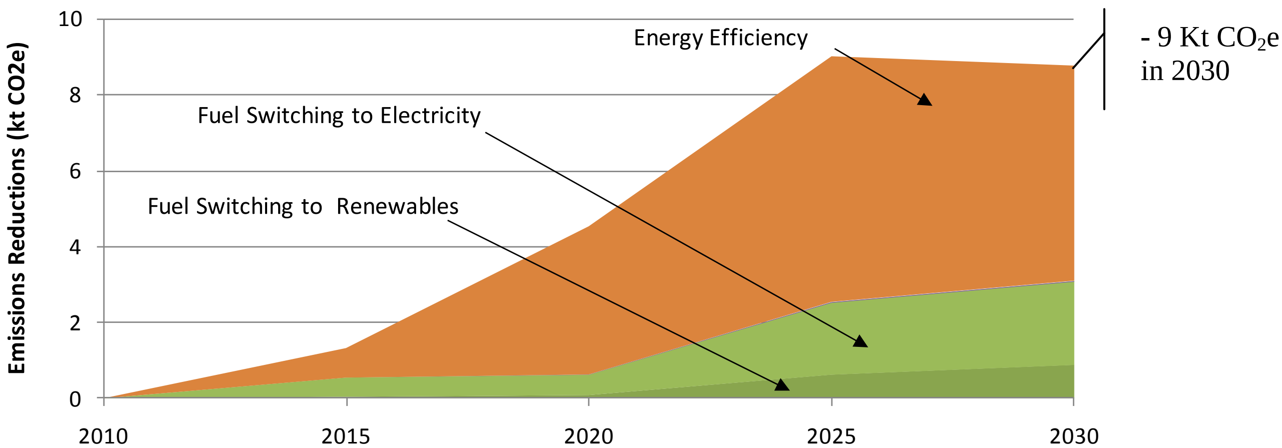
Figure 8 shows the wedge diagram for the personal transportation sector. The vehicle emissions standard has greater influence over sector emissions because it encourages a wide range of abatement activity including energy efficiency and fuel switching to renewables and electricity. The renewable fuel standard shifts a portion of fuel use from gasoline to ethanol.

The policies encourage greater adoption of low emission vehicles, including higher efficiency internal combustion, hybrid and plug-in-hybrid vehicles. In the latter half of the study period, the renewable fuel standard drives a further increase in the average ethanol content of gasoline from 5% in 2010 to 10% in 2030; the result of niche market stimulation.[23] Further increases to the renewable fuel standard, above 2010 policy levels, are likely given current fuel standard announcements in the United States (and Canada's current approach of policy alignment). Greater use of higher efficiency vehicles and biofuels contribute to over 60% of total sector abatement. Combined, the policies produce cumulative abatement of 24 Kt CO_2e over the study period.

[22] We do not simulate the biofuel requirements for diesel.

[23] Note: engine modifications are not required at this level of mixing.

Figure 8: CIMS wedge diagram for personal transportation



Electricity generation (utility and non-utility)

Policy Package

The GNWT has a number of focused strategies for increasing renewable capacity in the territories; specifically, hydro, wind, solar, geothermal and biomass power. Table 12 summarizes total expected capacity with these strategies estimated by the GNWT. The table represents total ***additional capacity*** relative to present levels; in other words, an ***additional*** 182 MW of hydro capacity is expected to be constructed by 2030, which is on top of existing capacity. In addition to its renewable power initiatives, the GNWT has also proposed programs to increase capacity of renewable combined heat and power generation in the territories. [24]

Policy Analysis

In the reference case, total utility and non-utility renewable generation remain fixed at current levels. Additional capacity requirements out to 2030, with the exception of demand from the MGP, are therefore met with diesel generation. Diesel capacity grows 233%, relative to current levels, primarily from demand in the mining sector in 2030. Natural gas generation also increases substantially, reaching 931 GWh/yr in 2030 with the development of the MGP. By 2030 about 90% of total electric supply is fossil fuel – in 2010, about 70% of total supply is fossil fuel – and emissions intensity in the sector grows 20% from current levels. Greater output (and emissions) is anticipated after 2020 because of development in the mining sector and the MGP. Emissions rise to 1,804 Kt CO_2e in 2030, up almost 300% from current sector emissions.

The development of renewable generation to displace diesel offers a significant opportunity to reduce both greenhouse gas emissions as well as exposure to high and

[24] Biomass combined heat and power systems are included in the buildings sector, while geothermal combined heat and power (electricity only) is accounted for in the electricity sector.

volatile fuel prices. While current renewable system costs are high, expensive fuel costs (mainly expensive diesel fuel) and expected cost reductions in renewable technologies make renewable development a feasible and practical solution to rising emissions and energy costs.

Table 12 shows the incremental renewable capacity development proposed by the GNWT for both utility and industrial own-generation (see appendices for detailed project assumptions). In 2030, it is expected that an additional 182 MW of hydro, 65 MW of wind, 5.3 MW of solar photovoltaic and 8 MW of geothermal is developed. This generation is assumed to displace diesel capacity, except for 125 MW of hydro capacity on the Bear River, which is assumed to displace natural-gas powered compressors along the MGP pipeline as well as other natural gas-fired electricity generation associated with the project and in the communities of Norman Wells and Inuvik. The remaining renewable capacity − 135 MW of hydro, wind, solar and geothermal − displaces both utility diesel generation (generation primarily for buildings), as well as industrial diesel own-generation (generate on-site for mining activity). Overall renewables are anticipated to grow substantially from current generation, growing from 251 in 2010 to 1,614 GWh in 2030.

