# FINAL REPORT

## Exploration of two Canadian greenhouse gas emissions targets: 25% below 1990 and 20% below 2006 levels by 2020

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# Executive Summary

M. K. Jaccard and Associates Inc. (MKJA) has reviewed the feasibility and cost of two levels of greenhouse gas (GHG) emissions reduction in Canada for the David Suzuki Foundation (DSF) and the Pembina Institute. The first is a 25% reduction in GHG emissions below 1990 levels by 2020, henceforth referred to as the "ENGO" (Environmental NGO) target. The second is compliance with the Canadian government's announced commitment to a 20% reduction of GHG from 2006 levels by 2020, henceforth referred to as the "GOVT" target.

The analysis was completed using a combination of the CIMS hybrid technology simulation model and the R-GEEM static computable general equilibrium (CGE) model. CIMS is regionally disaggregated into British Columbia and Canada's territories, Alberta, Saskatchewan, Manitoba, Ontario, Québec, and the Atlantic Provinces. R-GEEM is similarly disaggregated (except that the territories are added to the Atlantic Provinces rather than to British Columbia). R-GEEM also includes Canadian economic activity outside Canada. We found that both the ENGO and GOVT targets are achievable, but only with policy packages considerably more stringent than governments have offered to date in Canada.

### *The Policy Package*

**The core policy is a carbon dioxide equivalent ($CO_2$e) emissions price, implemented as a full auction upstream cap and trade system or a carbon tax covering all combustion and almost all fixed process emissions.** For the ENGO target the emissions price path begins at \$50/tonne $CO_2$e in 2010 rising to \$200/tonne $CO_2$e in 2020. For the GOVT target the emissions price path begins at \$40/tonne $CO_2$e starting in 2011 rising to \$100/tonne $CO_2$e in 2020. Assuming that government spending, with the exception of the climate policies, will remain constant between the reference and policy scenarios, carbon pricing revenues are recycled as follows:

- A portion is used for the purchase of international emissions permits;
- A portion is used for public-good spending programs to improve public transit and upgrade the electricity transmission grid to allow more geographically dispersed renewable electricity generation. The chosen programs have clear and distinct public goods characteristics (i.e., those goods not effectively and efficiently provided by private markets). Relative to the 2020 reference case, these investments increased transit use by an average of 35% across Canada (in the absence of the carbon price), and allowed intermittent renewables (mostly wind power) to capture up to 25% of generation in some regions;
- A portion is used to compensate households for their carbon charges[1] and increased energy costs for heating and electricity (not transportation);

[1] Note: in practice, carbon charges would not be levied directly on households' emissions from use of heating fuels. Instead the charges would be levied on fuel wholesalers, who would pass the charges on to households through fuel prices.

- A portion is used to purchase verifiable and additive domestic agricultural offsets;
- A portion is used to refund a sufficient amount of carbon charges to non-fossil fuels sectors to maintain output at their 2008 level (only the industrial minerals and metal smelting sectors required this refund);
- The remainder is used to directly reduce personal income taxes until government spending and revenue are returned to their reference case levels. This includes compensating for changes in all other government revenues (i.e., corporate and sales taxes and royalties) caused by the policy package. While other recycling mechanisms are plausible, the report only considers labour (i.e., personal income) tax recycling as per specification from DSF and Pembina.

**The carbon price is supplemented by a full suite of complementary regulations**. With the exception of the carbon capture regulation, included only under the ENGO target, complementary regulations are based on carbon market failures of coverage or operation. The regulations are as follows:

- The confinement of venting and flaring in the upstream oil and gas sector solely to safety purposes, with a carbon charge imposed for all registered safety emissions.
- A requirement that all new commercial buildings be built to LEED Gold standard or higher and residential buildings be 50% more efficient than current standard practices. Both categories of new buildings are also restrained from directly combusting fossil fuels, including natural gas, for heating in British Columbia, Manitoba and Québec. All electricity options are allowed, including baseboards and ground and air source heat pumps.
- A requirement that all new vehicles meet the California GHG emissions standard, with a gradually tightening standard due to become virtually zero by 2040.
- A requirement that as of 2011, white good appliance energy efficiency standards be raised to the most efficient commercially available versions of late 2008, and are gradually tightened over time.
- A requirement that almost all landfills be covered and the landfill gas flared or used to produce electricity and heat as the economics warrant.
- For the ENGO target only, carbon capture and storage (CCS) of all formation $CO_2$ from new natural gas processors, process $CO_2$ from new hydrogen production facilities, and all combustion $CO_2$ from all new coal fired electricity plants, oil sands facilities, and upgraders starting in 2016. This regulation, while not associated with a clear market failure, is meant to limit the carbon price level for the rest of the economy. It also helps reduce the cost of the deeper target by driving technological innovation and reducing costs associated with CCS.

The policy assumes the ENGO policy package is announced in late 2009, with the carbon price starting in January 2010 and the other policies in January 2011 (except for the carbon capture regulation starting in 2016). The GOVT package is announced in late 2009, with all policies implemented in January 2011.

DSF requested that we apply an estimate of full life-cycle costing for nuclear generation in this analysis, including construction, permitting, operation, liability insurance, waste handling and decommissioning. Under these conditions the cost of refurbishing, operating and decommissioning an existing reactor was set at 12.6 ¢/kwh, while the cost of a new reactor was set at 20.9 ¢/kwh. We also included a 4.0 ¢/kwh liability insurance charge to capture the implicit government insurance subsidy on nuclear power. Given these cost estimates, all modelling scenarios predicted only some delayed decommissioning of existing capacity, and no building of new generation capacity.[2]

The analysis shows that the carbon charge and complementary polices chosen are not sufficient alone to meet the targets. Their effect under two scenarios was tested: one where the OECD countries impose policies as stringent as Canada (OECD acts together – "OAT"), and one where Canada goes significantly further than its OECD trading partners (Canada goes further – "CGF"). To make up the difference between the target and domestic emissions reductions, purchases of international emissions permits are necessary in both scenarios. For the ENGO target in the "OECD acts together" case, purchases of 101 Mt $CO_2$e per year in 2020 are necessary, while in the "Canada goes further" case, 80 Mt of purchases are required. For the GOVT target in the "OECD acts together" case purchases of 73 Mt per year in 2020 are necessary, while in the "Canada goes further" case, 56 Mt of purchases are required. Fewer permits are required in the "Canada goes further" cases because there are greater reductions in output.

### *Actions to Reduce Emissions in Response to the Policy Packages*

The following actions provide the detailed emissions reductions, relative to the reference case (BAU, business as usual), associated with ENGO CGF. It is important to note that CIMS relies completely on commercially available (if not currently widely used) technologies in this analysis. Please see the main report for details for the other scenarios.

- Carbon capture and storage (76 Mt in 2020); this is partly driven by the CCS regulation, and partly by market forces. In early years this is primarily from relatively pure $CO_2$ sources, such as formation $CO_2$ from natural gas processing and $CO_2$ from steam reformation of methane to produce hydrogen.
- Energy efficiency (57 Mt in 2020), primarily in the personal and freight transportation sectors.
- Other GHG control (52 Mt in 2020), which includes control of fugitives in upstream oil and gas, and capping, flaring and cogeneration of landfill gas
- International permit purchases (80 Mt in 2020)

[2] Ontario Clean Air Alliance, *The Economics of Nuclear Power* (2006), puts the price of new nuclear build is 20.9 cents/kWh. The cost of refurbished nuclear capacity has been estimated to be 60% of the cost of new nuclear in Icyk, B., *At what cost? A comparative evaluation of the social cost of selected electricity generation alternatives in Ontario*, M.E.S. thesis, University of Waterloo (2006).

- Switching to electricity in all sectors, including buildings (33 Mt in 2020)
- Switching to renewables in electricity production (33 Mt in 2020). This is largely hydro and wind.
- Output reductions (64 Mt in 2020), mostly reduced fossil fuel output.

**Table 1: Actions taken to reduce emissions ENGO "Canada goes further," Mt $CO_2e$**

| | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|
| Baseline (BAU) emissions | 714* | 734 | 786 | 848 |
| Emissions after application of domestic policies | 714 | 711 | 595 | 514 |
| Domestic emissions reductions: | | | | |
| Output reduction | 0 | 12 | 46 | 64 |
| Other GHG control | 0 | 3 | 41 | 52 |
| Fuel switching to nuclear | 0 | 0 | 1 | 1 |
| Fuel switching to renewables | | 4 | 18 | 33 |
| Fuel switching to electricity | 0 | 0 | 14 | 33 |
| Fuel switching to other fuels | 0 | -3 | 2 | 10 |
| Carbon capture and storage | 0 | 1 | 29 | 76 |
| CCS energy efficiency penalty | 0 | 0 | 5 | 9 |
| Energy efficiency | 0 | 4 | 35 | 57 |
| International permit purchases | 0 | 5 | 40 | 80 |
| Target (remaining emissions) = Baseline– domestic emissions reductions – permit purchases | | | | 434 |

*Note: See Table 98 for a description of emissions included in CIMS.

**Figure 1: Emission reduction actions ENGO "Canada goes further"**

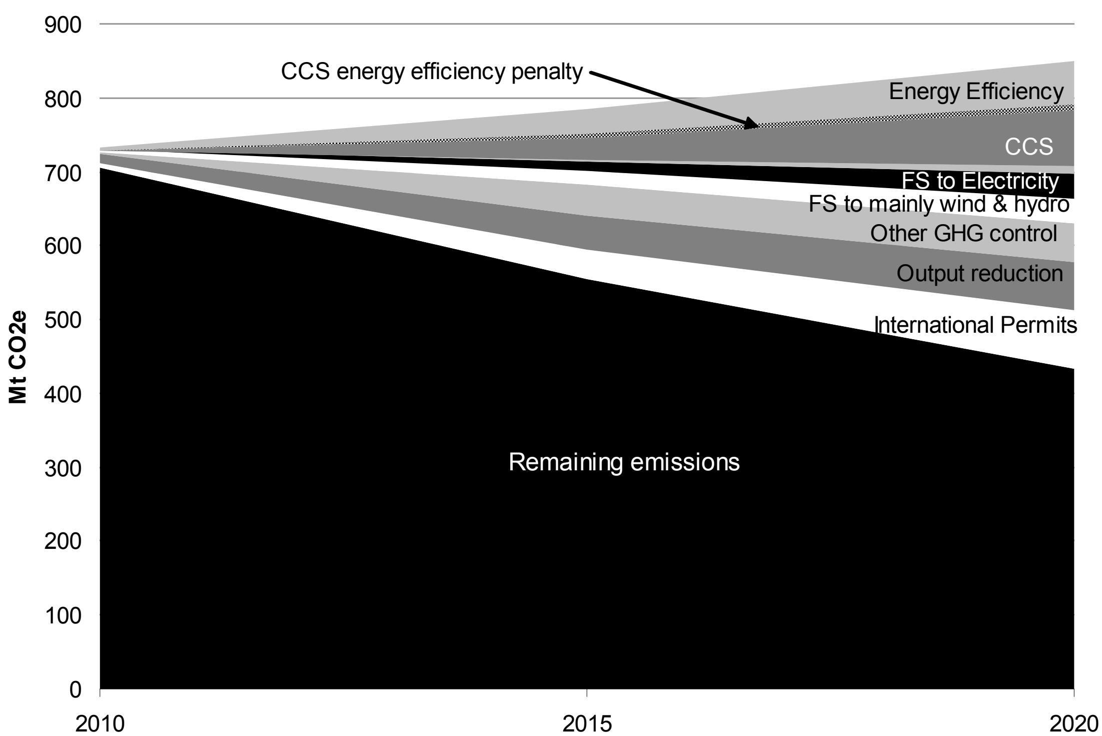


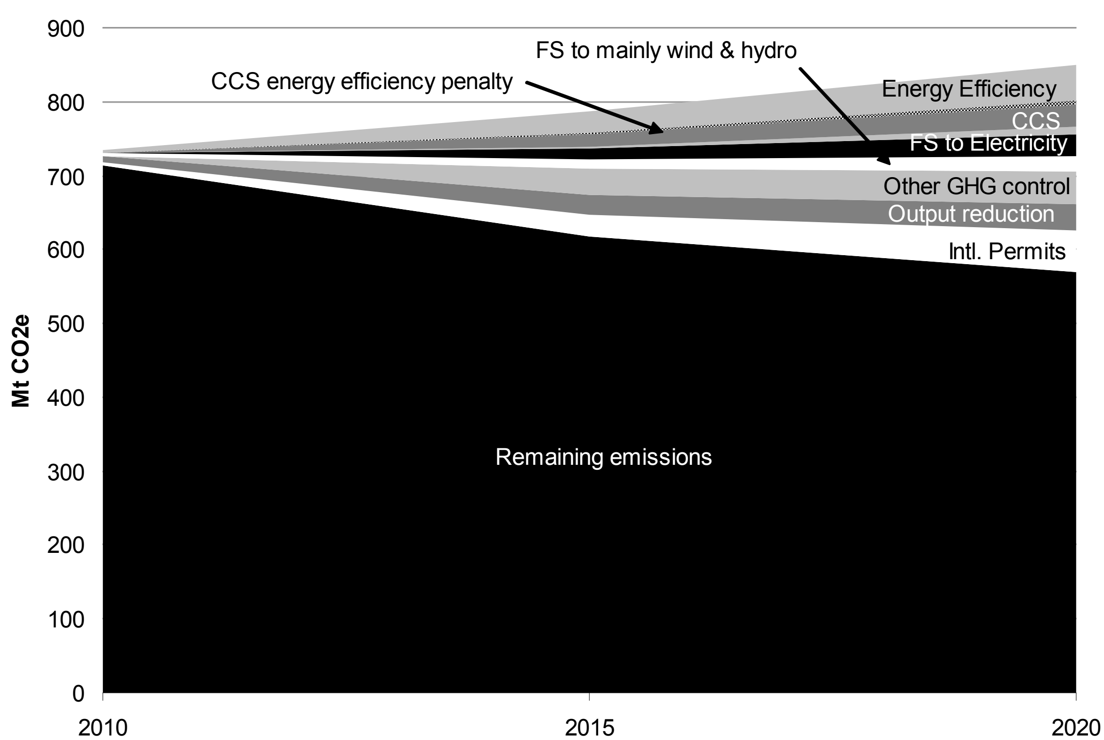
Table 2 and Figure 2 provide the emission reduction actions associated with GOVT CGF. It is important to note that in this case all CCS is completely market driven.

**Table 2: Actions taken to reduce emissions GOVT "Canada goes further", Mt $CO_2e$**

| | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|
| Baseline (BAU) emissions | 714* | 734 | 786 | 848 |
| Emissions after application of domestic policies | 704 | 718 | 647 | 626 |
| Domestic emissions reductions: | | | | |
| Output reduction | 6 | 8 | 26 | 36 |
| Other GHG control | 0 | 0 | 36 | 43 |
| Fuel switching to nuclear | 0 | 0 | 0 | 0 |
| Fuel switching to renewables | 2 | 5 | 13 | 22 |
| Fuel switching to electricity | 0 | 0 | 13 | 30 |
| Fuel switching to other fuels | 0 | 0 | 3 | 10 |
| Carbon capture and storage | 0 | 1 | 17 | 30 |
| CCS energy efficiency penalty | 0 | 0 | 3 | 5 |
| Energy efficiency | 2 | 3 | 28 | 49 |
| International permit purchases | 0 | 5 | 31 | 56 |
| Target (remaining emissions) = Baseline– domestic emissions reductions – permit purchases | | | | 570 |

*Note: See Table 97 for a description of emissions included in CIMS.

**Figure 2: Emission reduction actions GOVT "Canada goes further"**




Detailed results for all scenarios are provided in the main report.

### *Macroeconomic Effects*

Macroeconomic models like R-GEEM provide a key overarching measure of changes to household "welfare," which is derived from a composite of goods consumption and leisure. The theory behind this measure is that households possess capital (savings and investments) and time, neither of which is directly useful. They need to be converted to goods and leisure to produce welfare. Households therefore typically sell or lend all their capital to firms to produce goods for domestic use and export, in return for interest, dividends, etc. They also sell some of their time to firms to produces wages (i.e., they provide labour) so that they may consume the goods produced by firms. Finally, they keep some of their time for themselves, i.e., they "consume" leisure. Table 3 shows how overall welfare fares under the GOVT and ENGO targets and the two international scenarios.[3]

**Table 3 Overall change in welfare ("equivalent variation") from consumption and leisure relative to BAU by region, 2020**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada Average |
|---|---|---|---|---|---|---|---|---|
| ENGO OAT | -2.1% | -7.8% | -5.2% | -0.1% | -1.7% | -1.4% | -1.9% | -2.4% |
| ENGO CGF | -2.1% | -7.7% | -5.3% | 0.2% | -1.5% | -1.3% | -1.9% | -2.3% |
| GOVT OAT | -0.9% | -4.2% | -2.6% | 0.3% | -0.9% | -0.7% | -0.6% | -1.2% |
| GOVT CGF | -0.8% | -4.6% | -2.8% | 0.6% | -0.6% | -0.4% | -0.4% | -1.0% |

Overall Canadian welfare based on consumption and leisure falls ~2.4% from BAU in the ENGO case, and ~1.1% in the GOVT case. There are significant regional differences, however, with Alberta experiencing reductions of ~7.8 % in the ENGO case and ~4.4% in the GOVT case, while Ontario experiences reductions of ~1.6% and ~0.8% respectively. Welfare grows under all scenarios, with and without a climate policy.

Table 3 includes the effect of the carbon revenue returned to households. The carbon costs associated with heating fuels, as well as the increases in electricity and heating fuel costs relative to BAU, are returned to all households as equal per capita lump sum payments (Table 4).

**Table 4 Annual household compensation per capita 2020 ($2005)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada Average |
|---|---|---|---|---|---|---|---|---|
| ENGO OAT | 66.87 | 920.39 | 721.22 | 33.55 | 92.97 | 29.86 | 259.28 | 192.98 |
| ENGO CGF | 68.02 | 939.67 | 737.09 | 41.80 | 92.57 | 30.44 | 196.41 | 191.25 |
| GOVT OAT | 38.47 | 501.03 | 372.27 | 22.22 | 56.97 | 20.99 | 153.83 | 109.39 |
| GOVT CGF | 41.84 | 564.74 | 436.65 | 25.74 | 62.35 | 22.36 | 166.77 | 122.10 |

Table 5 shows the sources of carbon revenues by region: under the ENGO target, ~$23 billion comes from Alberta, ~$21 billion from Ontario, and ~$10 billion from Québec.

[3] This measure is derived from a dollar amount by which households would have to be compensated to return them to their pre-policy welfare levels (i.e., "equivalent variation" in economic parlance).