Table 12: Total additional renewable electricity capacity

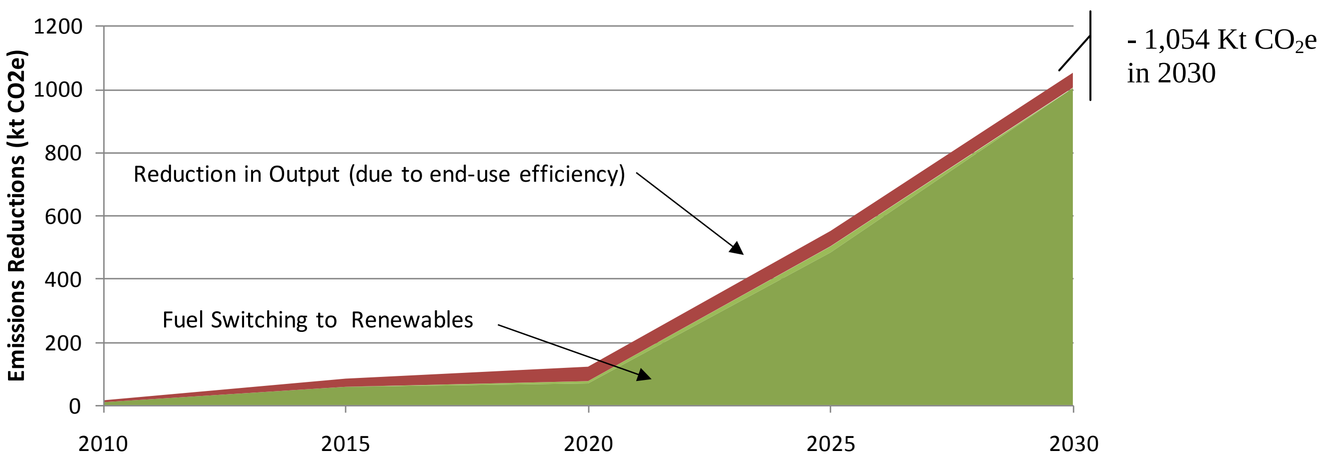
	Total Additional Capacity (MW)			
Supply Source	**2015**	**2020**	**2025**	**2030**
Hydroelectricity	1.0	21.0	56.0	182.0
Utility	1.0	7.0	7.0	8.0
Industrial	0.0	14.0	49.0	174.0
Wind	10.3	17.5	35.0	65.0
Utility	0.3	2.5	10.0	15.0
Industrial	10.0	15.0	25.0	50.0
Solar Photovoltaic	0.3	0.8	2.3	5.3
Utility/Community	0.2	0.3	0.8	2.3
Industrial	0.1	0.5	1.5	3.0
Geothermal	0.0	8.0	8.0	8.0

Notes: Geothermal capacity captures the electricity component of the mining CHP programs only; the heat component is assessed separately by the GNWT, and community geothermal CHP capacity is included in the buildings sector. Biomass CHP is also accounted for in the buildings sector. Due to modeling limitations, interim capacities in CIMS do not always match those in the table; however, CIMS does match table trends and 2030 capacity.

Figure 9 shows the wedge diagram for utility and non-utility electricity generation. Displacement of diesel and natural gas with renewables, "fuel switching to renewables", decreases the emissions intensity to 0.32 t/MWh, displacing almost 1,007 Kt CO2e by 2030 and reducing total sector emissions by 44% (relative to the reference case) − all actions combined reduce total emissions 57%. While in the reference case, diesel accounted for 55% of total generation in 2030, in the policy scenario its share decreases to 32%. Natural gas generation also decreases due to conversion of compressors and other generation to hydro; the exact magnitude of displacement would depend on various technical and project-specific characteristics of the MGP.

In the policy scenario, total electricity demand is reduced by 4% in 2030, due to the various energy efficiency initiatives aimed at the buildings sector. This reduction in demand in turn reduces sector output and results in emission savings of 47 Kt CO2e in 2030 (the top wedge in Figure 9).

Figure 9: CIMS wedge diagram for utility and non-utility electricity generation

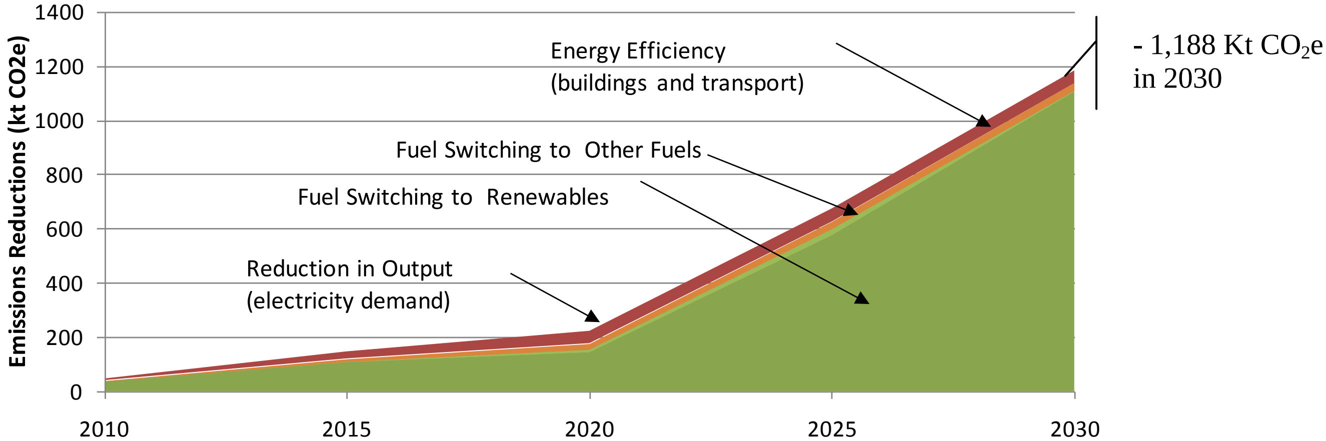


Economy-wide (CIMS methodology)

Table 9 shows the wedge diagram for all sectors affected by policy, buildings, personal transportation and electricity. Total cumulative reductions over the study period are 2,279 Kt CO_2e. As illustrated in the figure, fuel switching to renewables is the dominant abatement action, reducing emissions 1,107 Kt CO_2e relative to the reference case in 2030. Of this 1,107 Kt CO_2e, about 90% of abatement is the direct result of displacing diesel and natural gas generation capacity with renewable generation. The remaining 10% can be attributed to increased use of wood furnaces and boilers, solar hot water heaters, and ethanol transportation fuel. Although abatement from these actions is small relative to activity in the electricity sector, uptake of renewable energy is a dominant abatement action in each sector (with the exception of personal transport). Energy efficiency, switching to electricity and reduced electricity demand have less influence over total abatement with cumulative abatement of 306 Kt CO2e over the study period; however, these actions are important on a sector scale.