**Table 5 Regional sources of carbon revenue 2020 ($2005 billions)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | 7.28 | 23.71 | 3.84 | 1.76 | 20.72 | 9.90 | 4.74 |
| ENGO CGF | 7.35 | 21.84 | 3.74 | 1.79 | 21.04 | 10.10 | 4.81 |
| GOVT OAT | 4.27 | 17.18 | 2.49 | 1.02 | 12.06 | 5.74 | 2.79 |
| GOVT CGF | 3.76 | 15.50 | 2.24 | 0.90 | 10.63 | 5.02 | 2.57 |

Table 6 details how the carbon revenue, ~$70 billion in the ENGO case and ~$40 billion in the GOVT case, is redistributed. For example, in the case of ENGO "Canada goes further":

- $6.0 billion is used to purchase international permits;
- $1.0 billion is used to purchase verifiable and additive domestic agricultural offsets;
- $1.8 billion is refunded to the metal smelting sector to maintain output at 2008 levels;
- $9.0 billion is used to fund improvements to the electricity transmission grid and to improve transit;
- $7.1 billion is sent back to households to compensate them for their carbon charges and increased energy costs for heating and electricity;
- $8.0 billion is used to make up for reduced corporate taxes;
- $4.6 billion is used to make up for reduced excise taxes and royalties; and
- Finally, $33.2 billion is used to reduce personal income taxes.

**Table 6 Uses of carbon revenue 2020 ($2005 billions)**

| | Carbon revenues[4] | Inter-national permits | Agric-ultural offsets | Subsidies to maintain 2008 output | Elec. & transit subsidies | House-hold comp-ensation | Direct & indirect personal income taxes | Direct & indirect corporate taxes | Sum of other flows[5] |
|---|---|---|---|---|---|---|---|---|---|
| E-OAT | 71.95 | -10.01 | -1.02 | 0.00 | -9.05 | -7.16 | -31.88 | -8.21 | -4.62 |
| E-CGF | 70.68 | -5.93 | -1.02 | -1.76 | -9.05 | -7.09 | -33.15 | -8.03 | -4.64 |
| G-OAT | 40.61 | -5.43 | -0.36 | 0.00 | -9.05 | -4.06 | -14.53 | -5.08 | -2.10 |
| G-CGF | 45.53 | -2.80 | -0.36 | -0.08 | -9.05 | -4.53 | -21.16 | -5.34 | -2.21 |

Table 7 shows the destination of carbon revenues (not counting the international permit purchases) by region.

[4] R-GEEM tracks only fossil fuel combustion emissions, while CIMS tracks all emissions. Carbon revenues in R-GEEM are therefore somewhat under-estimated. The numbers in Tables 4–6 are based only on carbon revenues from fossil fuel combustion.

[5] Changes in sales taxes, other excise taxes, royalties of all types, etc.

**Table 7 Regional destination of carbon revenue 2020 ($2005 billions)**[6]

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | 9.19 | 19.30 | 2.50 | 0.91 | 14.91 | 9.76 | 4.29 |
| ENGO CGF | 9.68 | 19.18 | 3.00 | 1.09 | 16.25 | 10.23 | 4.25 |
| GOVT OAT | 6.25 | 12.32 | 1.28 | 0.50 | 6.38 | 5.93 | 2.58 |
| GOVT CGF | 7.12 | 14.23 | 1.78 | 0.73 | 9.10 | 6.93 | 2.86 |

Other recycling mechanisms, e.g. output-based or corporate tax recycling, could have significantly different revenue, sector, GDP and welfare impacts.

### *Employment*

The following tables outline the changes in employment, salaries and changes in wage rates. Table 8 provides numbers of jobs in 2010 and 2020 in the reference case (BAU), and jobs in 2020 under the four scenarios. A key caveat of these results is that RGEEM does not allow inter-regional migration as a response to policy. If this were the case more workers would leave the West, especially Alberta, and move to Manitoba, Ontario, Québec and the Atlantic provinces.

Table 9 shows how the number of jobs is expected to increase from 2010 to 2020 under all scenarios. Employment in all regions continues to grow from 2010 to 2020 under all scenarios, slightly faster under the climate policy scenarios than in the BAU scenario. Firms hire more under the climate policy scenarios because labour costs are lower, while at the same time labour supply increases in response to the recycling of carbon revenues to reduce personal income tax.

**Table 8 Jobs 2020 (1000s)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU 2010 | 2,353 | 2,043 | 517 | 615 | 6,724 | 3,896 | 1,207 | 17,354 |
| BAU 2020 | 2,600 | 2,245 | 564 | 664 | 7,702 | 4,136 | 1,247 | 19,156 |
| ENGO OAT | 2,608 | 2,177 | 563 | 674 | 7,774 | 4,176 | 1,238 | 19,211 |
| ENGO CGF | 2,605 | 2,176 | 560 | 673 | 7,776 | 4,177 | 1,244 | 19,211 |
| GOVT OAT | 2,614 | 2,211 | 567 | 671 | 7,751 | 4,163 | 1,242 | 19,219 |
| GOVT CGF | 2,617 | 2,207 | 566 | 673 | 7,773 | 4,178 | 1,247 | 19,260 |

**Table 9 Jobs expressed as a percentage increase from 2010 to 2020**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU 2020 | 10.5% | 9.9% | 9.2% | 7.9% | 14.5% | 6.2% | 3.3% | 10.4% |
| ENGO OAT | 10.9% | 6.6% | 8.9% | 9.6% | 15.6% | 7.2% | 2.6% | 10.7% |
| ENGO CGF | 10.7% | 6.5% | 8.3% | 9.4% | 15.7% | 7.2% | 3.1% | 10.7% |
| GOVT OAT | 11.1% | 8.2% | 9.7% | 9.1% | 15.3% | 6.9% | 2.9% | 10.7% |
| GOVT CGF | 11.2% | 8.0% | 9.5% | 9.4% | 15.6% | 7.2% | 3.3% | 11.0% |

[6] The accounting method used does not allow an exact match between revenues net of international permit outflows and regional allocation. The differences by scenario range from ~$0 to 1 billion.

Table 10 shows the average pre-tax salary by region. Under the climate policy scenarios, pre-tax salaries climb in most regions more slowly than under BAU.

**Table 10 Pre-tax annual salaries 2020 ($2005)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| BAU | 53,746 | 65,890 | 48,612 | 49,949 | 57,453 | 51,175 | 55,908 |
| ENGO OAT | 52,204 | 57,959 | 45,640 | 50,281 | 56,509 | 50,202 | 53,319 |
| ENGO CGF | 52,020 | 57,860 | 45,131 | 50,134 | 56,529 | 50,177 | 53,678 |
| GOVT OAT | 53,541 | 61,821 | 47,801 | 50,690 | 57,321 | 51,029 | 54,940 |
| GOVT CGF | 53,269 | 61,014 | 47,185 | 50,623 | 57,289 | 50,969 | 54,880 |

Table 11 provides wages from the perspective of firms (i.e., the cost of labour), while Table 12 provides wages from the perspective of employees (i.e., take home pay after taxes). Employee take home pay per hour increases under all scenarios but falls relative to BAU. However, pay falls less than firm labour costs because of the recycling of carbon revenues to reduce personal income tax. Effective personal income tax rates are set nationally, and fall 11.6% in the ENGO OAT scenario, 10.9% in ENGO CGF, 3.9% in GOVT OAT, and 7.9% in GOVT CGF.

**Table 11 Average hourly wage rate excluding direct taxes 2020 (% change from BAU) "firm cost"**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | -2.9% | -12.0% | -6.1% | 0.7% | -1.6% | -1.9% | -4.6% |
| ENGO CGF | -3.2% | -12.2% | -7.2% | 0.4% | -1.6% | -1.9% | -4.0% |
| GOVT OAT | -0.4% | -6.2% | -1.7% | 1.5% | -0.2% | -0.3% | -1.7% |
| GOVT CGF | -0.9% | -7.4% | -2.9% | 1.4% | -0.3% | -0.4% | -1.8% |

**Table 12 Average hourly wage rate including direct taxes 2020 (% change from BAU) "employee take home pay"**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | -1.0% | -10.4% | -4.1% | 2.9% | 0.5% | 0.7% | -2.5% |
| ENGO CGF | -1.2% | -10.4% | -5.0% | 2.8% | 0.7% | 0.8% | -1.7% |
| GOVT OAT | 0.3% | -5.5% | -0.9% | 2.3% | 0.5% | 0.6% | -1.0% |
| GOVT CGF | 0.5% | -6.1% | -1.4% | 3.0% | 1.3% | 1.5% | -0.3% |

Finally, there is significant shift away from capital intense (e.g. fossil fuel) to labour intense (manufacturing and services) industries in all regions.

### *Changes in Capital Investment*

R-GEEM, as a static CGE model with fixed and flexible capital, operates with the assumption that Canadian savings will support a given amount of capital investment between 2010 and 2020, to both replace worn out stock and make new investments. In the case of 2020, using Informetrica's economic forecast, the total capital stock available is $510 billion. Table 13 details how this capital is allocated in the BAU and policy scenarios in 2020. The new, flexible portion of this is free to migrate to whichever sectors and regions in the country that offer the highest returns. No *net* foreign capital is assumed to be available, i.e. all investment must be funded in the long run from Canadian sources. Table 14 illustrates the change in capital investment under the policy scenarios. Of note is that $12–15 billion less is invested in Alberta, and is instead invested in other regions, mainly Ontario and Québec. However, the total amount of capital investment does not change, which reflects the assumptions of the model.

**Table 13 Capital investment 2020 ($2005 billions)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU | 63.4 | 113.4 | 19.7 | 15.8 | 175.2 | 88.9 | 33.8 | 510.1 |
| ENGO OAT | 63.3 | 98.9 | 18.9 | 17.2 | 184.2 | 92.6 | 35.1 | 510.1 |
| ENGO CGF | 62.6 | 100.4 | 18.1 | 17.0 | 184.0 | 92.6 | 35.3 | 510.1 |
| GOVT OAT | 63.9 | 101.8 | 19.4 | 16.6 | 182.0 | 91.4 | 35.0 | 510.1 |
| GOVT CGF | 63.9 | 99.9 | 19.0 | 16.7 | 183.1 | 92.2 | 35.3 | 510.1 |

**Table 14 Absolute change in capital investment 2020 ($2005 billions relative to BAU)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| ENGO OAT | -0.1 | -14.5 | -0.8 | 1.4 | 9.0 | 3.7 | 1.3 | 0.0 |
| ENGO CGF | -0.8 | -13.0 | -1.6 | 1.2 | 8.8 | 3.7 | 1.6 | 0.0 |
| GOVT OAT | 0.5 | -11.6 | -0.3 | 0.8 | 6.8 | 2.5 | 1.2 | 0.0 |
| GOVT CGF | 0.5 | -13.5 | -0.7 | 0.9 | 7.9 | 3.3 | 1.6 | 0.0 |

### *Changes in Absolute and Per Capita GDP*

Table 15 provides relative changes in GDP from BAU to the policy scenarios, in basic prices, by region and for Canada. Overall Canadian GDP falls ~3.1% under the ENGO scenario, and ~1.5% under the GOVT scenario. Regional differences are marked, however, with 2020 GDP in Alberta falling ~12% under ENGO and ~8% under GOVT, while Ontario experiences no net impact.

The economy grows under all scenarios (Table 16): without climate policy the overall economy grows 27% from 2010–2020, and 23–25% under the climate policy scenarios. Alberta's economy grows 57% without climate policy, and 38–46% with climate policy.

GDP per capita also (Table 17) grows under all scenarios and in all regions: without climate policy Canada's GDP per capita grows 24% from 2010–2020, and 20–22% under the climate policy scenarios. Alberta's GDP per capita grows 42% without climate policy, and 25–32% with climate policy. However, a caveat of these results is that the model does not allow population to vary from the BAU forecast. In reality, population growth, especially migration from other regions, is tied to economic performance. Alberta's population growth is likely to be lower in the climate policy scenarios than under BAU, resulting in a GDP per capita in 2020 higher than shown below.

The relative regional impacts of the "OECD Acts Together" and "Canada Goes Further" scenarios very significantly. While the differences are not large at the national level (nominal 3.0 vs. 3.2% of GDP for ENGO (Table 15)) because Canada's overall economy is dominated by the service sector and much of the country's industrial sector is only moderately carbon intensive, the relative impacts are much higher for Saskatchewan (nominal 2.8% difference) and BC, Manitoba and the Atlantic provinces (0.6%). Across the nation, there is a migration of capital and labour out of carbon and trade exposed sectors (e.g., fossil fuels) to sectors that are less carbon and trade exposed (e.g., manufacturing, services and renewable electricity).

**Table 15 Relative change in GDP at basic prices in 2020 from BAU**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| ENGO OAT | -4.2% | -11.9% | -4.7% | 2.7% | 0.0% | -1.3% | -2.5% | -3.0% |
| ENGO CGF | -4.8% | -12.1% | -7.5% | 2.1% | 0.0% | -1.3% | -1.9% | -3.2% |
| GOVT OAT | -2.2% | -7.3% | -1.2% | 1.9% | 0.6% | -0.7% | -0.5% | -1.4% |
| GOVT CGF | -2.5% | -8.5% | -2.8% | 2.1% | 0.9% | -0.3% | -0.1% | -1.5% |

**Table 16 Relative change in GDP at basic prices 2010–2020**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU 2010-20 (+%) | 30% | 57% | 26% | 20% | 21% | 15% | 33% | 27% |
| ENGO OAT (+%) | 24% | 39% | 20% | 23% | 21% | 13% | 30% | 23% |
| ENGO CGF (+%) | 24% | 38% | 16% | 22% | 21% | 14% | 30% | 23% |
| GOVT OAT (+%) | 27% | 46% | 24% | 22% | 22% | 14% | 32% | 25% |
| GOVT CGF (+%) | 27% | 44% | 22% | 22% | 22% | 15% | 33% | 25% |

**Table 17 Relative change in GDP per capita at basic prices 2010–2020 (regional population held at BAU levels)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU 2010-20 (+%) | 17% | 42% | 16% | 12% | 9% | 9% | 30% | 17% |
| ENGO OAT (+%) | 12% | 25% | 11% | 15% | 9% | 7% | 26% | 13% |
| ENGO CGF (+%) | 12% | 25% | 8% | 14% | 9% | 7% | 27% | 13% |
| GOVT OAT (+%) | 15% | 32% | 15% | 14% | 10% | 8% | 29% | 15% |
| GOVT CGF (+%) | 14% | 30% | 13% | 14% | 10% | 9% | 30% | 15% |

Absolute GDP values for all scenarios are provided in the main report.

### *Conclusion*

Our analysis finds that both the ENGO and GOVT targets are feasible, but require that much more broad and stringent policies be implemented than have hitherto been offered by governments in Canada, and that they be implemented very soon. These policies are projected to trigger significant impacts on GDP with significant regional differences, especially for Alberta and Saskatchewan. BC is also negatively affected, while Manitoba is expected to benefit. The impacts of a carbon charge on GDP in Ontario, Quebec and the Atlantic provinces are compensated by an influx of capital that would have otherwise been invested in the fossil fuel industry in the western provinces, especially Alberta. The climate policy scenarios are projected to slightly accelerate the rate of employment growth, largely because of the recycling of carbon revenues to reduce personal income tax.

# Introduction

At the request of the David Suzuki Foundation (DSF) and the Pembina Institute, M. K. Jaccard and Associates Inc. (MKJA) used two models of the Canadian energy economy — the CIMS hybrid technology simulation model and the Regional GEEM (R-GEEM) static computable general equilibrium model — to explore the feasibility and cost of two greenhouse gas (GHG) emissions targets for Canada: a 25% reduction in Canada's GHG emissions from 1990 levels by 2020 (i.e., an emissions target of 434 Mt $CO_2e$ adjusted to exclude $N_2O$ from nitric and adipic acid, halocarbon and forestry and land use change emissions[7]), and the Canadian government's emissions target of a 20% reduction from 2006 levels by 2020 (an adjusted target of 570 Mt). Henceforth referred to as the "ENGO" (environmental NGO) and "GOVT" targets, both reduction schedules are deeper and faster than most analyzed in the past, especially for Canada, and are therefore as much an exploration of the potential to achieve this kind of reduction as a detailed analysis of the costs and necessary stringency of policy. This policy was explored under two contrasting global carbon policy scenarios: one where the OECD maintains the same level of carbon price as Canada, and one where Canada's policy is significantly more stringent. The non-OECD countries are assumed to have considerably weaker carbon emissions restrictions in both scenarios.

Two models were used to conduct the analysis because each model has different strengths. CIMS was used to explore the necessary emissions reductions and the sectoral technology, capital investment, energy, efficiency, and fuel switching implications, while R-GEEM was used to explore the regional and national macroeconomic impacts, such as changes in GDP, consumption, employment, and trade. Once a sufficient carbon price schedule combined with complementary regulations and spending programs was found in CIMS to achieve each reduction target, R-GEEM was run with the policy package to analyze the macroeconomic implications.

This report begins with an overview of the CIMS and R-GEEM models, followed by a description of the policy package and the scenario assumptions that were made. It concludes with results of the analysis, including incremental emissions reductions from individual policies and macroeconomic impacts. Appendices outline the penetration of key emission reduction technologies in the CIMS policy simulation and further describe CIMS and R-GEEM. The final appendix explains the assumptions used to construct the reference case.

# Method

### *Modelling Framework: CIMS*

The CIMS model was originally designed as a predecessor to the NEMS model of the United States Energy Information Administration, and has been subsequently developed

[7] See Table 98 for a more complete description of emissions not included in CIMS.

for Canada by MKJA and the Energy and Materials Research Group at Simon Fraser University. It simulates the technological evolution of the energy-using capital stock in the Canadian economy (such as buildings, vehicles, and equipment) and the resulting effect on output, investment, labor and fuel costs, energy use, GHG and criteria air contaminant (CAC) emissions, and some material flows. The stock of energy-using capital is tracked in terms of energy service provided ($m^2$ of lighting or space heating) or units of physical product (metric tons of market pulp or steel). New capital stocks are acquired as a result of time-dependent retirement of existing stocks and growth in stock demand. Market shares of technologies competing to meet new stock demands are determined by standard financial factors as well as behavioral parameters from empirical research on consumer and business consumption and investment preferences. CIMS has three modules — energy supply, energy demand, and macro-economy — that can be simulated as an integrated model or individually. A model simulation comprises the following basic steps:

1. A base-case macroeconomic forecast initiates model runs. The macroeconomic forecast is at a sectoral or sub-sectoral level (e.g., it estimates the growth in total passenger travel demand or in airline passenger travel demand). The forecast adopted for this study is described in the reference case appendix.
2. In each time period, some portion of the existing capital stock is retired according to stock lifespan data. Retirement is time-dependent, but sectoral decline can also trigger retirement of some stocks before the end of their natural lifespan. The output of the remaining capital stocks is subtracted from the forecast energy service or product demand to determine the demand for new stocks in each time period.
3. Prospective technologies compete for new capital stock requirements based on financial considerations (capital cost, operating cost), technological considerations (fuel consumption, lifespan), and consumer preferences (perception of risk, status, comfort), as revealed by behavioral-preference research. The model allows both firms and individuals to project future energy and carbon prices with imperfect foresight when choosing between new technologies (somewhere between total myopia and perfect foresight about the future). Market shares are a probabilistic consequence of these various attributes.
4. A competition also occurs to determine whether technologies will be retrofitted or prematurely retired. This is based on the same type of considerations as the competition for new technologies.
5. The model iterates between the macro-economy, energy supply and energy demand modules in each time period until equilibrium is attained, meaning that energy prices, energy demand and product demand are no longer adjusting to changes in each other. Once the final stocks are determined, the model sums energy use, changes in costs, emissions, capital stocks and other relevant outputs.