Note: A portion of abatement associated with the displacement of diesel and natural gas generation with renewables in the electricity sector could be considered "energy efficiency"; however, in this analysis this action is exclusively defined as "fuel switching to renewables".

Figure 10: CIMS wedge diagram for all sectors affected by policy



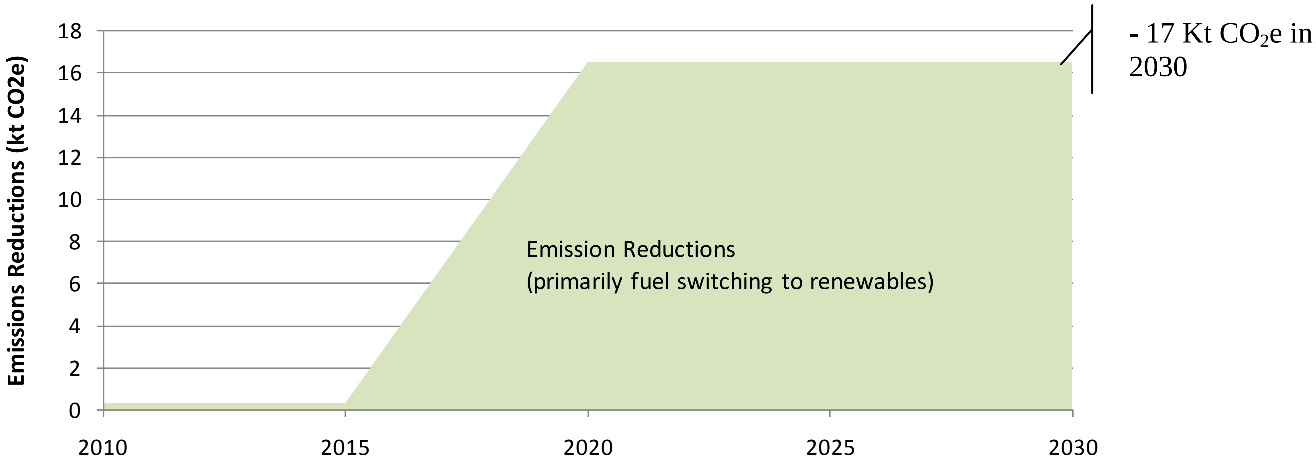
GNWT Decomposition

In the previous section we estimated emission reductions using the CIMS methodology. In this section we will explore additional policy abatement estimated by the GNWT. These policies include:

1. **Policy:** Geothermal combined heat and power initiative (heat generation in the mining sector only)
   Description: The initiative will produce 8 MW of geothermal capacity to displace diesel generation for space heating in mining operations from 2020 onwards (note that the electricity portion of this was included in the previous analysis of the electricity sector).
2. **Policy:** The Energy Conservation Program
   Description: The program helps communities and non-profit organizations reduce their energy use by providing funding for projects that install or upgrade equipment to make it more energy-efficient, or that improve systems that monitor and control energy use.
3. **Policy:** The Alternative Technology Development Program
   Description: The program promotes the use of renewable energy sources such as wind turbines, biofuels, ground-source heat pumps, and solar hot water heaters in the NWT. The GNWT provides financial support to communities, businesses in remote locations, and NWT residents in order to help them install renewable energy technologies.

Figure 11 shows the wedge diagram associated with these programs. Together, they account for about 17 Kt CO2e of reductions annually after 2020. The majority of these reductions (about 98%) result from the displacement of diesel space heating with geothermal power. The Energy Conservation and Alternative Technology Development programs have a much smaller community-level focus than the combined heat and power program and hence achieve a relatively lower level of emission reductions.

Figure 11: GNWT wedge diagram for industry and buildings



Combined Decomposition (Economy-Wide)

Figure 12 shows the results of combining the CIMS and GNWT diagrams for the entire NWT economy. Overall, economy-wide emissions (annual emissions) are reduced 238 Kt CO_2e in 2020 and 1,204 Kt CO_2e in 2030 with the policies examined in this study. Table 13 shows the emission reduction by policy package and methodology from 2010 to 2030, relative to the reference case. Cumulative abatement over the study period is 2,327 Kt CO_2e.

The electricity and building sector policy packages have the greatest influence over emissions in the NWT. Combined abatement from these policy packages is 217 and 1,179 Kt CO_2e in 2020 and 2030, respectively. The other policy packages result in lower relative abatement because of baseline emissions, and the number and scope of policies examined was smaller than was examined in the building and electricity sector.

Figure 12: Combined CIMS and GNWT wedge for all sectors affected by policy

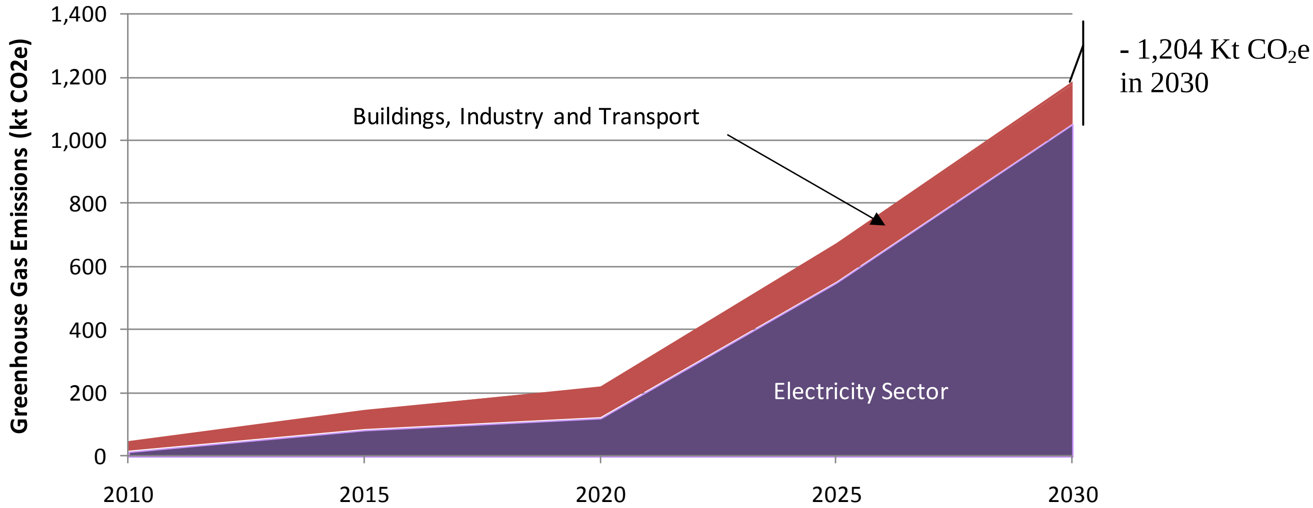


Table 13: Economy-wide emission reductions by policy package and methodology

	2010	2015	2020	2025	2030
Remaining Emissions (Kt CO_2e)	1,733	2,145	2,848	3,973	3,776
CIMS					
Buildings	30	61	96	115	125
Transportation	0	1	5	9	9
Electricity	15	84	122	552	1,054
GNWT					
Buildings and Mining	0	0	17	27	17
Total Emission Reductions (Kt CO_2e)	46	146	238	692	1,204