The key market-share competition in CIMS can be modified by various features depending on evidence about factors that influence technology choices. Technologies can be included or excluded at different time periods. Minimum and maximum market shares can be set. The financial costs of new technologies can decline as a function of market penetration, reflecting economies of learning and economies of scale. Intangible factors in consumer preferences for new technologies can change to reflect growing familiarity and lower risks as a function of market penetration. Output levels of technologies can be linked to reflect complementarities.

Personal mobility provides an example of CIMS' operation. The future demand for personal mobility is forecast for a simulation of 30 or more years and provided to the energy demand module. After the first five years, existing stocks of personal vehicles are retired because of age. The difference between forecast demand for personal mobility and the remaining vehicle stocks to provide it determines the need for new stocks. Competition among alternative vehicle types (high and low efficiency gasoline, natural gas, biofuel, electric, gasoline-electric hybrid, and eventually hydrogen fuel-cell) and even among alternative mobility modes (single occupancy vehicle, high occupancy vehicle, public transit, cycling and walking) determines technology market shares. The results from personal mobility and all other energy services determine the demand for fuels. Simulation of the energy supply module, in a similar manner, determines new energy prices, which are sent back to the energy demand module. The new prices may cause significant changes in the technology competitions. The models iterate until quantity and price changes are minimal, and then pass this information to the macro-economic module. A change from energy supply and demand in the cost of providing personal mobility may change the demand for personal mobility. This information will be passed back to the energy demand module, replacing the initial forecast for personal mobility demand. Only when the model has achieved minimal changes in quantities and prices does it stop iterating, and move on to the next five-year time period.

The model was recently recalibrated to reflect EC's *National Inventory Report - Greenhouse Gas Sources and Sinks in Canada 1990-2006* as well as EC's online *Criteria Air Contaminant Emissions Summaries: 1990-2015.* We also updated the values from Natural Resources Canada's (NRCan) *Canada's Energy Outlook 2006 (CEO 2006)*, which provides the foundation of CIMS' physical output forecast to 2020, to reflect recently released output, energy and emissions data for 2005 from Natural Resources Canada's *Comprehensive Energy Use Database* and Statistics Canada's *Report on Energy Supply and Demand*. The Canadian Association of Petroleum Producers' (CAPP) latest 2008 forecast was used for oil production to account for the recent slow down in investment in the petroleum sector. Details of the reference case are provided in an appendix. More on CIMS is also provided in an appendix.

### CIMS Limitations and Uncertainties

Like all models, CIMS is a representation of the real world, not a perfect copy. Even though CIMS is very detailed compared to other models used for similar purposes, its broad scope (it represents almost all GHG emissions and energy consumption throughout the economy) requires many simplifying assumptions. The main uncertainties and limitations in the model are:

- **Technological detail and dynamics:** CIMS contains a considerable level of technological detail in each of its sectoral sub-models. This detail enables CIMS to show accelerated market penetration of alternative technologies in response to an energy, climate change or CAC policy and to ensure that reference and policy scenarios are grounded in technological and economic reality, including realistic capital stock life and turnover. While care has been taken in representing the engineering and economic parameters of the many technologies in CIMS, including costs, uncertainty exists as to the appropriate cost and operating parameters of specific current and future technologies.

While CIMS contains a representation of dynamic technological change that depicts how the costs of new technologies can be reduced through economies of scale and production experience based on historical experience, there is no guarantee that these relationships will hold in the future. In addition, CIMS only contains technological options that are known today (including those that are not yet commercialized). By definition, CIMS does not contain a depiction of new technologies that have not yet been invented and as a result, CIMS could miss technological substitution options in later years of the forecast. There are, however, only 11 years to 2020 — 11 years for brand new technologies not currently in CIMS to be invented, prototyped, commercialized and to enter the capital stock. Capital is mostly fairly longed-lived in buildings and industry, and there is simply not enough time for radical change to occur, other than by shutting industrial sectors down. This uncertainty becomes larger over time, but is of more concern after 2025-2030, which limits the concern for this analysis.

- **Behavioural realism:** The technology choice algorithm of CIMS takes into account implicit discount rates revealed by real-world technology acquisition behavior, intangible costs that reflect consumer and business preferences, and heterogeneity in the marketplace. Incorporating behavioral realism is critical in order to predict realistic consumer and firm response to policies; incorporating these preferences at a detailed level into a model that is technologically explicit is challenging. In addition to the sheer volume of the data requirements, the non-financial preferences of consumers and firms are difficult to estimate, and can change over time. The complexities associated with estimating behavioral parameters, combined with the fact that information cannot be collected for all the technology competitions in CIMS, result in a high degree of uncertainty associated with these parameters overall. The potential for preference change is also a key uncertainty.

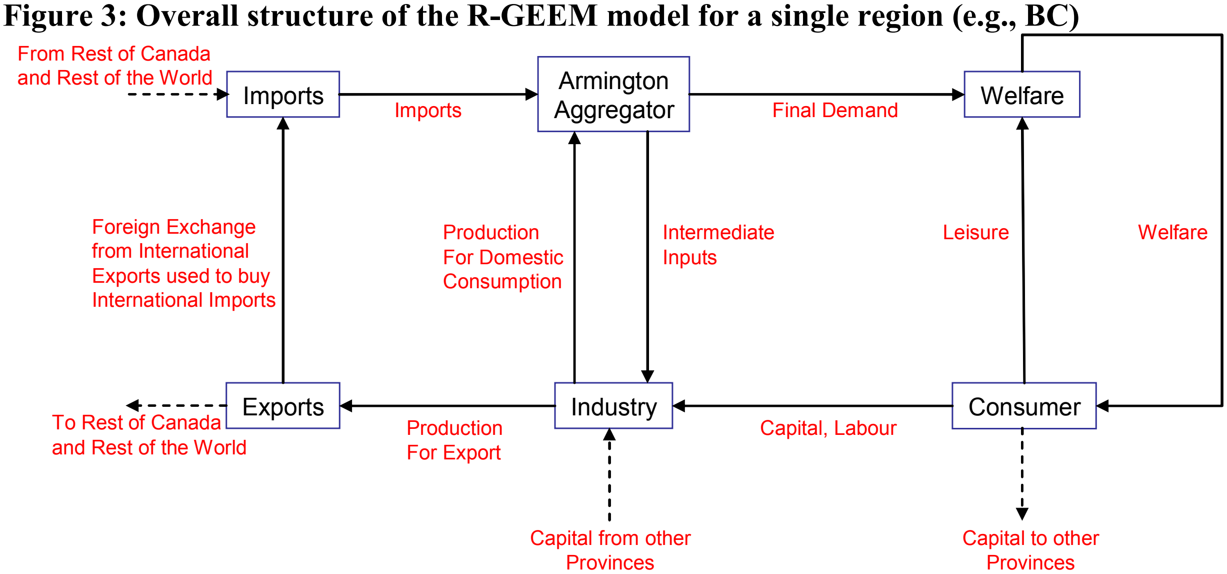
- **External inputs:** CIMS requires external forecasts of macroeconomic activity in each sub-sector: population growth forecasts and starting fuel price forecasts on which to base the analysis. These forecasts are uncertain and could affect the results of the simulations. In addition, since no individual forecast is available to provide all key inputs over the period of interest in this analysis, we have adopted inputs from several different sources. We have used respected sources that are cited in the reference case appendix, and attempt to ensure consistency between various sources, but it is likely that the various inputs we use are not perfectly consistent with one another.

➢ **Equilibrium feedbacks:** Unlike most computable general equilibrium models (which do not generally contain technological detail), the current version of CIMS, while it does include direct responses of firms and consumers to increased input and final goods prices, does not equilibrate government budgets nor 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. As a result, it is likely to underestimate the full structural response of the economy to energy and climate change policies. For this reason, using the results from CIMS, we use the R-GEEM model of the Canadian economy to estimate the effect of the specified emissions reduction target.

### *Modelling Framework: R-GEEM*

R-GEEM is a static multi-sector, open-economy computable general equilibrium (CGE) model that represents BC, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and Atlantic Canada as separate regions. In the current version Canadian economic activity outside Canada is included with the Atlantic Provinces. In the model, a representative consumer is the owner of the primary factors (labour and capital). The consumer rents these factors to producers, who combine them with intermediate inputs to create commodities. These commodities can be sold to other producers (as intermediate inputs), to final consumers, or sold to the rest of the world as exports. Commodities can also be imported from the rest of the world. R-GEEM is a small open-economy model and it would be assumed to be a price taker for internationally traded goods. The key economic flows in R-GEEM are captured schematically in Figure 3.

**Figure 3: Overall structure of the R-GEEM model for a single region (e.g., BC)**




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

As a static model, R-GEEM does not model the accumulation and depreciation of capital, so it cannot model incentives for investment. Instead, investment capital is modeled as a fixed stock; capital investment can be moved between different sectors or regions in response to a policy, but the overall level of investment remains constant.

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

The data underlying the model is derived primarily from the Statistics Canada System of National Accounts. We use the S&M Level Input, Output, and Final Demand tables to populate the model, and aggregate these somewhat to focus on sectors of primary interest.[8] Energy consumption is disaggregated using data from the CIMS model and from the Statistics Canada Report on Supply and Demand of Energy.

R-GEEM is implemented in GAMS, using the MPS/GE substructure. An appendix with more information is provided for R-GEEM.

#### R-GEEM Limitations and Uncertainties, and How They Interact with CIMS

Like CIMS, R-GEEM is a representation of the real world, not a perfect copy. R-GEEM is designed to capture the Canadian regional economies as a whole, and especially to integrate consumer demand, labour and capital supply, and the markets for all key inputs and outputs. This comes at the cost of simplifying assumptions. The main uncertainties and limitations in the model are:

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

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

RGEEM to CIMS with available time and resources, using a method borrowed from the MIT-EPPA model (McFarland et al 2004, Sue Wing 2008), we have altered the production functions for the crude oil, natural gas and electricity sectors so that they may employ discrete technologies that use CCS. When factors and emissions costs warrant, this method replaces the continuous production function with a discrete technology that employs CCS.

- **Calibration of the social accounting matrix:** Like all calibrated as opposed to estimated CGE models, R-GEEM must be calibrated to a given year's input and output of primary factors, goods and services.[9] This creates a base structure from which the model adjusts to policy shocks. If the chosen year is unrepresentative, or economic or technology structure is changing quickly, the outputs of the model may be biased.
- **Forecasts of population, labour-force participation and labour productivity.**

#### How CIMS and R-GEEM Relate to Each Other and the Analysis

In sum, R-GEEM and CIMS are two different ways of modeling the Canadian energy economy, each with strengths and weaknesses. In this analysis we have treated CIMS as the lead model for emissions responses, capital investment, and fuel and technology choices, and R-GEEM as the lead model for macroeconomic responses. R-GEEM's production function structure has been calibrated to CIMS' emissions pricing response to ensure the macroeconomic consistency, but we provide CIMS' results for all energy, emissions, and changes in sector output, unit cost, and expenditures on capital, energy and labour. In turn, we have provided R-GEEM's responses for changes in GDP, employment and trade.

## *Modelling the Targets*

The purpose of this project is to investigate the feasibility and cost of the ENGO and GOVT GHG emissions targets; 25% below 1990 and 20% below 2006 by 2020, respectively. A combination of carbon pricing, complementary regulations and spending programs on GHG reducing public goods are applied to reach the targets.

### *Carbon Pricing*

In 1990, Canada's GHG emissions (excluding $N_2O$ from nitric and adipic acid, halocarbon and forestry and land use change emissions[10]) were 579 Mt and in 2006, had reached 713 Mt. In order to reach the ENGO target of 25% below 1990 levels (434 Mt) by 2020, a reduction of almost 40% from 2006 levels is required.

Given the depth of the emissions target, we have assumed the implementation of the most economically efficient and effective core policy: carbon pricing through either a full auction upstream cap and trade system or a carbon tax covering all combustion and

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

[10] See Table 98 for a more complete description of emissions not included in CIMS.

almost all fixed process emissions. The carbon price path starts with a price of $50/tonne in 2010 and assumes a steady rise to $300/t by 2030 (Table 18).

**Table 18: Projected emissions prices (\$/tonne $CO_2$e \$2005) for covered emissions, ENGO target**

| 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 65 | 80 | 95 | 110 | 125 | 140 | 155 | 170 | 185 | 200 |
| **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031->** |
| 210 | 220 | 230 | 240 | 250 | 260 | 270 | 280 | 290 | 300 | 300 |

The less stringent GOVT target could be reached using the carbon pricing path shown in Table 19, when combined with the complementary regulations and spending programs described below. Canada's GHG emissions in 2006 (excluding $N_2O$ from nitric and adipic acid, halocarbon and forestry and land use change emissions[11]), were 713 Mt, yielding an absolute target of 570 Mt in 2020. The complementary policies used to reach this target are the same as for the target relative to 1990, excluding the carbon capture and storage regulation.

The ENGO carbon price is announced in late 2009 and enacted in January 2010. The GOVT carbon price is announced in late 2009 and implemented in January 2011.

**Table 19: Projected emissions prices (\$/tonne $CO_2$e \$2005) for covered emissions, GOVT target.**

| 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 40 | 47 | 53 | 60 | 67 | 73 | 80 | 87 | 93 | 100 |
| **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031->** |
| 107 | 113 | 120 | 127 | 133 | 140 | 147 | 153 | 160 | 167 | 167 |

To prevent undue economic dislocation, we established a rule for the non-fossil fuel sectors whereby a sufficient amount of carbon charge was refunded to a sector to maintain production, employment and investment at 2008 levels. This support was required only in the "Canada Goes Further" scenarios – half of revenue was returned to the industrial minerals and metal smelting sectors under the ENGO target, while 10% of revenue was returned to metal smelting under the GOVT target.

For each of the two targets, we have assumed the same package of carbon pricing, complementary regulations and spending programs under two opposing "bookend" scenarios: one where Canada's OECD trading partners maintain a carbon policy as strict as Canada's ("OECD acts together"), and one where Canada's carbon pricing policy is significantly more stringent than that of its trading partners ("Canada goes further"). The non-OECD countries are assumed to have considerably weaker carbon emissions restrictions in both scenarios. Because of the uncertainty surrounding future OECD and developing world climate policy, these two contrasting scenarios should be thought of as learning tools and not strict predictions of future events – they provide our best estimate of the bounds of carbon competitiveness effects. These effects are potentially significant for a number of sectors, but not for the economy as a whole.

[11] See Table 98 for a more complete description of emissions not included in CIMS.

Emissions reductions from the policy package were not large enough in either scenario to hit the ENGO target in 2020, despite the strong carbon price path and the complementary regulations and domestic spending programs. Since the price path and regulations are considered as strong as they may realistically be, 101 Mt of international permit purchases are made in 2020 in the "OECD acts together" case, an amount sufficient to hit the target once added to the domestic reductions.[12] In the "Canada goes further" case, 80 Mt of permits were required in 2020.

The same policy package was simulated for the GOVT target, excluding the carbon capture regulation (see below), but the $CO_2$e emissions charge was adjusted downward in light of the less stringent target. The emissions price path begins at $40/tonne $CO_2$e in 2011 rising to $100/tonne $CO_2$e in 2020. Under this price path Canada still purchases international emissions permits to make up the difference between the government target and domestic emissions reductions. Under the GOVT target, in the "OECD acts together" case, purchases of 73 Mt per year in 2020 are necessary, while in the "Canada goes further" case 56 Mt of purchases are required.

DSF and Pembina specified higher prices for international permits than is usual, with the intention that they represent real emission reductions of high environmental quality. For the ENGO target under the "OECD acts together" scenario, it was assumed that international permits would cost $100/tonne $CO_2$e in 2020. For the GOVT target under the "Canada goes further" scenario, it was assumed that international permits would cost $50/tonne $CO_2$e in 2020, reflecting a world with considerably weaker demand for permits. For the ENGO target under "Canada goes further" and the GOVT target under "OECD acts together," the international permit price was assumed to be $75/tonne $CO_2$e in 2020, since international demand for permits would be between the two extremes.

### *Complementary Regulations*

With the exception of the carbon capture and storage standard under the ENGO target, complementary regulations are based on carbon market failures of coverage or operation. The regulations are as follows. They all take effect in January 2011, except for the carbon capture regulation starting in 2016:

- **The confinement of well and line venting and flaring of fugitive GHG emissions in the upstream oil and gas sector solely to safety purposes**, with a carbon charge equivalent to the one in effect for the rest of the economy imposed for all safety orientated emissions. Any emissions over a given level found by random enforcement would be subject to fines significantly greater than the carbon price. Producers would be encouraged to flare or capture and sell well and line fugitives, or to shut in wells where this cannot be economically achieved within the context of the carbon price.

- **A requirement that all new commercial buildings be built to LEED Gold standard or higher, and be restrained from directly using fossil fuels, including natural gas, in British Columbia, Manitoba and Québec.** All other

[12] See the detailed permit purchase schedule from 2010 to 2020 in the results section.

options, including heat pumps, ground source heat pumps, and electric resistance heating are allowed. Other regions are allowed to continue using natural gas for space and water heating.

- **A requirement that all new residential houses be built to an energy efficiency standard 50% higher than today's average for new housing, and restrained from directly using fossil fuels, including natural gas, in British Columbia, Manitoba and Québec.** All other options, including heat pumps, ground source heat pumps, and electric resistance heating are allowed.
- **A requirement that all new vehicles sold meet the California GHG emissions standard**, with the expectation of a gradually tightening standard due to become virtually zero emissions by 2040.
- **A requirement that by 2011, white good appliance energy efficiency standards be raised to the most efficient commercially available versions of late 2008.** These are tightened thereafter.
- **A requirement that almost all landfills be covered and the landfill gas flared or used** to produce some combination of electricity and heat as the economics of the situation warrant.

For the ENGO target we also included a requirement, starting in 2016, of carbon capture and storage (CCS) of all formation $CO_2$ from new natural gas processors, process $CO_2$ from new hydrogen production facilities, and all combustion $CO_2$ from all new coal fired electricity plants, oil sands facilities, and upgraders starting in 2016. This regulation, while not associated with a clear market failure, is meant to limit the carbon price level for the rest of the economy. It also helps reduce the cost of the deeper target by driving technological innovation and reducing costs associated with CCS.

### *Domestic Spending Programs*

A portion of the revenue raised from the auction of emissions permits or carbon tax was redirected into spending programs to reduce domestic GHG emissions. The first two programs have clear and distinct public goods characteristics (i.e., they are not effectively and efficiently provided by private markets): improving urban and inter-city public transit, and investments in the electricity transmission grid to allow more capacity to be provided by intermittent and geographically dispersed renewable electricity sources. The third program, government purchase of agricultural offsets, is warranted by the administrative difficulty of applying either a carbon charge or regulations to agricultural GHG emissions.

#### Spending Programs – Improvements to Electricity Transmission

The electricity-transmission spending program is composed of investments to allow easier and more economic connection for dispersed intermittent renewables (i.e., wind and solar) as well as conversion of the grid to digital operation for ease of management (i.e., "smart grid"). The public goods premise is that if the improvements were paid for by all intermittent generation at once they would be economic. However, due to the "all or nothing" nature of these improvements, individual investments in renewable generation do not reach a sufficient scale to pay for them. The transmission improvements are funded from carbon revenues and amount to approximately $14 additional billion ($2005) over 10 years, not including necessary refurbishment and volume upgrades for existing flows. This program enables intermittent renewables, especially wind energy, to produce up to 25% of generation in a given province by 2020; under the ENGO target wind accounts for 18% of generation nationally in 2020.

During our analysis there was some discussion with the project advisory committee of the value of improving the cross Canada grid. The point was made that electricity is, in most cases, far more valuable sold to the United States, especially in a future where the United States pursues carbon constraints. For these reasons we did not model increased transfer capacity across Canada other than planned projects between Québec and Ontario.

### Spending Programs – Public Transit and High Speed Rail Programs

A survey done by the Canadian Urban Transit Association estimated that Canadian transit authorities need $40.1 billion in financing between 2008 and 2012 for the maintenance of existing transit infrastructure and the expansion of transit to deal with increased ridership. About half the costs of these projects, or $20.0 billion, require new external funding. This is in the existing policy environment, not one where GHGs are to be reduced by 20% by 2020 or more.

Aided by DSF and Pembina, we reviewed transit expansion plans across Canada to provide a specific base for potential carbon revenue spending (Table 20). Fully funded, these total $51.4 billion from 2010 through 2020 for intra-city transit. This increased to $59.2–$77.1 billion when we included some form of high speed intercity train system for the Québec City – Windsor corridor and between Edmonton and Calgary. We also found some research regarding a high-speed link between Vancouver and Seattle; initial key improvements total about $140 million. Using the Edmonton – Calgary example as a template, judgmentally adjusted for distance, geography and relative land values, we estimate that a full high-speed link would cost about $4 billion. If the cost were shared equally between Canada and the United States, the Canadian total would be about $2 billion. Based on all the above, we found that $7.7 billion per year could be valuably spent on urban and inter-city transit by 2020, and modelled a public transit spending program composed of several investments to improve and expand urban and inter-city transit.

The urban transit program includes increased rapid transit by rail in several Canadian cities, permitting transit ridership to rise by 35% relative to the BAU scenario by 2020 (in the absence of the carbon price), 80% of this increase is from rail transit. The intercity spending program funds an electric high-speed rail system for the Québec City – Windsor corridor, the Edmonton – Calgary corridor, and the Canadian portion of a Vancouver – Seattle service. Based on detailed forecasts for the Edmonton – Calgary corridor[13],

[13] Alberta Infrastructure and Transportation (2008), "Market Assessment of High Speed Rail Service in the Calgary-Edmonton Corridor".

Canada-wide, we assume this policy shifts 3% of inter-city travel to high speed rail by 2020.

## Table 20 Transit infrastructure project by city, including cost estimates

| Summary | | |
|---|---|---|
| Total by 2020: $51.4 B intracity plus $7.8 to 25.7 B for high speed intercity = $59.2-77.1 B<br>Montreal, $3.52 B; Toronto, $17.5 B; BC, $11.1 B; Ottawa, $3 B; Edmonton and Calgary $0.3 B each for existing, $5 B each for expansion; $5.7 B for smaller centres; Windsor to Québec City high speed, $4-20 B; Edmonton to Calgary high speed, $1.8-3.7 B; Vancouver to Seattle high speed, ~$2 B on the Cdn side | | |
| **Greater Toronto Area and Hamilton** | **Estimated Cost by 2020** | **Date Announced** |
| Metrolinx Regional Transportation Plan (RTP) (*includes MoveOntario 2020)* | $50 B over 25 years ($2.5 B/year by 2015) | |
| MoveOntario 2020 – 52 priority transit investments from the RTP, including rail link from Union to Pearson, subway extensions, GO transit expansions | $17.5 B ($11.5 B Ontario gov't, $6 B federal gov't) | $6 B (35%) requested from Fed. govt., Ontario $11.5 B (65%). |
| Sheppard East Light Rail Transit (LRT) project | $1 B | May 2009 funding commit. |
| Regional transit projects, including the Finch West LRT, Scarborough RT upgrade and extension, Eglinton Crosstown LRT (to Pearson), York Viva BRT, and feasibility study for rapid transit in Hamilton | $8.6 B | 2009 funding commit. |
| New Toronto Streetcars (204) | $1.2 B | June 2009 funding commit. |
| **MONTREAL** | | |
| | $6.7 B over 20 yrs, $1.76 B over the first 5 years | $250million/yr requested form federal government. |
| Construction of new LRT lines | $1 B | 2007 proposed |
| Rail link with airport | $0.5-$0.8 B | Fall 2009 final details expected |
| **OTTAWA** | | |
| LRT construction, BRT expansion | $3 B | 2008 proposed |
| **VANCOUVER** | | |
| Evergreen SkyTrain Line | $1.4 B | 2008 proposed |
| UBC/Millenium SkyTrain Lines | $2.8 B | 2008 proposed |
| Expo SkyTrain Line | $3.1 B | 2008 proposed |
| RapidBus BC – 9 new routes | $1.2 B | 2008 proposed |
| 1,500 Clean energy buses and maintenance infrastructure | $1.6 B | 2008 proposed |
| **EDMONTON** | | |
| LRT Expansion | $0.3 B | April 2009 funding commitment |
| New LRT lines to city boundaries | $9 B | 2009 proposed |
| **CALGARY** | | |
| C-Train platform and travel time improvements | $0.3 B | May 2009 funding commitment |
| **HIGH SPEED INTER-CITY TRAINS** | | |
| Windsor to Québec City (Feasibility study stage.) | $4-$20 B, depending on route, land costs, and # of stations, tunnels and bridges required. | Estimate does not include costs of local feeder transit systems[14] |
| Edmonton to Calgary | $1.8-$3.7 B | No proposals selected yet |
| Vancouver to Seattle (Detailed estimates available only for doubling volume of the current one train per day, and safeguarding existing slow speed infrastructure ~$130 million) | ~$4 B, $2 B on the Cdn side | |

[14] Kennedy, C., B Karney, E. Miller, and M. Hatzopoulou. 2009. Infrastructure and the Economy: Future directions for Ontario. Martin Prosperity Institute: Toronto, ON.

### Spending Programs – Agricultural Offsets

This program consists of the purchase by government of verifiable and additive domestic agricultural offsets. The price paid per tonne $CO_2e$ reduced is the carbon price applying to the rest of the economy as a result of the cap and trade system or carbon tax. Agricultural offsets purchased rise to 5 Mt in 2020 under the ENGO GHG price path (4 Mt under the GOVT GHG price path).

### *Compensation to households for carbon and increased energy supply costs*

Both the ENGO and GOVT targets are relatively stringent and attenuate the pace of growth in certain regions, especially those with GHG intense industry. This softening of economic growth can, however, be evened out to a certain degree with some level of compensation. While many different methods for compensation can be envisaged, DSF and Pembina requested that the policy package include equal per capita lump sum payments to all households across Canada to reimburse their carbon costs associated with heating fuels,[15] as well as the non-carbon related increases in electricity and heating fuel costs relative to BAU.

## *Scenario Assumptions*

In order to determine the GHG abatement opportunities in the Canadian economy over time, we use the concept of a reference scenario and a policy scenario. A reference scenario shows how the Canadian economy might evolve in the absence of specific new policies to reduce GHG emissions, while the policy scenario demonstrates how the economy might evolve under a new policy package. The difference between the two scenarios is due to the effect of the policy. When doing this type of analysis, many assumptions need to be made. Some key overall conditions include:

- *In the "OECD acts together" scenario we have assumed that Canada's OECD trading partners impose GHG policy at least as stringent as Canada's.* This assumption impacts on how the policy affects Canada's trade in industrial goods, and is realized in both CIMS' macroeconomic module and RGEEM. CIMS simulates international trade by using Armington substitution elasticities to proxy the demand for traded goods. These elasticities were calculated for use in the Finance Canada CASGEM model, and we use them to operate as price elasticities in CIMS.[16,17] These elasticities represent how the domestic and foreign demand for Canadian products might change in response to changes in the cost of

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[15] Note: in practice, carbon charges would not be levied directly on households' emissions from use of heating fuels. Instead the charges would be levied on fuel wholesalers, who would pass the charges on to households through fuel prices.

[16] The Armington elasticities in CIMS are from Wirjanto, T. (1999)."Estimation of Import and Export Elasticities: A report prepared for the Economic and Fiscal Policy Branch at the Department of Finance." Department of Economics, University of Waterloo

[17] For details of CIMS' macroeconomic mechanics see Bataille, C., M. Jaccard, J. Nyboer and N. Rivers. (2006). "Towards General Equilibrium in a Technology-Rich Model with Empirically Estimated Behavioral Parameters." In *Hybrid Modeling: New Answers to Old Challenges, Special Issue of the Energy Journal*, 27:93-112.

domestic production, and are a composite of domestic and foreign demand for Canadian traded goods, i.e., if the elasticity is -1, and price goes up 1%, demands fall 1%. The Armington formulation is a composite of the propensity of customers of Canadian goods to substitute foreign equivalents and the end-use demand for a given good. If Canada's major trading partners have similar climate policies, their costs of production would presumably change in a similar magnitude to Canada, reducing the propensity of customers of Canadian goods to substitute foreign equivalents because the relative prices remain the same (i.e., they go up in all regions). It does not, however, reduce the propensity for them to substitute low carbon equivalents (i.e., to replace high carbon cement with lower carbon building materials); because the price of carbon intense goods has gone up in all regions, demand falls in all regions subject to its own price elasticity. We use our best judgement to reduce the Armington elasticities to remove the effect of the first component, and preserve the end-use demand effect.

- *In the "Canada goes further" scenario we have assumed that while the OECD and the US in particular could impose carbon pricing, Canada imposes sufficiently stronger carbon pricing (approximately 25-50% greater) that it can be considered to be "acting alone",* and the Armington elasticities were adjusted accordingly.
- *We have assumed the carbon pricing and complementary regulations are at least as stringent following 2020 as they are in 2020.* Firms and consumers in CIMS make investment and consumption decisions with limited foresight of future emissions prices. The carbon price is assumed to rise to \$300/tonne $CO_2$e by 2030 to meet the ENGO target. As a result, consumers factor this in to some degree in decisions made prior to 2021. Similarly, for the GOVT target the GHG price continues to rise to \$167/tonne $CO_2$e by 2030.
- *NRCan's "Canada's Energy Outlook 2006" was considered to be the starting point for output and energy data* because of its comprehensiveness and status as Canada's national energy use forecast. *EC's GHG Inventory was considered the starting points for all emissions intensity data* because of its comprehensiveness and status as Canada's national emissions inventory, as are EC's emissions coefficients for fuel combustion. When NRCan's energy use is calculated by EC's emissions coefficients, the results do not always match, but we have attempted to reconcile them as best as possible. The differences are most significant in the upstream oil and gas sector, specifically the combustion coefficients associated with upstream and transmission oil and gas fugitives. All forecast values have been updated for the most recent official historical data.
- The oil production forecast is the Canadian Association of Petroleum Producers's (CAPP) 2008 forecast; this differs from the December 2008 version of this report.
- *We have allowed domestic and export demand for crude oil to fluctuate in response to the cost of producing it, including rents.* Rents are specifically included in the R-GEEM analysis, which was used to determine changes in output in the crude oil and natural gas sectors. *We have also allowed natural gas*

*production to fluctuate based on its cost of production, and how this affects the price and demand.* There is substantial uncertainty what will happen to Canadian gas production in a carbon limited North America. Domestic consumption of natural gas drops somewhat under both scenarios, but if the United States imposes any sort of carbon restrictions, as we have assumed, it will need to make significant efforts to decarbonize its electricity system. This will likely involve a substantial switch from coal to natural gas generation, which will likely require some combination of more LNG imports, shale gas production, and Mexican and Canadian gas imports. Given there are pressures to both increase and reduce gas production in a carbon limited world, we experimented with both fixed and flexible NG production, and finally chose flexible production.

- *The emissions charge policy simulated here is based on an upstream cap and trade with full auction, or a carbon tax, with much of the revenue attained from the emissions charge recycled to households and personal income tax reductions.* Assuming that government spending non-inclusive of climate policies will remain constant between the reference and policy scenarios, carbon pricing revenues are recycled as follows:
    - Permit/tax revenues are collected by government;
    - A portion is used for the purchase of international emissions permits;
    - A portion is used for public-good spending programs to improve public transit and upgrade the electricity transmission grid to allow more geographically dispersed renewable electricity generation. The chosen programs have clear and distinct public goods characteristics (i.e., those goods not effectively and efficiently provided by private markets). These investments increased transit use by an average of 35% across Canada (in the absence of the carbon price), and allowed intermittent renewables to capture up to 25% of generation in some regions.;
    - A portion is used to compensate households for their carbon charges and increased energy costs for heating and electricity (not transportation);
    - A portion is used to purchase verifiable and additive domestic agricultural offsets;
    - A portion is used to refund a sufficient amount of carbon charges to non-fossil fuels sectors to maintain output at their 2008 level (only the industrial minerals and metal smelting sectors required this refund);
    - The remainder is used to directly reduce personal income taxes until government spending and revenue are returned to their reference case levels. This includes compensating for changes in all other government revenue changes (i.e. corporate and sales taxes and royalties) caused by the policy package.
- Agricultural offsets are assumed to be strictly additional and verifiable with adequate government enforcement to ensure additionality and verifiability. The agricultural emissions model in CIMS was designed to incorporate only those

emissions reductions that are highly likely to be additional, verifiable and resistant to free-ridership, and its estimate of emissions reductions is used for this analysis. Further, it is assumed government purchases these emissions reductions, not industry, with the appropriate monetary flows.

## Results

We first provide emissions reductions, key emission reduction actions, changes in physical output, and capital, labour and energy costs from CIMS for each scenario. We then provide the changes in GDP, wages, capital investment and employment from R-GEEM.

### CIMS – Sector, Emissions, Investment and Energy Impacts – ENGO Target

Table 21 provides the annual reductions in emissions, relative to the reference case (BAU, business as usual) by sector and for the whole economy under the influence of the policy package that achieves a 25% reduction in GHG emissions relative to 1990 by 2020.

**Table 21: Annual reduction of all GHG emissions (Mt $CO_2e$) from BAU to Policy (ENGO)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 0 | 0 | 10 | 10 | 18 | 18 |
| Commercial | 0 | 0 | 10 | 10 | 23 | 22 |
| Personal Trans. | 0 | 0 | 10 | 10 | 21 | 21 |
| Freight Trans. | 6 | 6 | 33 | 33 | 55 | 55 |
| Chemical Products | 0 | 1 | 4 | 4 | 5 | 6 |
| Industrial Minerals | 0 | 0 | 3 | 4 | 4 | 6 |
| Iron and Steel | 0 | 0 | 1 | 1 | 2 | 3 |
| Metal Smelting | 0 | 0 | 0 | 1 | 1 | 1 |
| Mineral Mining | 0 | 0 | 0 | 1 | 1 | 2 |
| Paper Manufacturing | 0 | 0 | 0 | 0 | 0 | 0 |
| Other Manufacturing | 0 | 0 | 3 | 3 | 6 | 6 |
| Agriculture | 1 | 1 | 4 | 4 | 6 | 6 |
| Waste | 1 | 1 | 22 | 22 | 23 | 23 |
| Electricity | 8 | 9 | 32 | 34 | 55 | 56 |
| Petroleum Refining | 0 | 0 | 4 | 4 | 9 | 9 |
| Petroleum Crude Extr. | 2 | 3 | 23 | 32 | 67 | 78 |
| Natural Gas Extraction | 1 | 1 | 17 | 19 | 20 | 23 |
| Coal Mining | 0 | 0 | 0 | 0 | 0 | 1 |
| Ethanol | 0 | 0 | 0 | 0 | -0.10 | -0.10 |
| Biodiesel | 0 | 0 | -1 | -1 | -1.80 | -1.74 |
| **Total** | **20** | **23** | **174** | **191** | **313** | **335** |

Emissions reductions were 21 Mt greater in the "Canada goes further" scenario in 2020, a 6.4% portion of the overall reduction of 335 Mt. The differences between the two scenarios, mainly greater reduction in output, were significant only for a few sectors: industrial minerals, chemical products, natural gas and petroleum crude extraction. Only two sectors in the "Canada goes further" scenario – metal smelting and industrial minerals – qualified for carbon charge refunds to keep output at its 2008 level; each was returned 50% of its carbon charges after the sectors made their investment decisions. No carbon charges were refunded in the "OECD acts together" scenario.

The biggest reductions come from petroleum crude extraction (67 to 78 Mt in 2020), freight transportation (55 Mt), electricity (55 to 56 Mt), personal transportation (21 Mt), residential and commercial buildings (41 Mt), natural gas extraction (20 to 23 Mt) and the landfill waste sector (23 Mt). These reductions are due to capital investment in energy and GHG efficiency measures (e.g., CCS), fuel switching, and output reductions in a couple of key sectors. The overall reductions are 80 to 101 Mt short of the target in 2020, and it is assumed this is made up through international permit purchases – the cost and foreign exchange requirements associated with this are included in the R-GEEM macroeconomic analysis.

Table 22 provides the annual emissions reductions expressed as percentages compared to the reference case. Again, there are very small differences between the scenarios. The very large percentage increases in biodiesel and ethanol are due to the very low starting values.

**Table 22: % reduction of all GHG emissions (Mt $CO_2$e) from BAU to Policy (ENGO)**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | -1% | -1% | 28% | 28% | 52% | 52% |
| Commercial | 0% | 0% | 26% | 26% | 52% | 52% |
| Personal Trans. | 0% | 0% | 10% | 10% | 20% | 20% |
| Freight Trans. | 7% | 7% | 28% | 28% | 41% | 42% |
| Chemical Products | 1% | 5% | 26% | 32% | 36% | 42% |
| Industrial Minerals | 1% | 1% | 16% | 23% | 23% | 31% |
| Iron and Steel | 0% | 1% | 9% | 10% | 16% | 20% |
| Metal Smelting | 0% | 0% | 3% | 6% | 8% | 10% |
| Mineral Mining | 1% | 2% | 8% | 20% | 15% | 34% |
| Paper Manufacturing | 0% | 0% | 3% | 7% | 6% | 11% |
| Other Manufacturing | 0% | 0% | 11% | 12% | 21% | 22% |
| Agriculture | 1% | 1% | 7% | 7% | 11% | 11% |
| Waste | 3% | 3% | 83% | 83% | 83% | 83% |
| Electricity | 7% | 7% | 26% | 27% | 42% | 43% |
| Petroleum Refining | 1% | 1% | 16% | 17% | 36% | 37% |
| Petroleum Crude Ext. | 2% | 3% | 19% | 27% | 45% | 52% |
| Natural Gas Ext. | 2% | 2% | 27% | 30% | 36% | 42% |
| Coal Mining | 5% | 5% | 11% | 13% | 18% | 20% |
| Ethanol | -10% | -11% | -593% | -602% | -685% | -693% |
| Biodiesel | -3% | -2% | -985% | -969% | -1291% | -1249% |
| **Total** | **3%** | **3%** | **22%** | **24%** | **37%** | **39%** |

Table 23 provides the emissions reductions by sector and region for the "OECD acts together" scenario, and Table 24 for the "Canada goes further" scenario. For "OECD acts together," most reductions occur in Alberta (133 Mt / 43%) and Ontario (70 Mt / 22%), with 21% (65 Mt) of all reduction occurring in the Alberta Petroleum Crude sector. Emissions reductions are greatest in the petroleum crude sector (21%), freight transportation (17%) and electricity (17%). The results are very similar for "Canada goes further."