Comparison with Other Regions

The NWT faces unique challenges for reducing emissions due to its geography, climate and economy. The population of the NWT is small and dispersed, with communities spread across the territories often in remote areas where access to fuels, food and other amenities is costly (in some regions access is by air only). Combined with its harsh climate − with winter temperatures ranging from -20°C to below -40°C − the cost of living, especially the cost of fuel, is high. In fact, average energy costs in the region are amongst the highest in Canada. The NWT economy is also unlike most regions in Canada because of its resource-base. In 2010, GDP from the mining, oil and gas sectors contributed 63% of territorial GDP, and has averaged about 50% over the last decade.[25] The NWT economy is strongly defined by its resource extraction activity. As with its settlements, extraction activity is located in remote areas where access to energy sources is constrained and often limited to high-cost refined petroleum products. Consequently,

[25] GNWT Bureau of Statistics. 2010. NWT gross domestic product, by industry: millions of chained (2002) dollars. Available from: http://www.stats.gov.nt.ca/economy/gdp/index.otp.

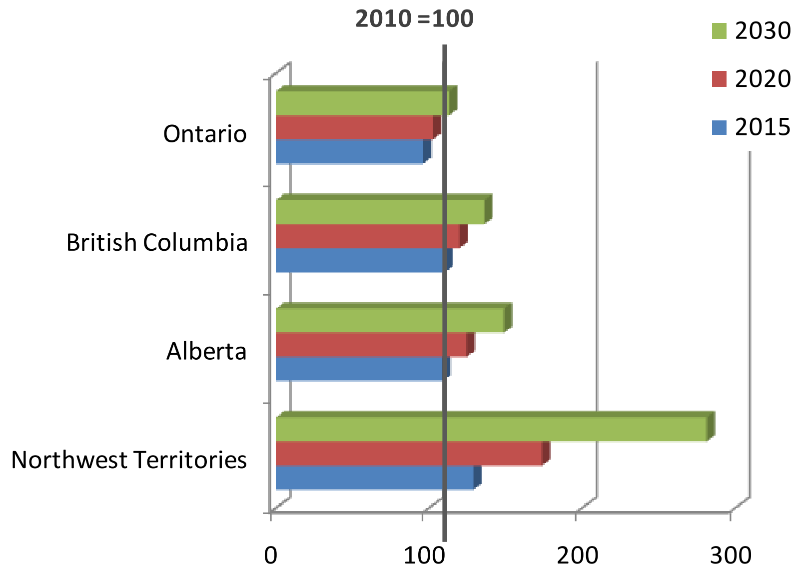
emissions from these sectors are significant and much like GDP, their activity largely defines emission trends in the territories.

In the next two decades, these sectors will play an even bigger role defining the economic and emissions profile of the NWT (if anticipated growth occurs). Development in the mining sector is projected to increase from 8.3 million tonnes of ore to over 29 million tonnes by 2030, an increase of 70%. Natural gas production is also projected to increase markedly with the development of the MGP, rising to 34,002 thousand cubic meters a day by the end of the decade and remaining constant out to 2030. GDP levels are anticipated to rise 92% from 2005 levels by 2020 and are likely to continue to grow thereafter − combined GDP from mining and gas in 2020 is estimated at $4 billion ($2005 CDN).[26] Jobs are also projected to increase and average salaries could rise 34% (from 2005) by 2020.

Due to this growth, emissions in the territories are anticipated to more than double over the next two decades. This level of growth outpaces the growth projected for other regions in Canada; even those with strong resource-based economies like Alberta and British Columbia (see Figure 13). Under business as usual conditions (i.e., no climate or energy policy intervention), forecasted emissions growth in Alberta and British Columbia are indexed (i.e., 2010=100) at 120 and 124 relative to current levels by 2020, while forecasted emissions in the NWT are indexed at 174. This difference becomes even greater by 2030, when forecasted emissions in the territories approach three times their 2010 values, far outpacing growth in other jurisdictions.

[26] MKJA. 2011. An Exploration into the Impact of Carbon Pricing in the Northwest Territories: Reference Case & Quantitative Policy Analysis, prepared for the Government of the Northwest Territories, March, 2011.

Figure 13: Forecasted emissions growth in selected Canadian regions under business as usual assumptions, 2010=100



Source: Simulations using CIMS

Despite the growth projected over the next twenty years, this analysis shows that emission reductions are possible. In 2020, as policies increase in strength, emissions reduction of 7% from reference case (or no policy) levels are realized. However, as inertia in the economy subsides with the turnover of capital stock, policies exert a greater influence over emissions. By 2030, it is possible that territorial emissions could be up to 23% lower from what they would have been in the absence of policy. Figure 14 shows policy and reference emissions in the NWT in 2015 to 2030. While forecasted emissions are greater than current levels, the abatement achieved in both the near- (2020) and mid-term (2030) are notable given anticipated growth in resource extraction. In the long-term (past 2030), momentum from policy is likely to increase over time as inertia in the economy declines even further and new opportunities for abatement, especially in the resource sectors, arise (see Figure 15).

Emissions abatement in the NWT should be viewed in the context of its unique geography and demographics, and anticipated growth in its economy. Therefore, emission reductions should be judged relative to this baseline and abatement should be incremental if it is to be sustainable over the long-term, starting off slow and ramping up over time at a pace aligned with capital investment and economic growth.