**Table 23: Emissions reductions in 2020 by sector and region (Mt $CO_2e$) from BAU to Policy "OECD acts together" (ENGO)**

| | BC | AB | SK | MB | ON | PQ | ATL | ∑ | % |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 1.7 | 4.7 | 0.6 | 0.4 | 8.5 | 1.8 | 0.7 | 18.5 | 6% |
| Commercial | 2.6 | 3.0 | 0.9 | 1.1 | 9.2 | 3.8 | 1.9 | 22.5 | 7% |
| Personal Trans. | 3.3 | 2.8 | 0.7 | 0.6 | 6.4 | 6.0 | 1.5 | 21.3 | 7% |
| Freight Trans. | 10.1 | 10.4 | 2.3 | 1.3 | 15.9 | 9.1 | 5.3 | 54.5 | 17% |
| Chemicals | 0.1 | 3.1 | - | - | 1.8 | 0.2 | - | 5.1 | 2% |
| Ind. Minerals | 0.7 | 0.8 | - | - | 2.0 | 0.8 | 0.1 | 4.4 | 1% |
| Iron and Steel | - | - | - | - | 2.0 | 0.0 | - | 2.1 | 1% |
| Metal Smelting | 0.1 | - | - | 0.0 | 0.0 | 0.5 | 0.0 | 0.6 | 0% |
| Mineral Mining | 0.1 | - | 0.4 | 0.0 | 0.1 | 0.2 | 0.1 | 0.9 | 0% |
| Paper Mnftg | 0.1 | 0.0 | - | - | 0.0 | 0.1 | 0.0 | 0.2 | 0% |
| Other Mnftg | 1.6 | 0.6 | 0.0 | 0.1 | 1.9 | 1.1 | 0.3 | 5.6 | 2% |
| Agriculture | 0.2 | 1.4 | 1.0 | 1.4 | 0.2 | 1.0 | 0.3 | 5.5 | 2% |
| Waste | 4.3 | 2.3 | 0.8 | 0.8 | 5.9 | 6.4 | 2.2 | 22.8 | 7% |
| Electricity | 0.8 | 28.1 | 7.7 | -1.4 | 11.0 | 3.0 | 5.4 | 54.6 | 17% |
| Pet. Refining | 1.2 | 1.4 | 0.3 | - | 4.4 | 1.2 | 0.7 | 9.1 | 3% |
| Pet. Crude Ext. | 0.4 | 64.5 | 2.1 | 0.0 | 0.1 | - | 0.1 | 67.3 | 21% |
| NG Ext. | 6.6 | 10.3 | 1.4 | 0.1 | 0.8 | 0.1 | 0.6 | 19.8 | 6% |
| Coal Mining | 0.2 | 0.2 | 0.0 | - | - | - | 0.0 | 0.4 | 0% |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0% |
| Biodiesel | -0.1 | -0.5 | -0.2 | 0.0 | -0.4 | -0.2 | -0.3 | -1.8 | -1% |
| **Total** | **34** | **133** | **18** | **4** | **70** | **35** | **19** | **313** | **100%** |
| % | 11% | 43% | 6% | 1% | 22% | 11% | 6% | 100% | |

**Table 24: Emissions reductions in 2020 by sector and region (Mt $CO_2e$) from BAU to Policy ENGO) "Canada goes further"**

| | BC | AB | SK | MB | ON | PQ | ATL | ∑ | % |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 1.7 | 4.7 | 0.6 | 0.4 | 8.5 | 1.8 | 0.7 | 18.5 | 6% |
| Commercial | 2.6 | 3.0 | 0.9 | 1.1 | 9.2 | 3.8 | 1.9 | 22.5 | 7% |
| Personal Trans. | 3.3 | 2.8 | 0.7 | 0.6 | 6.4 | 6.0 | 1.5 | 21.3 | 6% |
| Freight Trans. | 10.4 | 10.4 | 2.3 | 1.3 | 16.0 | 9.2 | 5.4 | 55.0 | 16% |
| Chemicals | 0.1 | 3.7 | - | - | 2.0 | 0.2 | - | 5.9 | 2% |
| Ind. Minerals | 0.9 | 1.1 | - | - | 2.7 | 1.1 | 0.2 | 6.0 | 2% |
| Iron and Steel | - | - | - | - | 2.5 | 0.0 | - | 2.6 | 1% |
| Metal Smelting | 0.1 | - | - | 0.0 | 0.1 | 0.6 | 0.1 | 0.9 | 0% |
| Mineral Mining | 0.1 | - | 1.2 | 0.0 | 0.2 | 0.2 | 0.2 | 1.9 | 1% |
| Paper Mnftg | 0.1 | 0.0 | - | - | 0.1 | 0.1 | 0.0 | 0.4 | 0% |
| Other Mnftg | 1.6 | 0.7 | 0.0 | 0.1 | 2.1 | 1.1 | 0.3 | 6.0 | 2% |
| Agriculture | 0.2 | 1.4 | 1.0 | 1.4 | 0.2 | 1.0 | 0.3 | 5.6 | 2% |
| Waste | 4.3 | 2.3 | 0.8 | 0.8 | 5.9 | 6.4 | 2.2 | 22.8 | 7% |
| Electricity | 0.9 | 28.9 | 8.0 | -1.4 | 11.3 | 3.1 | 5.4 | 56.0 | 17% |
| Pet. Refining | 1.2 | 1.4 | 0.3 | - | 4.4 | 1.2 | 0.7 | 9.2 | 3% |
| Pet. Crude Ext. | 0.4 | 73.2 | 4.2 | 0.0 | 0.1 | - | 0.1 | 78.1 | 23% |
| NG Ext. | 7.0 | 12.6 | 1.6 | 0.1 | 1.2 | 0.1 | 0.8 | 23.4 | 7% |
| Coal Mining | 0.2 | 0.3 | 0.0 | - | - | - | 0.0 | 0.5 | 0% |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0% |
| Biodiesel | -0.1 | -0.5 | -0.2 | 0.0 | -0.4 | -0.2 | -0.3 | -1.7 | -1% |
| **Total** | **35** | **146** | **21** | **5** | **73** | **36** | **20** | **335** | **100%** |
| % | 10% | 44% | 6% | 1% | 22% | 11% | 6% | 100% | |

Table 25 and Figure 4 describe the actions taken to reduce GHGs out to 2020 in the "OECD acts together" scenario, assuming the policy package continues to increase in stringency out to 2030 (i.e., carbon price rising to \$300/tonne $CO_2e$).*Note: See Table 97 for a description of emissions included in CIMS.

Figure 5 provides the same for when "Canada goes further." In the short to medium term out to 2020, the most important actions are:

- Carbon capture and storage (84 Mt in 2020 in "OECD acts together" and 76 Mt in "Canada goes further"). In early years this is primarily from relatively pure $CO_2$ sources, such as formation $CO_2$ from natural gas processing and $CO_2$ from steam reformation of methane to produce hydrogen.
- Energy efficiency (58 Mt in 2020 in "OECD acts together" and 57 Mt in "Canada goes further"), primarily in the personal and freight transportation sectors.
- Other GHG control (46 Mt in 2020 in "OECD acts together" and 52 Mt in "Canada goes further"), which includes control of fugitives in upstream oil and gas, and capping, flaring and cogeneration of landfill gas
- International permit purchases (101 Mt in 2020 in "OECD acts together" and 80 Mt in "Canada goes further")

- Switching to electricity in all sectors, including buildings (33 Mt in 2020 in "OECD acts together" and "Canada goes further")
- Switching to renewables in electricity production (35 Mt in 2020 in "OECD acts together" and 33 Mt in "Canada goes further"). This is largely hydro and wind.
- Output reductions (36 Mt in 2020 in "OECD acts together" and 64 Mt in "Canada goes further"), mostly reduced output in the entire fossil fuel industry.

**Table 25: Actions taken to reduce emissions ENGO "OECD acts together," Mt $CO_2e$**

| | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|
| Baseline (BAU) emissions | 714* | 734 | 786 | 848 |
| Emissions after application of domestic policies | 714 | 714 | 612 | 535 |
| Domestic emissions reductions: | | | | |
| Output reduction | 0 | 11 | 28 | 36 |
| Other GHG control | 0 | 2 | 36 | 46 |
| Fuel switching to nuclear | 0 | 0 | 1 | 1 |
| Fuel switching to renewables | 0 | 4 | 18 | 35 |
| Fuel switching to electricity | 0 | 0 | 14 | 33 |
| Fuel switching to other fuels | 0 | -3 | 3 | 11 |
| Carbon capture and storage | 0 | 1 | 33 | 84 |
| CCS energy efficiency penalty | 0 | 0 | 6 | 10 |
| Energy efficiency | 0 | 4 | 35 | 58 |
| International permit purchases | 0 | 5 | 50 | 101 |
| Target (remaining emissions) = Baseline– domestic emissions reductions – permit purchases | | | | 434 |

*Note: See Table 98 for a description of emissions included in CIMS.

**Figure 4: Emission reduction actions ENGO "OECD acts together"**

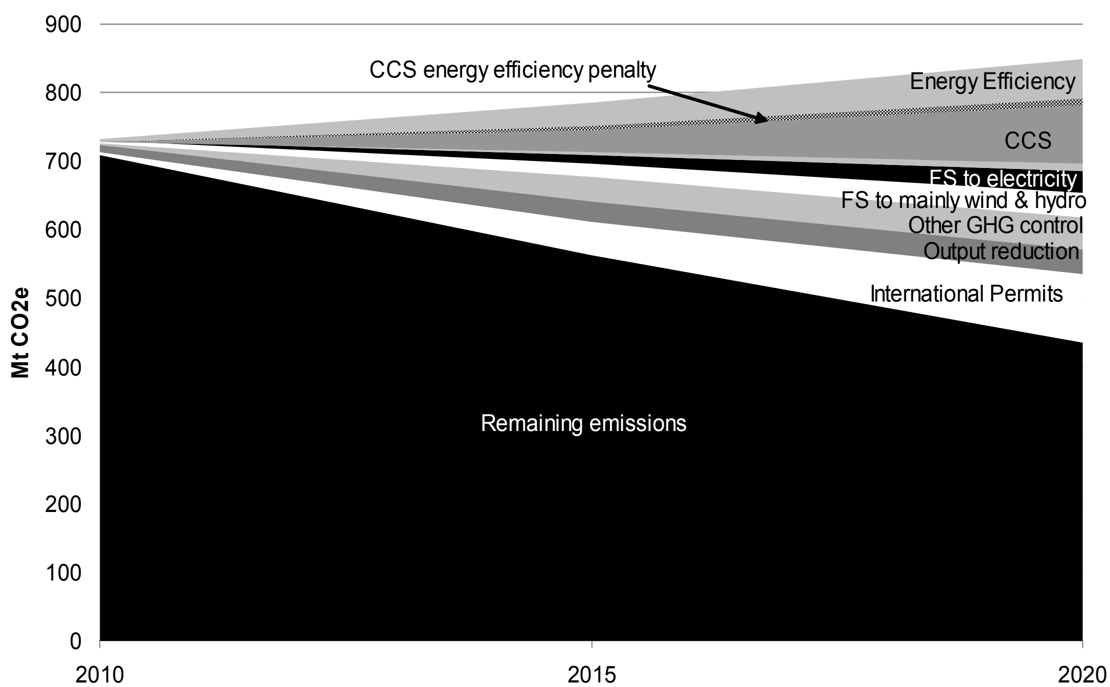
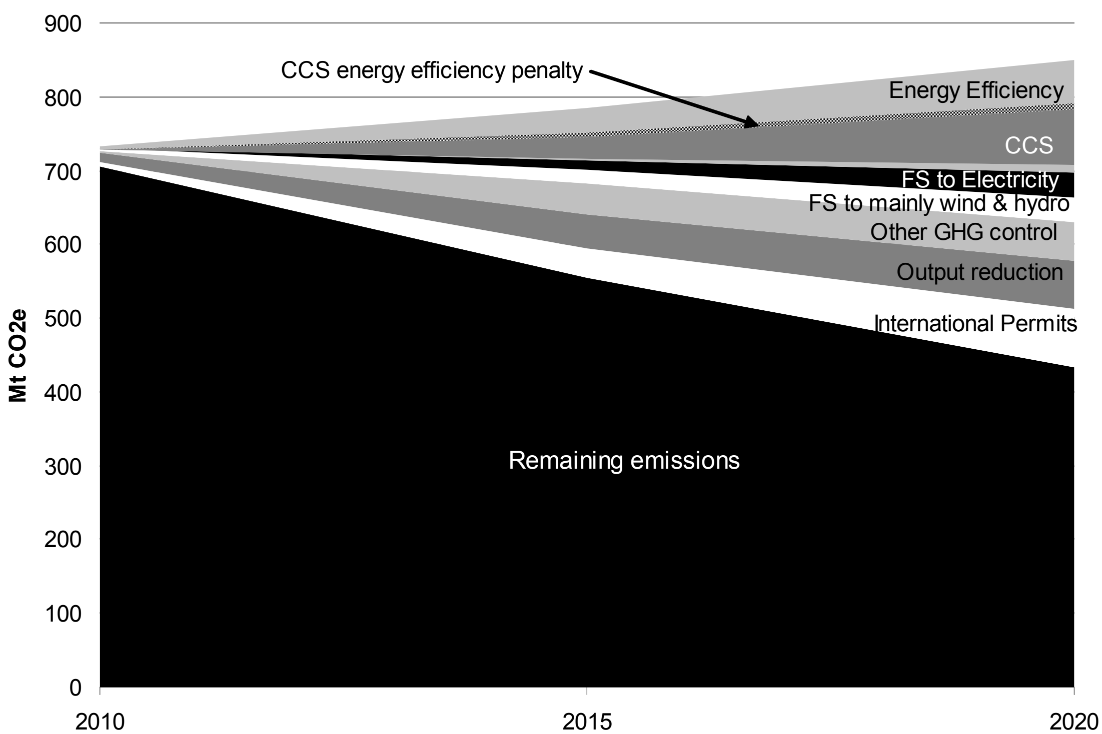


**Table 26: Actions taken to reduce emissions ENGO "Canada goes further," Mt $CO_2e$**

| | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|
| Baseline (BAU) emissions | 714* | 734 | 786 | 848 |
| Emissions after application of domestic policies | 714 | 711 | 595 | 514 |
| Domestic emissions reductions: | | | | |
| Output reduction | 0 | 12 | 46 | 64 |
| Other GHG control | 0 | 3 | 41 | 52 |
| Fuel switching to nuclear | 0 | 0 | 1 | 1 |
| Fuel switching to renewables | | 4 | 18 | 33 |
| Fuel switching to electricity | 0 | 0 | 14 | 33 |
| Fuel switching to other fuels | 0 | -3 | 2 | 10 |
| Carbon capture and storage | 0 | 1 | 29 | 76 |
| CCS energy efficiency penalty | 0 | 0 | 5 | 9 |
| Energy efficiency | 0 | 4 | 35 | 57 |
| International permit purchases | 0 | 5 | 40 | 80 |
| Target (remaining emissions) = Baseline– domestic emissions reductions – permit purchases | | | | 434 |

*Note: See Table 97 for a description of emissions included in CIMS.

**Figure 5: Emission reduction actions ENGO "Canada goes further"**




The necessary capital investment, operations, and fuel switching changes in each sector engender changes in capital, energy, labour and emissions costs. Output impacts, which are included in these values, will be discussed later. Table 27 through Table 30 document, by sector:

- the changes in capital expenditure for energy using and producing capital stock;
- changes in labour related to energy using and producing capital stock;
- changes in energy costs; and
- payments for emissions (which are transfers within the economy).

**Table 27: Increase in annual capital costs ($2005 millions) from BAU to Policy (ENGO)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 99 | 100 | 1813 | 1857 | 3036 | 3030 |
| Commercial | -154 | -149 | -1071 | -1011 | 857 | 853 |
| Personal Trans. | -342 | -342 | -12902 | -12900 | -9516 | -9512 |
| Freight Trans. | -623 | -613 | -5324 | -5430 | -3994 | -4317 |
| Chemical Products | -4 | -17 | 43 | -169 | 50 | -109 |
| Industrial Minerals | -6 | -14 | -54 | -168 | 17 | -20 |
| Iron and Steel | -5 | -16 | 83 | -68 | 22 | -111 |
| Metal Smelting | -9 | -18 | -74 | -160 | -38 | -101 |
| Mineral Mining | -24 | -80 | -218 | -667 | -121 | -443 |
| Paper Manufacturing | -14 | -66 | -225 | -783 | -29 | -252 |
| Other Manufacturing | -3 | -7 | -20 | -77 | 3 | -23 |
| Agriculture | -10 | -10 | -61 | -61 | -32 | -32 |
| Waste | 6 | 6 | 208 | 208 | 52 | 52 |
| Electricity | 1017 | 865 | 8787 | 7084 | 11851 | 10653 |
| Petroleum Refining | -24 | -25 | -307 | -312 | -191 | -196 |
| Petroleum Crude Ext. | -138 | -368 | 117 | -1915 | 3449 | 1536 |
| Natural Gas Ext. | -308 | -482 | -956 | -1508 | -694 | -1082 |
| Coal Mining | -35 | -38 | -85 | -112 | -59 | -79 |
| Ethanol | 0 | 0 | 7 | 7 | 199 | 202 |
| Biodiesel | 1 | 0 | 725 | 715 | 692 | 645 |
| **Total** | **-578** | **-1,273** | **-9,516** | **-15,470** | **5,553** | **692** |

The capital investment patterns differ significantly between the two scenarios. In general, more capital is required in the "OECD acts together" case than the "Canada goes further" case. Output falls less, and therefore more capital is required to decarbonise electricity generation equipment, buildings, industrial machinery, rolling stock, etc.

Differences between the sectors are evident, with the largest impacts on the transport and electricity sectors. Over $9.5 billion less capital is invested and spent annually in the personal transport sector in 2020, because more efficient vehicles tend to be smaller and less costly. There is also significant mode shifting in personal transportation, due to the urban and intercity transit spending policies, and in freight transportation, both of which reduce capital expenditure. There may be disagreement as to whether these reductions should be directly construed as benefits as consumers and firms are induced to use different vehicles and modes than they would have chosen in the reference case, implying a reduction in welfare and profits. It is beyond the scope of this analysis to fully analyze the costs and benefits of mode switching and the use of smaller, more efficient vehicles, as it would require discussion of the welfare impacts of urban form and its amenability to transit, improvements on local air quality, and host of other issues.

Another sector with significant changes in capital investment is the electricity sector whose requirements for capital have risen by $10.7–$11.9 billion annually by 2020. This is due to across-the-board fuel switching to electricity, further impelled by regulations prohibiting direct use of fossil fuels for space and water heating for all new buildings (commercial and residential) in British Columbia, Manitoba, and Québec. Electricity production is one of the lowest cost areas to achieve low and zero GHG energy production, and its use goes up markedly across the economy.

Table 28 presents the changes in operating & maintenance costs (labour or equivalent time expenditures, e.g., in transportation) directly associated with energy using capital in the economy. A wider picture of the impacts on labour will be provided in the R-GEEM macroeconomic section following the CIMS results. The labour results roughly match the impact of the capital results.

**Table 28: Increase in annual operating & maintenance costs ($2005 millions) from BAU to Policy (ENGO)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | -2 | -2 | -21 | -20 | -34 | -33 |
| Commercial | -1 | -1 | -13 | -13 | -22 | -22 |
| Personal Trans. | -94 | -94 | -3,749 | -3,749 | -6,526 | -6,526 |
| Freight Trans. | -833 | -831 | -5,653 | -5,686 | -8,241 | -8,330 |
| Chemical Products | 1 | -2 | 4 | -51 | 12 | -73 |
| Industrial Minerals | -1 | -2 | 0 | -17 | 6 | -17 |
| Iron and Steel | -6 | -18 | -49 | -185 | -97 | -354 |
| Metal Smelting | -3 | -6 | -31 | -58 | -53 | -93 |
| Mineral Mining | -5 | -16 | -48 | -158 | -72 | -241 |
| Paper Manufacturing | -6 | -19 | -53 | -210 | -63 | -265 |
| Other Manufacturing | 0 | -1 | -2 | -15 | 0 | -18 |
| Agriculture | 23 | 23 | 98 | 98 | 137 | 137 |
| Waste | 3 | 3 | 102 | 102 | 125 | 125 |
| Electricity | 172 | 153 | 987 | 782 | 2,043 | 1,717 |
| Petroleum Refining | -67 | -67 | -274 | -279 | -500 | -510 |
| Petroleum Crude Ext. | -190 | -368 | -1,149 | -2,934 | -1,547 | -4,459 |
| Natural Gas Ext. | -134 | -187 | -723 | -1,210 | -1,150 | -1,943 |
| Coal Mining | -13 | -14 | -33 | -41 | -48 | -60 |
| Ethanol | 0 | 0 | 13 | 13 | 184 | 186 |
| Biodiesel | 1 | 1 | 1,540 | 1,519 | 2,990 | 2,871 |
| **Total** | **-1,151** | **-1,446** | **-9,057** | **-12,110** | **-12,856** | **-17,908** |

Table 29 shows the changes in annual energy expenditures by sector (not including carbon costs associated with direct fuel use, or the compensation provided to households). There are significant differences between the sectors. Both scenarios have considerable savings in early years, which continue to grow to $9 to $14 billion annually by 2020. Large amounts are saved in the transport sector due to efficiency and the significant mode shifting induced by the transit spending policies. The electricity transmission spending policy encourages more renewable energy capacity, especially wind, substantially reducing the sector's fuel costs. The residential and commercial sectors spend more mainly due to increased NG and electricity prices.

**Table 29: Increase in annual energy expenditures ($2005 millions) from BAU to Policy (ENGO)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 299 | 277 | 1,322 | 1,151 | 2,393 | 2,241 |
| Commercial | 183 | 163 | 1,355 | 1,200 | 1,809 | 1,657 |
| Personal Trans. | -195 | -196 | -3,256 | -3,260 | -5,337 | -5,344 |
| Freight Trans. | -2,414 | -2,400 | -6,364 | -6,451 | -8,721 | -9,163 |
| Chemical Products | 30 | 9 | 229 | -59 | 291 | -206 |
| Industrial Minerals | 8 | 5 | 105 | 45 | 95 | 17 |
| Iron and Steel | -5 | -9 | 69 | 1 | 106 | -20 |
| Metal Smelting | 24 | 13 | 196 | 82 | 315 | 166 |
| Mineral Mining | 30 | 6 | 224 | -79 | 299 | -196 |
| Paper Manufacturing | 44 | 16 | 266 | -4 | 307 | -9 |
| Other Manufacturing | 10 | -3 | 391 | 230 | 796 | 578 |
| Agriculture | 28 | 26 | 369 | 357 | 653 | 648 |
| Waste | -6 | -6 | -208 | -206 | -346 | -344 |
| Electricity | -985 | -1,006 | -1,981 | -2,185 | -2,881 | -3,228 |
| Petroleum Refining | -46 | -48 | -214 | -240 | -384 | -421 |
| Petroleum Crude Ext. | 7 | -110 | 320 | -772 | 1,571 | -358 |
| Natural Gas Ext. | -70 | -129 | -349 | -799 | -598 | -1,207 |
| Coal Mining | -6 | -7 | 29 | 18 | 48 | 30 |
| Ethanol | 0 | 0 | 7 | 7 | 17 | 17 |
| Biodiesel | 0 | 0 | 388 | 380 | 737 | 698 |
| **Total** | **-3,064** | **-3,398** | **-7,103** | **-10,583** | **-8,830** | **-14,446** |

Table 30 shows the direct average annual payments made for emissions by all sectors. These revenues are recycled as described earlier. The amounts involved are considerable, rising from $8.3 billion in the "OECD acts together" case and $6.2 billion in the "Canada goes further" case in 2010, to $77–85 billion in 2020.[18] Half of the sector specific revenue is returned in the cases of the industrial minerals and metals smelting sectors in the "Canada goes further" scenario.

**Table 30: Average annual emissions charge costs (ENGO, $2005 millions)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 387 | 387 | 2,456 | 2,457 | 2,860 | 2,861 |
| Commercial | 362 | 362 | 2,753 | 2,754 | 3,484 | 3,485 |
| Personal Trans. | 986 | 986 | 12,546 | 12,545 | 14,682 | 14,677 |
| Freight Trans. | 917 | 917 | 7,902 | 7,886 | 13,161 | 13,091 |
| Chemical Products | 131 | 126 | 971 | 895 | 1,529 | 1,396 |
| Industrial Minerals | 161 | 80 | 1,412 | 645 | 2,480 | 1,107 |
| Iron and Steel | 136 | 136 | 1,126 | 1,110 | 1,890 | 1,801 |
| Metal Smelting | 107 | 53 | 877 | 429 | 1,344 | 653 |
| Mineral Mining | 57 | 56 | 500 | 436 | 835 | 651 |
| Paper Manufacturing | 60 | 60 | 454 | 436 | 616 | 583 |
| Other Manufacturing | 209 | 208 | 1,990 | 1,969 | 3,549 | 3,493 |
| Electricity | 1,183 | 1,180 | 8,948 | 8,812 | 12,652 | 12,403 |
| Petroleum Refining | 213 | 213 | 1,842 | 1,836 | 2,751 | 2,733 |
| Petroleum Crude Ext. | 827 | 814 | 8,956 | 8,067 | 14,256 | 12,418 |
| Natural Gas Ext. | 619 | 615 | 4,361 | 4,129 | 6,107 | 5,485 |
| Coal Mining | 22 | 22 | 197 | 193 | 348 | 337 |
| Ethanol | 0 | 0 | 7 | 7 | 19 | 19 |
| Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **8,386** | **6,217** | **59,313** | **54,607** | **84,582** | **77,193** |

[18] RGEEM only includes combustion GHGs, not process GHGs. For this reason the macroeconomic analysis deal with a smaller amount of revenue, ~$72 billion in the ENGO OAT case. If RGEEM included all emissions, most of the extra revenue would be used to reduce personal income taxes. Please see the macroeconomic results section for further comment.

Table 31 describes the impact of the increased production costs on physical output in each sector (note this is physical output, not gross output in dollar terms). The most heavily impacted sectors are industrial minerals (-8 to -18% relative to BAU, limited by revenue recycling sufficient to maintain estimated 2008 production for "Canada goes Further") and the fossil fuel sectors, notably petroleum refining (-29% to -30%) and natural gas extraction (-19 to -29%). Electricity production increases somewhat (5 to 8% by 2020) to accommodate fuel switching. These results do not include any form of border tax adjustment to value imports according to their GHG content; this would alleviate the impacts, but also increase emissions.

**Table 31: Annual % reduction in physical output from BAU to Policy (ENGO)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 0% | 0% | -5% | -5% | -6% | -6% |
| Commercial | -1% | -1% | -6% | -6% | -9% | -8% |
| Personal Trans. | 0% | 0% | -2% | -2% | -2% | -2% |
| Freight Trans. | -6% | -6% | -7% | -7% | -10% | -11% |
| Chemical Products | 0% | -1% | -2% | -7% | -3% | -9% |
| Industrial Minerals | -1% | -1% | -6% | -15% | -8% | -18% |
| Iron and Steel | 0% | 0% | -1% | -5% | -3% | -9% |
| Metal Smelting | 0% | -1% | -3% | -6% | -4% | -9% |
| Mineral Mining | 0% | 0% | -2% | -5% | -2% | -8% |
| Paper Manufacturing | 0% | -1% | -2% | -8% | -3% | -10% |
| Other Manufacturing | 0% | 0% | -1% | -2% | -1% | -2% |
| Electricity | -1% | -1% | 3% | 1% | 8% | 5% |
| Petroleum Refining | -3% | -3% | -16% | -16% | -29% | -30% |
| Petroleum Crude Ext. | -2% | -3% | -8% | -19% | -11% | -24% |
| Natural Gas Ext. | -2% | -3% | -11% | -17% | -19% | -29% |
| Coal Mining | -6% | -7% | -14% | -17% | -18% | -23% |
| Ethanol | 10% | 11% | 482% | 488% | 5097% | 5130% |
| Biodiesel | 3% | 2% | 1568% | 1547% | 2099% | 2015% |
| **Total** | **-0.8%** | **-1.0%** | **-4.4%** | **-6.1%** | **-5.2%** | **-7.7%** |

To provide perspective, Table 32 provides the change in physical output from 2005 to 2020 in the policy cases. Except for the petroleum refining and natural gas extraction sectors, whose outputs decrease by 18–19% and 16–26% respectively, no sector actually reduces output from 2005 levels in 2020. In the metal smelting and industrial minerals sectors, rebates of 50% of their carbon charge costs in the "Canada goes further" scenario prevent physical output from falling below the 2005 level.

In an environment where all of North America is reducing emissions, there is some uncertainty that Canada's natural gas output will fall, especially with recent shale gas discoveries (which are relatively expensive to produce; they require approximately $4–5/GJ as opposed to $2–3/GJ for most deposits). The price of natural gas, based on its relatively low GHG intensity and utility for making electricity, could stay high enough to maintain Canadian production.

**Table 32: Increase in physical output from 2005 to 2020 in the policy case (ENGO)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 7% | 7% | 10% | 10% | 15% | 15% |
| Commercial | 11% | 11% | 17% | 17% | 27% | 28% |
| Personal Trans. | 14% | 14% | 24% | 24% | 35% | 35% |
| Freight Trans. | 12% | 12% | 24% | 24% | 32% | 31% |
| Chemical Products | 6% | 5% | 10% | 6% | 16% | 9% |
| Industrial Minerals | 7% | 7% | 12% | 1% | 18% | 5% |
| Iron and Steel | 4% | 3% | 8% | 4% | 12% | 5% |
| Metal Smelting | 5% | 5% | 3% | 0% | 3% | 0% |
| Mineral Mining | 6% | 6% | 8% | 4% | 9% | 3% |
| Paper Manufacturing | 2% | 1% | 3% | -2% | 7% | -1% |
| Other Manufacturing | 13% | 13% | 27% | 25% | 42% | 40% |
| Electricity | 5% | 5% | 16% | 14% | 29% | 26% |
| Petroleum Refining | 0% | 0% | -10% | -10% | -18% | -19% |
| Petroleum Crude Ext. | 21% | 19% | 36% | 21% | 58% | 34% |
| Natural Gas Ext. | 2% | 1% | 0% | -6% | -16% | -26% |
| Coal Mining | 1% | 1% | 0% | -3% | 7% | 1% |
| Ethanol | 433% | 434% | 4160% | 4206% | 51756% | 52088% |
| Biodiesel | 2652% | 2625% | 102438% | 101176% | 195949% | 188555% |
| **Total** | **9%** | **9%** | **15%** | **13%** | **24%** | **21%** |

One of the key emissions reduction actions is decarbonization of electricity generation and fuel switching to electricity from other fuels, requiring more electricity be made. Figure 6 provides the BAU and policy electricity generation mix for "OECD acts together," and Figure 7 for "Canada goes further".

There were some key changes in the electricity sector for this analysis compared to previous analyses done with CIMS:

- Updates were made in this analysis to nuclear generation costing. DSF requested that we apply an estimate of full life-cycle costing for nuclear generation in this analysis, including construction, permitting, operation, liability insurance, waste handling and decommissioning. Under these conditions the cost of refurbishing, operating and decommissioning an existing reactor was set at 12.6 ¢/kwh, while the cost of a new reactor was set at 20.9 ¢/kwh. We also included a 4.0 ¢/kwh liability insurance charge to capture the implicit government insurance subsidy on nuclear power. Given these cost estimates, all modelling scenarios predicted only some delayed decommissioning of existing capacity, and no building of new generation capacity.[19]

- CCS costs were raised significantly to reflect recent estimate of costs (i.e., post combustion CCS has been raised an average of 50%).
- Reflecting recent experience with wind power in other jurisdictions (e.g., Spain, Portugal, Germany and Denmark), in previous versions of this analysis we set near term constraints on wind to a maximum of 15% of generation in any region by 2020, assuming no upgrades to electricity transmission systems. In this analysis, we assume some of the emissions charge revenues are used to fund transmission upgrades. To reflect this, we raised the constraint on wind to a maximum of 25% of generation nationally by 2020. As a result, under the ENGO target, wind rose to 18% of national generation in 2020.

In the "OECD acts together" scenario (Figure 6) total generation is 57 TWh greater in 2020 than BAU, while in the "Canada goes further" scenario (Figure 7) total generation is 39 TWh greater. Of the increase in 2020 production relative to BAU, small and large hydro took 8 to 13 TWh, wind took 70 to 88 TWh, nuclear 5 TWh, and coal and natural gas with CCS 37–39 TWh. Coal and natural gas without CCS lost about 90 TWh of generation share.

[19] Ontario Clean Air Alliance, *The Economics of Nuclear Power* (2006), puts the price of new nuclear build is 20.9 cents/kWh. The cost of refurbished nuclear capacity has been estimated to be 60% of the cost of new nuclear in Icyk, B., *At what cost? A comparative evaluation of the social cost of selected electricity generation alternatives in Ontario*, M.E.S. thesis, University of Waterloo (2006).

**Figure 6: Electricity production and mix "OECD acts together"[20] (ENGO)**

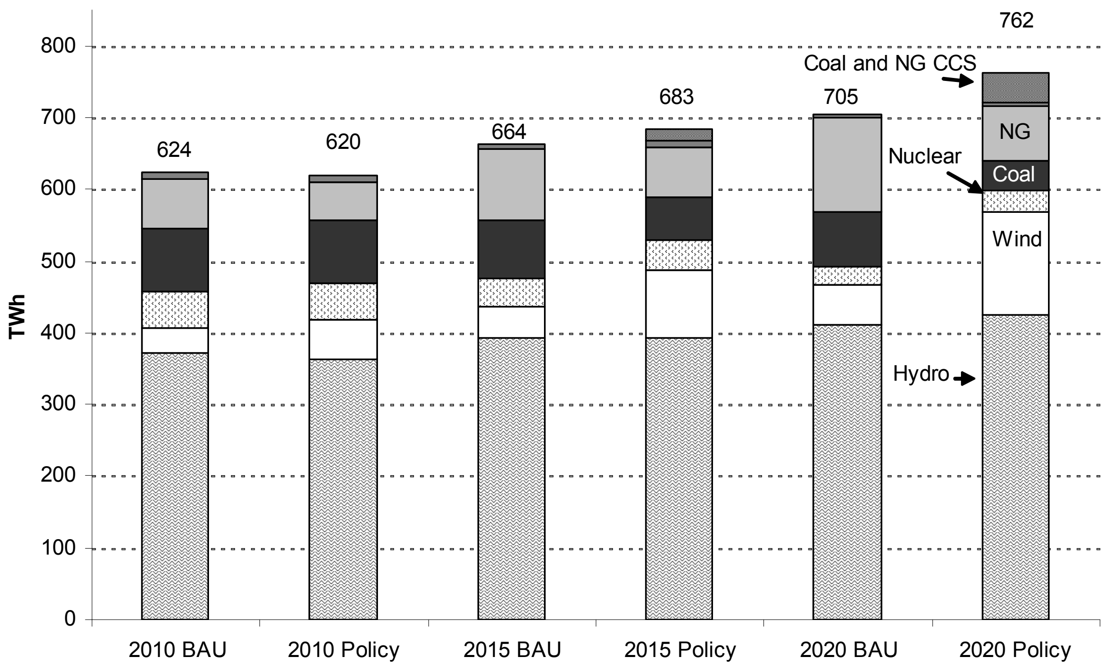
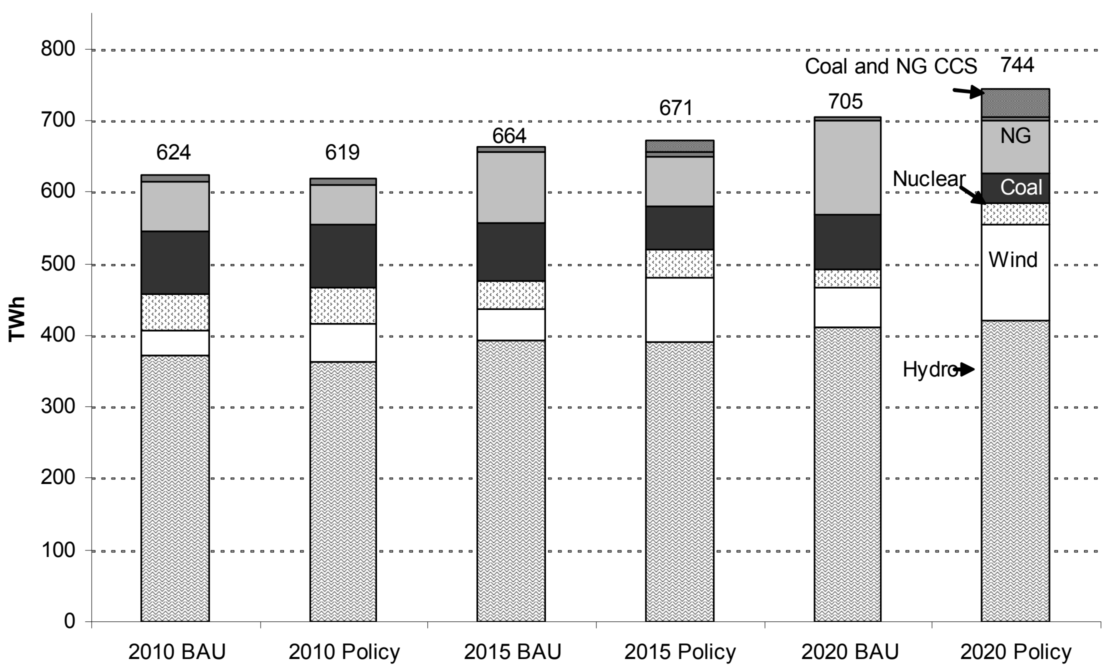



**Figure 7: Electricity production and mix "Canada goes further" (ENGO)**




20 The near term BAU projections for electricity production are based on long term economic forecasts. The recent economic downturn may delay the completion of some generation capacity.