Figure 14: Policy and reference emissions in the NWT in 2015, 2020 and 2030

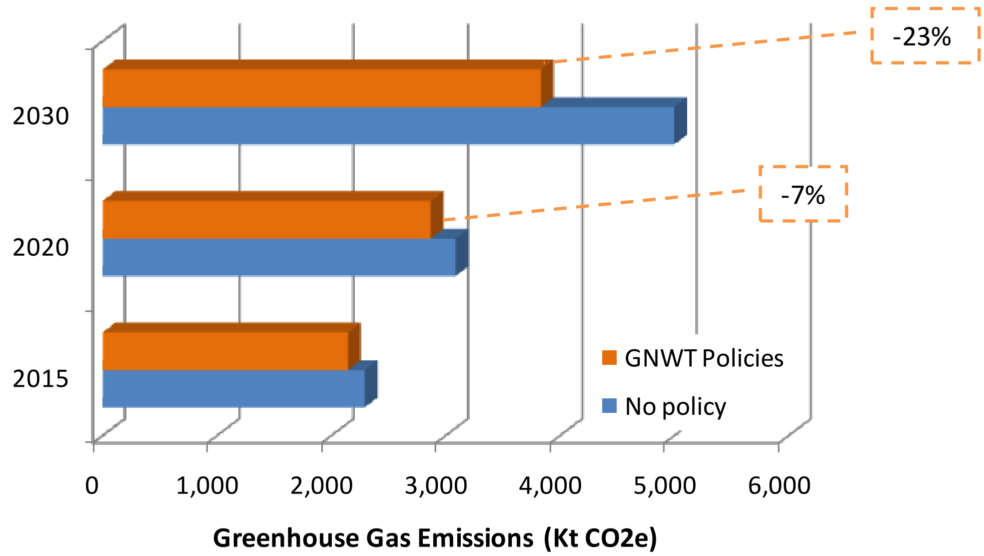
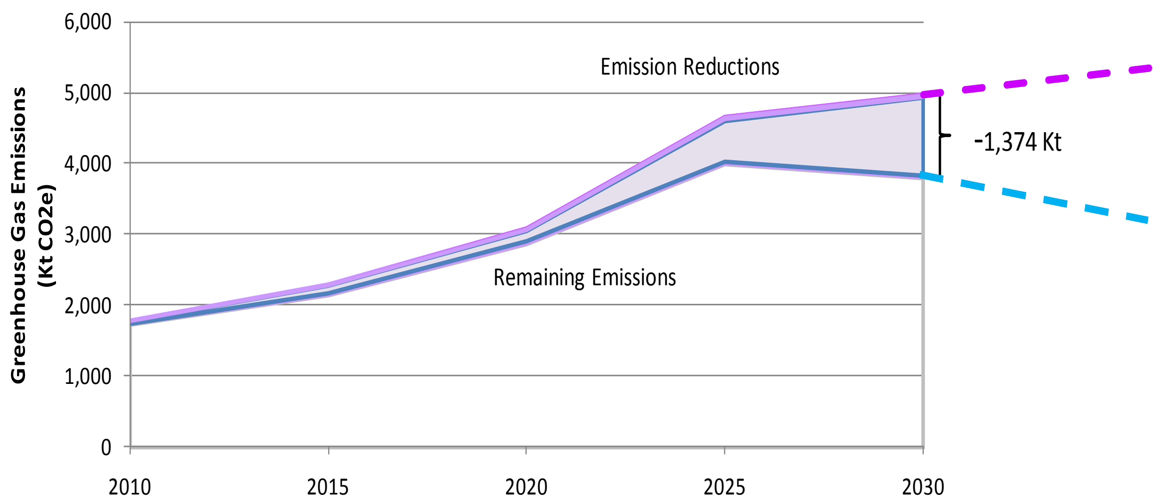


Figure 15: Emissions reduction and remaining emissions 2010-2030 in the NWT



Discussion and Conclusion

Fossil fuels, particularly refined petroleum products, supply the majority of energy needs in the NWT. However, this energy system comes at a high cost, both financially and environmentally. In an effort to mitigate these risks (i.e., costs and emissions), the GNWT is implementing policies and programs to reduce its emissions and dependence on fossil fuels.

The GNWT has implemented and proposed a wide variety of policies to address rising emissions and energy use in the territories. The GNWT has reported success with past policy implementation and is currently pursuing additional measures to build on and accelerate this momentum. Moving forward, the GNWT intends to set longer-term emissions targets. To aid in its efforts the GNWT selected MKJA to estimate the effectiveness of current and future policies over the next twenty years.

The analysis provides a detailed examination of the key actions and impacts stimulated by GNWT policies. Results indicate that relative to a future with no policy, substantial emissions reductions in sectors targeted by policy could be achieved by 2030. It is estimated that 2,327 Kt CO_2e of cumulative emissions reduction is possible within the timeframe of the study. Moreover, policies result in a lower emissions trajectory than predicted in the reference case − 23% below reference case values in 2030. While significant emission reductions are realized in the electricity and building sectors, territorial emissions continue to grow from current levels.

Emissions growth, especially after 2020, is due to projected mining and natural gas development. While a few policies explored in this analysis address these emissions (e.g., renewable heat and electricity generation initiatives), policies specifically targeting activities within these sectors are not considered. Although beyond the scope of this analysis, it is possible that future policy action in these sectors could result in further sector abatement. However, access to fuel and project economics will likely constrain future abatement efforts to some extent.

The policies explored in this study focus on emissions in the building, personal transportation, and electricity and heat generation sectors. In sectors targeted with a wider range and scope of policies, greater emission reductions were realized; considerable emissions reductions (i.e., emissions relative to the reference case) were generated from buildings and electricity generation. The following highlights key policy insights from the analysis:

- High energy costs encourage improvements in energy and emissions intensity in the reference case, but policy action accelerates this trend.
- Conversion to renewable energy for space and water heating (from fuel oil) is an important policy action in the building sector and results in approximately 344 Kt CO_2e of cumulative emissions reductions over the study period.
- Increased use of wood pellet furnaces and boilers are especially important for reducing emissions from buildings. To ensure the success of this action, an affordable and reliable source of biomass is needed.
- Federal policies have minimal impact on emissions from personal transportation. Increased policy strength and additional policy measures would likely result is greater sector abatement. Moreover, high energy prices encourage notable efficiency in the reference scenario, reducing emissions reductions from policy in the short-term.
- Expanding renewable generation capacity (instead of building fossil fuel capacity) has a significant impact on both sector and territorial emissions. Abatement in the sector is responsible for 80% of cumulative abatement, while emissions in the sector fall by 57% in 2030. Much of this abatement is contingent on displacing diesel generation associated with mining developments.