Table 33 summarizes the net financial effects that come out of CIMS. It adds the changes in annual capital, energy, and labour costs. Emissions costs are not included as they are transfers to the rest of the economy.

**Table 33: Annual net financial costs by sector ("+" = costs, "-" = gains, $2005 millions, ENGO) . Sum of annual capital, labour related to energy use, and energy costs, relative to BAU.**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 396 | 375 | 3,114 | 2,988 | 5,395 | 5,238 |
| Commercial | 28 | 14 | 271 | 176 | 2,644 | 2,487 |
| Personal Trans. | -631 | -631 | -19,908 | -19,910 | -21,379 | -21,382 |
| Freight Trans. | -3,870 | -3,843 | -17,341 | -17,566 | -20,956 | -21,810 |
| Chemical Products | 28 | -10 | 276 | -280 | 352 | -388 |
| Industrial Minerals | 1 | -10 | 51 | -140 | 117 | -20 |
| Iron and Steel | -16 | -42 | 102 | -252 | 30 | -485 |
| Metal Smelting | 12 | -11 | 90 | -135 | 224 | -28 |
| Mineral Mining | 1 | -90 | -42 | -904 | 107 | -880 |
| Paper Manufacturing | 24 | -70 | -12 | -996 | 215 | -526 |
| Other Manufacturing | 7 | -11 | 369 | 137 | 799 | 537 |
| Agriculture | 41 | 40 | 406 | 394 | 758 | 753 |
| Waste | 3 | 3 | 102 | 104 | -169 | -167 |
| Electricity | 205 | 12 | 7,792 | 5,681 | 11,013 | 9,142 |
| Petroleum Refining | -137 | -140 | -795 | -832 | -1,075 | -1,128 |
| Petroleum Crude Ext. | -322 | -846 | -713 | -5,620 | 3,473 | -3,281 |
| Natural Gas Ext. | -511 | -798 | -2,028 | -3,516 | -2,442 | -4,233 |
| Coal Mining | -54 | -60 | -89 | -135 | -59 | -108 |
| Ethanol | 0 | 0 | 27 | 27 | 401 | 405 |
| Biodiesel | 2 | 1 | 2,653 | 2,615 | 4,419 | 4,213 |
| **Total** | **-4,793** | **-6,116** | **-25,676** | **-38,163** | **-16,133** | **-31,662** |

Table 34 interpolates the financial impacts of "OECD acts together" between 2010, 2015 and 2020, and adds net foreign permit purchases. Table 35 shows the assumed schedule of foreign permit purchases, which rise in price from $25/tonne in 2010 to $100/tonne in 2020 for "OECD acts together", and to $75/tonne for "Canada goes further." Total payments are $28–44 billion by 2020; the annual payment in 2020 is $6.0–10.1 billion. Emissions costs are not included as they are transfers to the rest of the economy. The summed impacts over time in the "OECD acts together" scenario, *which are not discounted*, are a net *reduction* in expenditure on capital, labour and energy of $147 billion. If the transportation impacts are removed, the summed impacts are a net *increase* in expenditure of $180 billion. In the "Canada goes further" scenario (Table 36) the total including transportation is a reduction in expenditure of $277 billion, while excluding transportation the net increase in financial costs is $54 billion. These values do not necessarily represent net benefits to society; these are usually calculated as changes in consumer surplus or welfare.

**Table 34: Annual net financial costs by sector ("+" = costs, "-" = gains, $2005 billions, ENGO "OECD acts together"). Sum of annual capital, labour related to energy use, and energy costs, relative to BAU.**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | ∑ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential | 0.4 | 0.9 | 1.5 | 2.0 | 2.6 | 3.1 | 3.6 | 4.0 | 4.5 | 4.9 | 5.4 | 32.9 |
| Commercial | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.7 | 1.2 | 1.7 | 2.2 | 2.6 | 9.4 |
| Trans. Personal | -0.6 | -4.5 | -8.3 | -12.2 | -16.1 | -19.9 | -20.2 | -20.5 | -20.8 | -21.1 | -21.4 | -165.6 |
| Trans. Freight | -3.9 | -6.6 | -9.3 | -12.0 | -14.6 | -17.3 | -18.1 | -18.8 | -19.5 | -20.2 | -21.0 | -161.2 |
| Chem. Products | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 2.5 |
| Ind. Minerals | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.6 |
| Iron and Steel | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.6 |
| Metal Smelting | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 1.2 |
| Mineral Mining | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 |
| Paper Man. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.7 |
| Other Man. | 0.0 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.8 | 4.3 |
| Agriculture | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.8 | 4.4 |
| Waste | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | -0.1 | -0.1 | -0.2 | 0.0 |
| Electricity | 0.2 | 1.7 | 3.2 | 4.8 | 6.3 | 7.8 | 8.4 | 9.1 | 9.7 | 10.4 | 11.0 | 72.6 |
| Pet. Refining | -0.1 | -0.3 | -0.4 | -0.5 | -0.7 | -0.8 | -0.9 | -0.9 | -1.0 | -1.0 | -1.1 | -7.6 |
| Crude Oil Ext. | -0.3 | -0.4 | -0.5 | -0.6 | -0.6 | -0.7 | 0.1 | 1.0 | 1.8 | 2.6 | 3.5 | 5.9 |
| NG Ext. | -0.5 | -0.8 | -1.1 | -1.4 | -1.7 | -2.0 | -2.1 | -2.2 | -2.3 | -2.4 | -2.4 | -19.0 |
| Coal Mining | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.8 |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 1.3 |
| Biodiesel | 0.0 | 0.5 | 1.1 | 1.6 | 2.1 | 2.7 | 3.0 | 3.4 | 3.7 | 4.1 | 4.4 | 26.5 |
| International Permit Payments | 0.1 | 0.5 | 1.0 | 1.6 | 2.4 | 3.3 | 4.4 | 5.6 | 7.0 | 8.5 | 10.1 | 44.4 |
| **Total** | **-4.7** | **-8.5** | **-12.2** | **-15.7** | **-19.1** | **-22.4** | **-19.4** | **-16.3** | **-13.0** | **-9.6** | **-6.0** | **-146.8** |

**Table 35: Schedule of international permit payments ($2005 millions, ENGO)**

| | OECD acts together | | | Canada goes further | | |
|---|---|---|---|---|---|---|
| | Price ($/tonne $CO_2$e) | Mt | Payments | Price ($/tonne $CO_2$e) | Mt | Payments |
| 2010 | 25 | 5 | $125 | 25 | 5 | $125 |
| 2011 | 33 | 15 | $475 | 30 | 13 | $375 |
| 2012 | 40 | 24 | $968 | 35 | 20 | $700 |
| 2013 | 48 | 34 | $1,606 | 40 | 28 | $1,100 |
| 2014 | 55 | 43 | $2,387 | 45 | 35 | $1,575 |
| 2015 | 63 | 53 | $3,313 | 50 | 43 | $2,125 |
| 2016 | 70 | 63 | $4,382 | 55 | 50 | $2,750 |
| 2017 | 78 | 72 | $5,596 | 60 | 58 | $3,450 |
| 2018 | 85 | 82 | $6,953 | 65 | 65 | $4,225 |
| 2019 | 93 | 91 | $8,455 | 70 | 73 | $5,075 |
| 2020 | 100 | 101 | $10,100 | 75 | 80 | $6,000 |
| **Total** | | | **$44,358** | | | **$27,500** |

**Table 36: Annual net financial cost ("+" = costs, "-" = gains, $2005 billions, ENGO "Canada goes further"). Sum of annual capital, labour related to energy use, & energy costs, relative to BAU.**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | ∑ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential | 0.4 | 0.9 | 1.4 | 1.9 | 2.5 | 3.0 | 3.4 | 3.9 | 4.3 | 4.8 | 5.2 | 31.8 |
| Commercial | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.6 | 1.1 | 1.6 | 2.0 | 2.5 | 8.4 |
| Trans. Personal | -0.6 | -4.5 | -8.3 | -12.2 | -16.1 | -19.9 | -20.2 | -20.5 | -20.8 | -21.1 | -21.4 | -165.6 |
| Trans. Freight | -3.8 | -6.6 | -9.3 | -12.1 | -14.8 | -17.6 | -18.4 | -19.3 | -20.1 | -21.0 | -21.8 | -164.8 |
| Chem. Products | 0.0 | -0.1 | -0.1 | -0.2 | -0.2 | -0.3 | -0.3 | -0.3 | -0.3 | -0.4 | -0.4 | -2.6 |
| Ind. Minerals | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | -0.8 |
| Iron and Steel | 0.0 | -0.1 | -0.1 | -0.2 | -0.2 | -0.3 | -0.3 | -0.3 | -0.4 | -0.4 | -0.5 | -2.8 |
| Metal Smelting | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | -0.8 |
| Mineral Mining | -0.1 | -0.3 | -0.4 | -0.6 | -0.7 | -0.9 | -0.9 | -0.9 | -0.9 | -0.9 | -0.9 | -7.4 |
| Paper Man. | -0.1 | -0.3 | -0.4 | -0.6 | -0.8 | -1.0 | -0.9 | -0.8 | -0.7 | -0.6 | -0.5 | -6.8 |
| Other Man. | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.5 | 2.3 |
| Agriculture | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.8 | 4.3 |
| Waste | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | -0.1 | -0.1 | -0.2 | 0.0 |
| Electricity | 0.0 | 1.1 | 2.3 | 3.4 | 4.5 | 5.7 | 6.4 | 7.1 | 7.8 | 8.4 | 9.1 | 55.9 |
| Pet. Refining | -0.1 | -0.3 | -0.4 | -0.6 | -0.7 | -0.8 | -0.9 | -1.0 | -1.0 | -1.1 | -1.1 | -8.0 |
| Crude Oil Ext. | -0.8 | -1.8 | -2.8 | -3.7 | -4.7 | -5.6 | -5.2 | -4.7 | -4.2 | -3.7 | -3.3 | -40.5 |
| NG Ext. | -0.8 | -1.3 | -1.9 | -2.4 | -3.0 | -3.5 | -3.7 | -3.8 | -3.9 | -4.1 | -4.2 | -32.7 |
| Coal Mining | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -1.2 |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 1.3 |
| Biodiesel | 0.0 | 0.5 | 1.0 | 1.6 | 2.1 | 2.6 | 2.9 | 3.3 | 3.6 | 3.9 | 4.2 | 25.7 |
| International Permit Payments | 0.1 | 0.4 | 0.7 | 1.1 | 1.6 | 2.1 | 2.8 | 3.5 | 4.2 | 5.1 | 6.0 | 27.5 |
| **Total** | **-6.0** | **-12.2** | **-18.2** | **-24.2** | **-30.2** | **-36.0** | **-34.1** | **-32.1** | **-30.0** | **-27.9** | **-25.7** | **-276.6** |

### *CIMS – Sector, Emissions, Investment and Energy Impacts– Government Target*

Table 37 provides the annual reductions in emissions, relative to the reference case (BAU, business as usual) by sector and for the whole economy under the influence of the policy package that achieves the government emissions target, a 20% reduction in GHG emissions relative to 2006 by 2020. To achieve this target, Canadian emissions must fall to 570 Mt in 2020 versus the 434 Mt needed to achieve the ENGO target.

**Table 37: Annual reduction of all GHG emissions (Mt $CO_2$e) from BAU to Policy (GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 0 | 0 | 10 | 10 | 18 | 18 |
| Commercial | 0 | 0 | 10 | 10 | 22 | 22 |
| Personal Trans. | 0 | 0 | 6 | 6 | 13 | 13 |
| Freight Trans. | 6 | 6 | 19 | 19 | 29 | 30 |
| Chemical Products | 0 | 0 | 3 | 4 | 4 | 5 |
| Industrial Minerals | 0 | 0 | 2 | 3 | 3 | 5 |
| Iron and Steel | 0 | 0 | 1 | 1 | 1 | 1 |
| Metal Smelting | 0 | 0 | 0 | 0 | 0 | 1 |
| Mineral Mining | 0 | 0 | 0 | 1 | 0 | 1 |
| Paper Manufacturing | 0 | 0 | 0 | 0 | 0 | 0 |
| Other Manufacturing | 0 | 0 | 1 | 1 | 3 | 3 |
| Agriculture | 0 | 0 | 3 | 3 | 4 | 4 |
| Waste | 0 | 0 | 22 | 22 | 23 | 23 |
| Electricity | 10 | 10 | 23 | 24 | 39 | 40 |
| Petroleum Refining | 1 | 1 | 3 | 3 | 6 | 6 |
| Petroleum Crude Extr. | 0 | 0 | 11 | 17 | 23 | 33 |
| Natural Gas Extraction | 0 | 0 | 14 | 15 | 16 | 18 |
| Coal Mining | 0 | 0 | 0 | 0 | 0.3 | 0.4 |
| Ethanol | 0 | 0 | 0 | 0 | -0.1 | -0.1 |
| Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **17** | **17** | **128** | **139** | **205** | **223** |

Emissions reductions were 17 Mt greater in the "Canada goes further" scenario in 2020, accounting for 7.7% of the overall reduction of 223 Mt. The differences between the two scenarios, mainly due to greater reduction in output, were significant only for petroleum crude extraction, natural gas extraction and industrial minerals and metal smelting. 10% of the carbon charges taken from the metal smelting sector were returned to keep its output above 2008 levels by 2020.

The biggest reductions come from petroleum crude extraction (23 to 33 Mt in 2020), freight transportation (29 to 30 Mt), electricity (39 to 40 Mt), personal transportation (13 Mt), residential and commercial buildings (40 Mt), natural gas extraction (16 to 18 Mt) and the landfill waste sector (23 Mt). These reductions are due to capital investment in energy and GHG efficiency measures (e.g., CCS), fuel switching, and output reductions in a couple of key sectors. The overall reductions are 56 to 73 Mt short of the target in 2020, and it is assumed this is made up through international permit purchases – the cost and foreign exchange requirements associated with this are included in the R-GEEM macroeconomic analysis.

Table 38 provides the annual emissions reductions expressed as percentages compared to the reference case. Again, there are very small differences between the scenarios. The very large percentage increases in biodiesel and ethanol are due to the very low starting values.

**Table 38: % reduction of all GHG emissions (Mt $CO_2e$) from BAU to Policy (GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 0% | 0% | 28% | 28% | 52% | 52% |
| Commercial | 0% | 0% | 26% | 26% | 52% | 52% |
| Personal Trans. | 0% | 0% | 6% | 6% | 12% | 12% |
| Freight Trans. | 6% | 6% | 16% | 16% | 22% | 22% |
| Chemical Products | 0% | 0% | 21% | 25% | 30% | 35% |
| Industrial Minerals | 0% | 0% | 11% | 18% | 16% | 25% |
| Iron and Steel | 0% | 0% | 4% | 5% | 6% | 9% |
| Metal Smelting | 0% | 0% | 2% | 3% | 4% | 7% |
| Mineral Mining | 0% | 0% | 5% | 12% | 8% | 18% |
| Paper Manufacturing | 0% | 0% | 2% | 4% | 4% | 7% |
| Other Manufacturing | 0% | 0% | 5% | 6% | 11% | 12% |
| Agriculture | 0% | 0% | 6% | 6% | 8% | 8% |
| Waste | 0% | 0% | 83% | 83% | 83% | 83% |
| Electricity | 8% | 8% | 18% | 19% | 30% | 31% |
| Petroleum Refining | 2% | 2% | 12% | 12% | 22% | 23% |
| Petroleum Crude Ext. | 1% | 1% | 9% | 14% | 15% | 22% |
| Natural Gas Ext. | 1% | 1% | 22% | 25% | 29% | 33% |
| Coal Mining | 4% | 4% | 8% | 9% | 14% | 15% |
| Ethanol | -2% | -2% | -198% | -201% | -583% | -590% |
| Biodiesel | 3% | 3% | -205% | -203% | -280% | -275% |
| **Total** | **2%** | **2%** | **16%** | **18%** | **24%** | **26%** |

Table 39 provides the emissions reductions by sector and region for the "OECD acts together" scenario, and Table 40 describes them for the "Canada goes further" scenario. For "OECD acts together," most reductions occur in Alberta (71 Mt / 34%) and Ontario (51 Mt / 25%), now with only 10% (21 Mt) of all reduction occurring in the Alberta Petroleum Crude sector. Emissions reductions are greatest in freight transportation (14%) and electricity (19%). The results are very similar for "Canada goes further", although greater output reductions in the petroleum crude sector result in fewer emissions.