- Mining and natural gas extraction (e.g., the MGP) development is likely to benefit from expanding renewable electricity and heat generation capacity; however, additional abatement opportunities may exist within these sectors.

Implications for target setting

The analysis reveals that emissions reductions are possible in the sectors targeted by policy. Study findings may assist the GNWT in setting longer-term targets for emission reduction past 2011 that are both realistic and achievable.

It is recommended that long-term targets reflect a disaggregated approach to address the unique constraints affecting the economy. This approach would see separate targets set for each sector. For sectors where emission reductions below current levels could be realized, an absolute target could be set (e.g., "X" Kt below 2010 levels). For sectors where emissions reductions below current levels are not possible in the mid-term (e.g., new resource development), intensity targets could be set. This approach would result in an overall lower environmental impact, while preserving (and not discouraging) future development. The mining and resource extraction sectors are essential to NWT's economy, so it will be important to encourage emission reduction actions that are both achievable and cost effective. Targets should ideally be reviewed periodically to assess policy effectiveness and progress, changes to sector activity (e.g. expected sector growth) and other factors.

The recommendations above should not be interpreted as direct or solicited policy advice to policy makers in the GNWT, but rather as academic conclusions from the study findings. The ultimate form and design of future policies and targets will be determined by the GNWT.

Appendix: Detailed Policy Assumptions

GNWT assumptions for CIMS modelling

Conversion of furnaces and boilers to biomass

		Capacity (MW) Heat				
Supply Source	**Project**	**2011**	**2015**	**2020**	**2025**	**2030**
Biomass	Cord Wood	7.5	7.75	8	8.25	8.5
	Pellets (Residential)	1	2	5	7.5	10
	Pellets (Commercial)	8	15	25	35	50
	% of total heat	0.1	0.15	0.22	0.29	0.39

Combined heat and power initiatives

		Capacity (MW) Electricity			
Supply Source	**Project**	**2015**	**2020**	**2025**	**2030**
Biomass	Buildings	1.0	2.5	5.0	7.5
Geothermal	Mining	0.0	8.0	8.0	8.0
Geothermal	Buildings	1.3	4.3	4.3	4.3
		Capacity (MW) Heat			
Supply Source	**Project**	**2015**	**2020**	**2025**	**2030**
Biomass	Buildings	1.0	2.5	5.0	7.5
Geothermal	Mining	0.0	8.0	8.0	8.0
Geothermal	Buildings	1.3	4.3	4.3	4.3

Solar strategy (solar thermal)

Supply Source	Project	2015	2020	2025	2030
Solar Thermal Water	Penetration of buildings	1%	2%	5%	10%
	Number of buildings	150	300	750	1,500
	MW heating	0.3	0.6	1.5	3.0

Renewable strategies (utility and non-utility electricity generation)

	Total Additional Capacity (MW)			
Supply Source	**2015**	**2020**	**2025**	**2030**
Hydroelectricity	1.0	21.0	56.0	182.0
Utility	1.0	7.0	7.0	8.0
Industrial	0.0	14.0	49.0	174.0
Wind	10.3	17.5	35.0	65.0
Utility	0.3	2.5	10.0	15.0
Industrial	10.0	15.0	25.0	50.0
Solar Photovoltaic	0.3	0.8	2.3	5.3
Utility/Community	0.2	0.3	0.8	2.3
Industrial	0.1	0.5	1.5	3.0
Geothermal	0.0	8.0	8.0	8.0

Generation assumptions (total additional capacities):

Year	Cumulative Capacity	Project
Wind (Utility)		
2015	300 KW	Tuktoyaktuk Wind – Diesel system
2020	2.5 MW	Expansion of Tuktoyaktuk Wind Project to 1.0 MW
		Paulatuk (0.5 MW), Ulukhaktok (0.5 MW) and Sachs Harbour (0.5 MW)
2025	10 MW	Yellowknife (5 MW) and Norman Wells (2.5 MW)
2030	15 MW	Added capacity (5MW) in community wind-diesel systems
Wind (Industry)		
2015	10 MW	Diavik Diamond Mine project
2020	15 MW	Avalon Rare Earth Minerals (5 MW wind-diesel)
2025	25 MW	Ekati (5 MW) and Gahcho Kue (2.5 MW)
2030	50 MW	25 MW expansion with new mine development

Year	Cumulative Capacity	Project
Solar PV (Utility and community)		
2015	0.172 MW	172 kW for Community for solar –diesel hybrid demonstration project
2020	0.322 MW	100 kW for Community solar-diesel hybrid and 50 kW for off-grid applications
2025	0.822 MW	450 kW for additional community solar-diesel hybrid and 50 kW for off-grid applications
2030	2.32 MW	1.5MW with solar-diesel hybrid systems and off-grid applications*
Solar PV (Industry)		
2015	0.100 MW	Diavik Diamond Mines - 100 kW pilot project
2020	0.500 MW	400 kW, other diamond mines and possible rare earth mine
2025	1.5 MW	1 MW –mine expansion*
2030	3.0 MW	1.5 MW expansion

* The assumption is that solar will be more cost effective (thin film solar technology) and advanced storage systems will allow for higher penetration into isolated diesel grids.

Year	Cumulative Capacity	Project
Hydro (Utility)		
2015	1 MW	Lutzel'Ke (1 MW)
2020	7 MW	Wha Ti and Yellowknife Grid (6 MW)
2025	7 MW	
2030	8 MW	Deline (1 MW)
Hydro (Industry)		
2015	0	
2020	14 MW	Nico Mine (14 MW)
2025	49 MW	Other Mines (35 MW)
2030	174 MW	Pipeline compressors (125 MW)

Year	Cumulative Capacity	Project
Geothermal (Utility)		
2015	1.3	For Liard (300 kW), Fort Simpson (1 MW)
2020	4.3	Hay River (2 MW), Fort Providence (2 MW)
2025	4.3	
2030	4.3	
Geothermal (Industry)		
2015	0	
2020	8 MW	Avalon, Tamerlane (8 MW)
2025	8 MW	
2030	8 MW	

Note: Utility geothermal electricity generation is modelled in the building sector.

GNWT policy assumptions

	2010	2015	2020	2025	2030
Policy	*Emission Reductions (Kt CO_2e)*				
Geothermal (mining, heat component only)	0	0	16	16	16
ECP	0.2	0.2	0.2	0.2	0.2
AETP	0.08	0.08	0.08	0.08	0.08

Appendix: Detailed CIMS Results

Reference case results

Greenhouse gas emissions (Kt CO2e)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	1,778	2,292	3,089	4,675	5,000
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	81	79	77	74	70
Commercial	258	275	315	316	328
Transportation Personal	135	135	138	139	146
Transportation Freight	629	935	1,092	1,177	1,280
Mineral Mining	94	126	192	221	252
Electricity	467	655	1,001	1,615	1,804
Oil and Gas Extraction	115	87	273	1,133	1,122

Total energy consumption (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	28.7	35.9	48.4	69.3	74.3
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	1.8	1.8	1.8	1.9	1.9
Commercial	4.9	5.3	6.1	6.2	6.5
Transportation Personal	1.9	1.9	2.0	2.0	2.1
Transportation Freight	8.8	13.2	15.5	16.7	18.1
Mineral Mining	2.3	3.2	5.1	6.0	6.9
Electricity	7.3	9.2	14.9	24.8	27.2
Oil and Gas Extraction	1.7	1.3	3.1	11.7	11.6

Natural gas (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	4.2	3.7	9.3	21.1	21.3
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.2	0.3	0.3	0.3	0.2
Commercial	2.4	2.9	3.8	4.2	4.4
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	1.5	0.3	3.9	9.9	9.9
Oil and Gas Extraction	0.1	0.1	1.4	6.7	6.8

Note: Includes propane

Coal (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	0.0	0.0	0.0	0.0	0.0
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Refined petroleum products (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	20.8	28.0	33.1	39.2	43.3
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.9	0.9	0.9	0.8	0.8
Commercial	1.7	1.4	1.2	0.9	0.9
Transportation Personal	1.9	1.9	1.9	2.0	2.1
Transportation Freight	8.8	13.1	15.3	16.5	17.9
Mineral Mining	1.3	1.7	2.7	3.1	3.5
Electricity	4.9	8.0	10.1	14.0	16.4
Oil and Gas Extraction	1.3	1.0	1.0	1.9	1.7

Electricity (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	2.6	3.1	4.8	7.7	8.3
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.42	0.46	0.51	0.56	0.62
Commercial	0.84	0.93	1.08	1.12	1.17
Transportation Personal	0.00	0.00	0.00	0.00	0.01
Transportation Freight	0.00	0.00	0.01	0.01	0.01
Mineral Mining	1.04	1.49	2.42	2.91	3.40
Electricity	0.00	0.00	0.00	0.00	0.00
Oil and Gas Extraction	0.29	0.22	0.75	3.08	3.06

Ethanol (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	0.0	0.0	0.0	0.0	0.0
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Renewable (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	1.0	1.1	1.1	1.1	1.2
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.2	0.2	0.2	0.3	0.3
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.9	0.9	0.9	0.9	0.9
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Note: Includes wood fuel in the residential sector, as well as primarily hydro and wind in the electricity sector. Primary energy coefficients adopted from the International Energy Agency.

Hydrogen (PJ)

Summary for Northwest Territories					
	2010	***2015***	***2020***	***2025***	***2030***
Total	0.0	0.0	0.0	0.0	0.0
Summary by Sector					
	2010	***2015***	***2020***	***2025***	***2030***
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Other (PJ)

Summary for Northwest Territories					
	2010	***2015***	***2020***	***2025***	***2030***
Total	0.0	0.0	0.0	0.0	0.0
Summary by Sector					
	2010	***2015***	***2020***	***2025***	***2030***
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Electricity

Northwest Territories					
	2010	***2015***	***2020***	***2025***	***2030***
Energy Intensity (GJ / MWh Electric Generation)	9.19	9.80	10.24	10.57	10.68
Emissions Intensity (t CO2e / MWh Electric Generation)	0.59	0.69	0.69	0.69	0.71
Hydroelectric Generation (Gwh)	241	242	243	243	243
Wind Generation (Gwh)	0	0	0	0	0
Other Renewable Generation (Gwh)	0	0	0	0	0
Natural Gas Generation (Gwh)	140	32	365	937	931
Diesel Generation (Gwh)	411	669	845	1,169	1,370
Total Generation	**792**	**943**	**1,454**	**2,350**	**2,545**

Note: Values account for transmission and distribution losses. Other generation includes biomass, solar and geothermal power. In 2030, roughly 17.4 Fwh of biomass power is generated.

Policy case results

Greenhouse gas emissions (Kt CO_2e)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	1,733	2,146	2,869	4,017	3,834
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	67	57	52	50	48
Commercial	242	236	244	225	223
Transportation Personal	135	134	133	130	137
Transportation Freight	629	935	1,092	1,177	1,280
Mineral Mining	94	126	192	221	252
Electricity	452	571	882	1,082	772
Oil and Gas Extraction	115	87	273	1,133	1,122

Total energy consumption (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	28.6	35.1	46.8	63.6	64.2
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	1.7	1.7	1.7	1.8	1.8
Commercial	4.9	5.1	5.8	5.8	6.0
Transportation Personal	1.9	1.9	1.9	1.9	2.1
Transportation Freight	8.8	13.2	15.5	16.7	18.1
Mineral Mining	2.3	3.2	5.1	6.0	6.9
Electricity	7.2	8.7	13.8	19.6	17.8
Oil and Gas Extraction	1.7	1.3	3.1	11.7	11.6

Natural gas (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	3.8	2.7	4.6	10.4	10.4
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.2	0.2	0.2	0.2	0.1
Commercial	2.1	2.4	2.7	2.9	2.8
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	1.4	0.1	0.3	0.6	0.6
Oil and Gas Extraction	0.1	0.1	1.4	6.7	6.8

Note: Includes propane.

Coal (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	0.0	0.0	0.0	0.0	0.0
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Refined petroleum products (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	20.5	26.8	33.4	37.8	35.7
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.8	0.6	0.6	0.6	0.6
Commercial	1.6	1.3	1.1	0.7	0.8
Transportation Personal	1.9	1.9	1.9	1.8	1.9
Transportation Freight	8.8	13.1	15.3	16.5	17.9
Mineral Mining	1.3	1.7	2.7	3.1	3.5
Electricity	4.8	7.1	10.9	13.2	9.3
Oil and Gas Extraction	1.3	1.0	1.0	1.9	1.7

Electricity (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	2.6	3.0	4.5	7.4	7.9
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.42	0.46	0.51	0.56	0.61
Commercial	0.81	0.80	0.83	0.80	0.80
Transportation Personal	0.00	0.00	0.01	0.02	0.03
Transportation Freight	0.00	0.00	0.01	0.01	0.01
Mineral Mining	1.04	1.49	2.42	2.91	3.40
Electricity	0.00	0.00	0.00	0.00	0.00
Oil and Gas Extraction	0.29	0.22	0.75	3.08	3.06

Ethanol (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	0.0	0.0	0.0	0.0	0.1
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.1
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Renewable (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	1.7	2.5	4.1	7.7	10.0
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.3	0.4	0.5	0.5	0.5
Commercial	0.3	0.6	1.1	1.4	1.6
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	1.1	1.4	2.6	5.8	7.9
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Note: Includes wood fuel in the residential sector, as well as primarily hydro and wind in the electricity sector. Primary energy coefficients adopted from the International Energy Agency.

Hydrogen (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	0.0	0.0	0.0	0.0	0.0
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Other (PJ)

Summary for Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Total	0.0	0.0	0.0	0.0	0.0
Summary by Sector					
	2010	*2015*	*2020*	*2025*	*2030*
Residential	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.0	0.0	0.0	0.0
Transportation Personal	0.0	0.0	0.0	0.0	0.0
Transportation Freight	0.0	0.0	0.0	0.0	0.0
Mineral Mining	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0
Oil and Gas Extraction	0.0	0.0	0.0	0.0	0.0

Electricity

Northwest Territories					
	2010	*2015*	*2020*	*2025*	*2030*
Energy Intensity (GJ / MWh Electric Generation)	9.27	9.58	9.94	8.67	7.27
Emissions Intensity (t CO2e / MWh Electric Generation)	0.58	0.63	0.64	0.48	0.32
Hydroelectric Generation (Gwh)	246	283	389	960	1,446
Wind Generation (Gwh)	0	7	28	85	99
Other Renewable Generation (Gwh)	5	11	31	61	69
Natural Gas Generation (Gwh)	130	7	27	57	56
Diesel Generation (Gwh)	401	595	910	1,103	778
Total Generation	**782**	**903**	**1,384**	**2,266**	**2,448**

Note: Values account for transmission and distribution losses. Other generation includes biomass, solar and geothermal power. In 2030, roughly 17.4 Fwh of biomass power is generated.

Appendix: CIMS

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 14. 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 14: 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.

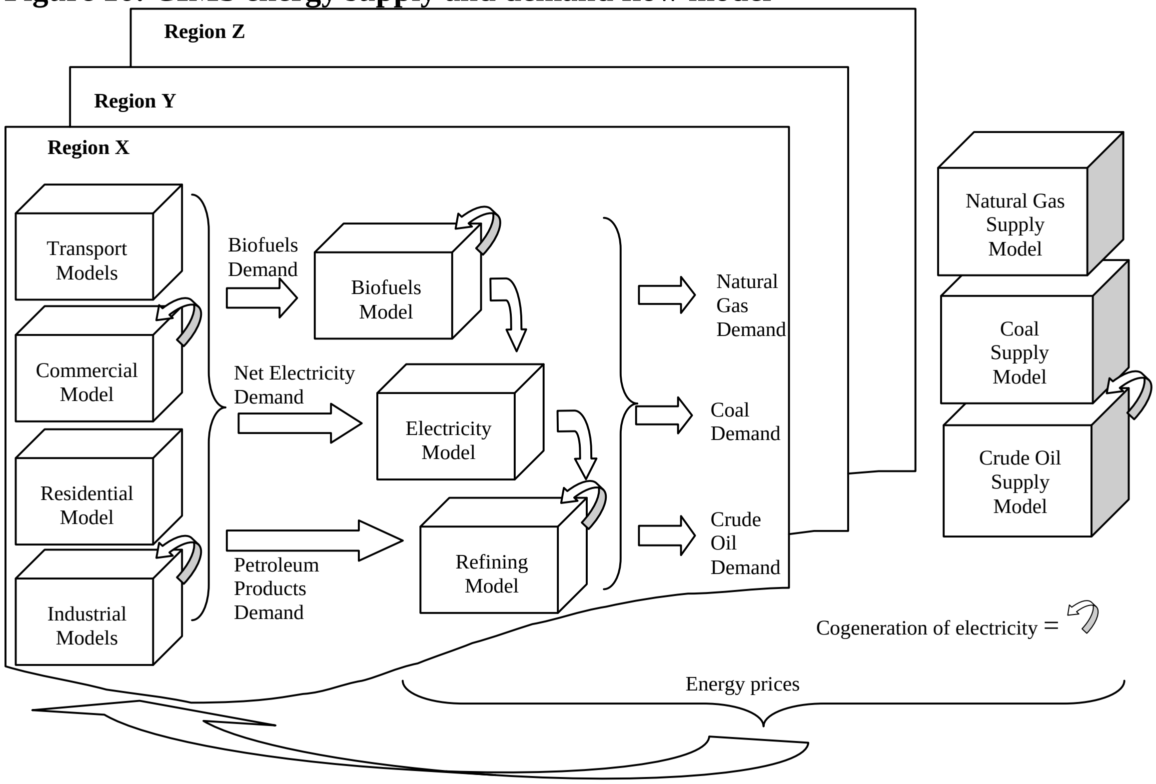
CIMS simulates the competition of technologies at each energy service node in the economy based on a comparison of their life cycle cost (LCC) and some technology-specific controls, such as a maximum market share limit in the cases where a technology is constrained by physical, technical or regulatory 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 16 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 16: 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).[27] 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

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

annual energy consumption of the individual capital stocks tracked by the model (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.[28]

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.

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[28] 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.