**Table 39: Emissions reductions in 2020 by sector and region (Mt $CO_2e$) from BAU to Policy "OECD acts together" (GOVT)**

| | BC | AB | SK | MB | ON | PQ | ATL | ∑ | % |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 1.6 | 4.7 | 0.6 | 0.4 | 8.4 | 1.7 | 0.7 | 18.3 | 9% |
| Commercial | 2.6 | 3.0 | 0.9 | 1.0 | 9.2 | 3.8 | 1.9 | 22.3 | 11% |
| Personal Trans. | 1.8 | 1.7 | 0.4 | 0.3 | 3.9 | 3.5 | 0.9 | 12.6 | 6% |
| Freight Trans. | 5.5 | 5.5 | 1.1 | 0.7 | 9.7 | 4.2 | 2.7 | 29.4 | 14% |
| Chemicals | 0.0 | 2.6 | - | - | 1.6 | 0.0 | - | 4.3 | 2% |
| Ind. Minerals | 0.4 | 0.7 | - | - | 1.3 | 0.6 | 0.1 | 3.1 | 2% |
| Iron and Steel | - | - | - | - | 0.8 | 0.0 | - | 0.8 | 0% |
| Metal Smelting | 0.0 | - | - | 0.0 | 0.0 | 0.3 | 0.0 | 0.4 | 0% |
| Mineral Mining | 0.0 | - | 0.2 | 0.0 | 0.1 | 0.1 | 0.1 | 0.5 | 0% |
| Paper Mnftg | 0.1 | 0.0 | - | - | 0.0 | 0.0 | 0.0 | 0.2 | 0% |
| Other Mnftg | 0.6 | 0.5 | 0.0 | 0.1 | 0.9 | 0.6 | 0.2 | 2.8 | 1% |
| Agriculture | 0.2 | 0.9 | 0.6 | 1.3 | 0.0 | 0.8 | 0.2 | 4.0 | 2% |
| Waste | 4.3 | 2.3 | 0.8 | 0.8 | 5.9 | 6.4 | 2.2 | 22.8 | 11% |
| Electricity | 0.7 | 18.9 | 6.5 | 0.2 | 5.1 | 2.7 | 4.9 | 39.0 | 19% |
| Pet. Refining | 0.7 | 0.5 | 0.1 | - | 3.1 | 0.8 | 0.4 | 5.7 | 3% |
| Pet. Crude Ext. | 0.4 | 20.9 | 1.5 | 0.0 | 0.1 | - | 0.1 | 23.0 | 11% |
| NG Ext. | 5.7 | 8.2 | 1.3 | 0.1 | 0.6 | 0.0 | 0.3 | 16.4 | 8% |
| Coal Mining | 0.1 | 0.2 | 0.0 | - | - | - | 0.0 | 0.3 | 0% |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0% |
| Biodiesel | 0.0 | -0.1 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.4 | 0% |
| **Total** | **25** | **71** | **14** | **5** | **51** | **25** | **15** | **205** | **100%** |
| % | 12% | 34% | 7% | 2% | 25% | 12% | 7% | 100% | |

**Table 40: Emissions reductions in 2020 by sector and region (Mt $CO_2e$) from BAU to Policy "Canada goes further" (GOVT)**

| | BC | AB | SK | MB | ON | PQ | ATL | ∑ | % |
|---|---|---|---|---|---|---|---|---|---|
| Residential | 1.6 | 4.7 | 0.6 | 0.4 | 8.4 | 1.7 | 0.7 | 18.3 | 8% |
| Commercial | 2.6 | 3.0 | 0.9 | 1.0 | 9.2 | 3.8 | 1.9 | 22.3 | 10% |
| Personal Trans. | 1.8 | 1.7 | 0.4 | 0.3 | 3.9 | 3.5 | 0.9 | 12.6 | 6% |
| Freight Trans. | 5.8 | 5.5 | 1.1 | 0.7 | 9.7 | 4.3 | 2.7 | 29.7 | 13% |
| Chemicals | 0.1 | 3.1 | - | - | 1.7 | 0.0 | - | 4.9 | 2% |
| Ind. Minerals | 0.7 | 1.0 | - | - | 2.0 | 0.9 | 0.1 | 4.7 | 2% |
| Iron and Steel | - | - | - | - | 1.2 | 0.0 | - | 1.2 | 1% |
| Metal Smelting | 0.1 | - | - | 0.0 | 0.0 | 0.4 | 0.1 | 0.6 | 0% |
| Mineral Mining | 0.1 | - | 0.7 | 0.0 | 0.1 | 0.1 | 0.1 | 1.1 | 0% |
| Paper Mnftg | 0.1 | 0.0 | - | - | 0.1 | 0.1 | 0.0 | 0.3 | 0% |
| Other Mnftg | 0.7 | 0.5 | 0.0 | 0.1 | 1.0 | 0.6 | 0.2 | 3.1 | 1% |
| Agriculture | 0.2 | 0.9 | 0.6 | 1.3 | 0.0 | 0.8 | 0.2 | 4.0 | 2% |
| Waste | 4.3 | 2.3 | 0.8 | 0.8 | 5.9 | 6.4 | 2.2 | 22.8 | 10% |
| Electricity | 0.7 | 19.7 | 6.6 | 0.2 | 5.3 | 2.7 | 4.9 | 40.2 | 18% |
| Pet. Refining | 0.8 | 0.5 | 0.1 | - | 3.1 | 0.8 | 0.4 | 5.8 | 3% |
| Pet. Crude Ext. | 0.4 | 29.8 | 2.3 | 0.0 | 0.1 | - | 0.1 | 32.6 | 15% |
| NG Ext. | 6.1 | 9.6 | 1.4 | 0.1 | 0.8 | 0.1 | 0.5 | 18.5 | 8% |
| Coal Mining | 0.1 | 0.2 | 0.0 | - | - | - | 0.0 | 0.4 | 0% |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.1 | 0% |
| Biodiesel | 0.0 | -0.1 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.4 | 0% |
| **Total** | **26** | **83** | **15** | **5** | **53** | **26** | **15** | **223** | **100%** |
| % | 12% | 37% | 7% | 2% | 24% | 12% | 7% | 100% | |

Table 41 and Figure 8 describe the actions taken to reduce GHGs out to 2020 in the "OECD acts together" scenario, assuming the policy package remains at the same stringency out to 2030 (i.e., complementary regulations plus $167/tonne $CO_2e$). Table 42 and Figure 9 and provide the same for when "Canada goes further". In the short to medium run out to 2020, the most important actions are:

- Carbon capture and storage (32 Mt in 2020 in "OECD acts together" and 30 Mt in "Canada goes further"). In early years this is primarily from relatively pure $CO_2$ sources, such as formation $CO_2$ from natural gas processing and $CO_2$ from steam reformation of methane to produce hydrogen. It is important to note that in this scenario all CCS is completely market driven.
- Energy efficiency (49 Mt in 2020 in both "OECD acts together" and "Canada goes further"), primarily in the personal and freight transportation sectors.
- Other GHG control (38 Mt in 2020 in "OECD acts together" and 43 Mt in "Canada goes further"), which includes control of fugitives in upstream oil and gas, and capping, flaring and cogeneration of landfill gas
- International permit purchases (73 Mt in 2020 in "OECD acts together" and 56 Mt in "Canada goes further")

- Switching to electricity in all sectors, including buildings (30 Mt in 2020 in “OECD acts together” and “Canada goes further”)
- Switching to renewables (mainly in electricity and to hydro and wind) (25 Mt in 2020 in “OECD acts together” and 24 Mt in “Canada goes further”).
- Output reductions (21 Mt in 2020 in “OECD acts together” and 36 Mt in “Canada goes further”), mostly reduced output in the entire fossil fuel industry.

**Table 41: Emissions reduction actions GOVT "OECD acts together," Mt $CO_2e$**

| | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|
| Baseline (BAU) emissions | 714* | 734 | 786 | 848 |
| Emissions after application of domestic policies | 714 | 718 | 658 | 643 |
| Domestic emissions reductions: | | | | |
| Output reduction | 0 | 8 | 16 | 21 |
| Other GHG control | 0 | 0 | 32 | 38 |
| Fuel switching to nuclear | 0 | 0 | 0 | 0 |
| Fuel switching to renewables | 0 | 5 | 14 | 22 |
| Fuel switching to electricity | 0 | 0 | 13 | 29 |
| Fuel switching to other fuels | 0 | 0 | 3 | 10 |
| Carbon capture and storage | 0 | 1 | 18 | 32 |
| CCS energy efficiency penalty | 0 | 0 | 3 | 5 |
| Energy efficiency | 0 | 3 | 29 | 49 |
| International permit purchases | 0 | 5 | 39 | 73 |
| Target (remaining emissions) = Baseline– domestic emissions reductions – permit purchases | | | | 570 |

*Note: See Table 98 for a description of emissions included in CIMS.

**Figure 8: Emission reduction actions GOVT "OECD acts together"**

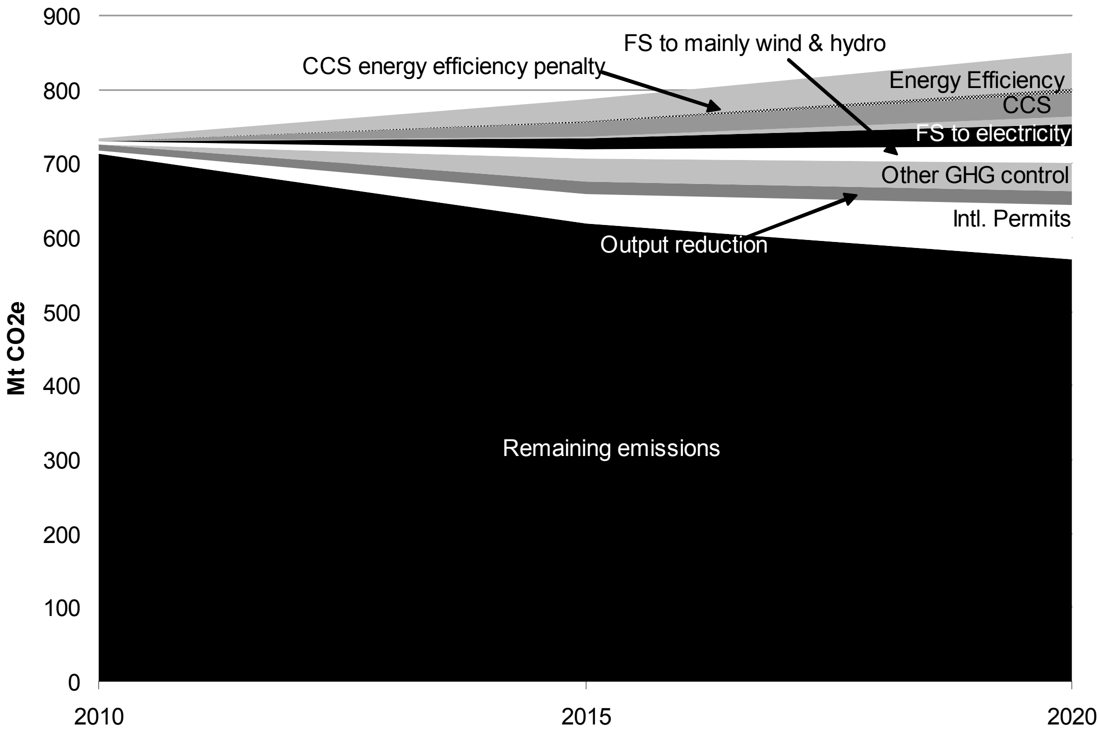
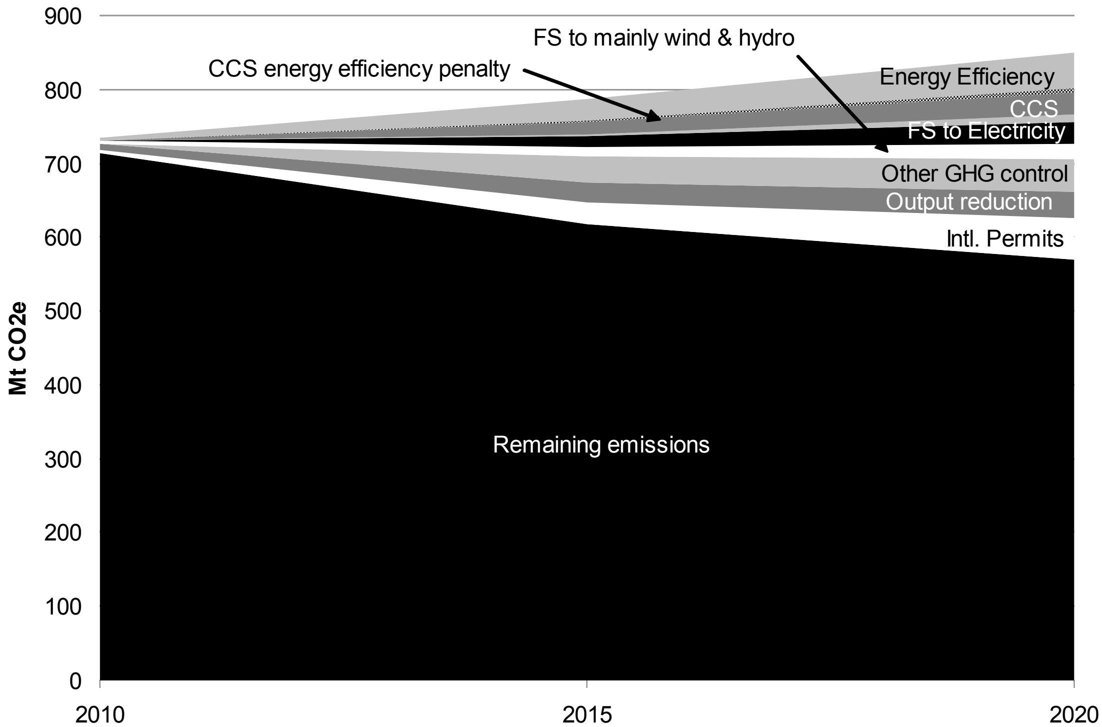



**Table 42: Emissions reduction actions GOVT "Canada goes further", Mt $CO_2$e**

| | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|
| Baseline (BAU) emissions | 714* | 734 | 786 | 848 |
| Emissions after application of domestic policies | 704 | 718 | 647 | 626 |
| Domestic emissions reductions: | | | | |
| Output reduction | 6 | 8 | 26 | 36 |
| Other GHG control | 0 | 0 | 36 | 43 |
| Fuel switching to nuclear | 0 | 0 | 0 | 0 |
| Fuel switching to renewables | 2 | 5 | 13 | 22 |
| Fuel switching to electricity | 0 | 0 | 13 | 30 |
| Fuel switching to other fuels | 0 | 0 | 3 | 10 |
| Carbon capture and storage | 0 | 1 | 17 | 30 |
| CCS energy efficiency penalty | 0 | 0 | 3 | 5 |
| Energy efficiency | 2 | 3 | 28 | 49 |
| International permit purchases | 0 | 5 | 31 | 56 |
| Target (remaining emissions) = Baseline– domestic emissions reductions – permit purchases | | | | 570 |

*Note: See Table 98for a description of emissions included in CIMS.

**Figure 9: Emission reduction actions GOVT "Canada goes further"**




The necessary capital investment, operations, and fuel switching changes in each sector engender changes in capital, energy, labour and emissions costs. Output impacts, which are included in these values, will be discussed later. Table 43 through to Table 46 document, by sector:

- the changes in capital expenditure for energy using and producing capital stock;
- changes in labour related to energy using and producing capital stock;
- changes in energy costs; and
- payments for emissions (which are transfers within the economy).

**Table 43: Increase in annual capital costs ($2005 millions) from BAU to Policy (GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 149 | 149 | 2497 | 2526 | 3068 | 3069 |
| Commercial | 6 | 6 | 47 | 87 | 1070 | 1071 |
| Personal Trans. | 2 | 2 | -8959 | -8958 | -6714 | -6712 |
| Freight Trans. | -408 | -408 | -3485 | -3485 | -2059 | -2173 |
| Chemical Products | 0 | 0 | 25 | -127 | 45 | -45 |
| Industrial Minerals | 0 | 0 | -38 | -137 | -8 | -53 |
| Iron and Steel | 0 | 1 | 19 | -64 | -4 | -57 |
| Metal Smelting | -1 | -2 | -49 | -146 | -21 | -63 |
| Mineral Mining | -1 | -4 | -138 | -452 | -58 | -204 |
| Paper Manufacturing | 4 | 1 | -148 | -504 | -19 | -134 |
| Other Manufacturing | -1 | 0 | -13 | -46 | 1 | -14 |
| Agriculture | -1 | -1 | -61 | -61 | -32 | -32 |
| Waste | 0 | 0 | 204 | 203 | 42 | 41 |
| Electricity | 1115 | 1107 | 7640 | 6571 | 8050 | 7537 |
| Petroleum Refining | -13 | -13 | -181 | -185 | -241 | -247 |
| Petroleum Crude Ext. | -50 | -52 | -389 | -1589 | 6 | -816 |
| Natural Gas Ext. | -146 | -147 | -828 | -1175 | -583 | -782 |
| Coal Mining | -21 | -21 | -66 | -80 | -74 | -85 |
| Ethanol | 0 | 0 | 2 | 2 | 18 | 18 |
| Biodiesel | -1 | -1 | 149 | 148 | 152 | 148 |
| **Total** | **634** | **620** | **-3773** | **-7472** | **2637** | **466** |

The capital investment patterns differ significantly between the two scenarios. In general, more capital is required in the "OECD acts together" case than the "Canada goes further" case. Output falls less, and therefore more capital is required to decarbonise electricity generation equipment, buildings, industrial machinery, rolling stock, etc.

Differences between the sectors are evident, with the largest impacts on the transport and electricity sectors. Almost $7 billion less capital is invested and spent annually in the personal transport sector in 2020, because more efficient vehicles tend to be smaller and less costly. There is also significant mode shifting in personal transportation, due to the urban and intercity transit spending policies, and in freight transportation, both of which reduce capital expenditure.

Another sector with significant changes in capital investment is the electricity sector whose requirements for capital have risen by $7.5–$8.1 billion annually by 2020. This is due to across-the-board fuel switching to electricity, further impelled by regulations prohibiting direct use of fossil fuels for space and water heating for all new buildings in commercial and residential in British Columbia, Manitoba, and Québec. As with the ENGO target, electricity production is one of the lowest cost areas to achieve low and zero GHG energy production, and its use goes up markedly across the economy.

Table 44 describes the changes in labour or equivalent time expenditures (e.g., in transportation) directly associated with energy using capital in the economy. A wider picture of the impacts on labour will be provided in the R-GEEM macroeconomic section following the CIMS results. The labour results roughly match the impact of the capital results.

**Table 44: Increase in annual operating & maintenance costs ($2005 millions) from BAU to Policy (GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 0 | 0 | -12 | -12 | -22 | -21 |
| Commercial | 0 | 0 | -9 | -9 | -16 | -16 |
| Personal Trans. | 0 | 0 | -2,488 | -2,488 | -4,412 | -4,412 |
| Freight Trans. | -584 | -584 | -3,649 | -3,655 | -5,235 | -5,258 |
| Chemical Products | 1 | 1 | 5 | -27 | 14 | -37 |
| Industrial Minerals | 0 | 0 | 0 | -14 | 3 | -17 |
| Iron and Steel | 1 | 2 | -27 | -100 | -52 | -180 |
| Metal Smelting | 0 | -1 | -19 | -44 | -32 | -68 |
| Mineral Mining | 0 | -1 | -27 | -90 | -39 | -130 |
| Paper Manufacturing | -1 | -3 | -37 | -123 | -31 | -145 |
| Other Manufacturing | 0 | 0 | -1 | -7 | 1 | -9 |
| Agriculture | 3 | 3 | 78 | 78 | 117 | 117 |
| Waste | 0 | 0 | 97 | 97 | 116 | 115 |
| Electricity | 114 | 111 | 830 | 713 | 1,552 | 1,381 |
| Petroleum Refining | -32 | -32 | -153 | -155 | -315 | -322 |
| Petroleum Crude Ext. | -98 | -99 | -755 | -1,748 | -1,147 | -2,775 |
| Natural Gas Ext. | -69 | -70 | -544 | -824 | -884 | -1,308 |
| Coal Mining | -10 | -10 | -25 | -29 | -43 | -49 |
| Ethanol | 0 | 0 | 5 | 5 | 31 | 32 |
| Biodiesel | -1 | -1 | 318 | 316 | 641 | 631 |
| **Total** | **-677** | **-685** | **-6,413** | **-8,117** | **-9,752** | **-12,471** |

Table 45 describes the changes in annual energy expenditures by sector (not including carbon costs associated with direct fuel use, or the compensation provided to households). There are significant differences between the sectors. Both scenarios have considerable savings in early years, which continue to grow to $12 to $15 billion annually by 2020. Considerable amounts are saved in the transport sector due to efficiency and the significant mode shifting induced by the transit spending policies. The electricity transmission spending policy encourages more renewable energy capacity, especially wind, substantially reducing the sector's fuel costs.

**Table 45: Increase in annual energy expenditures ($2005 millions) from BAU to Policy (GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 168 | 165 | 675 | 564 | 1,077 | 952 |
| Commercial | 9 | 7 | 594 | 493 | 410 | 282 |
| Personal Trans. | -1 | -1 | -2,151 | -2,153 | -3,595 | -3,599 |
| Freight Trans. | -2,119 | -2,117 | -5,206 | -5,209 | -7,575 | -7,702 |
| Chemical Products | 6 | 4 | 133 | -37 | 149 | -134 |
| Industrial Minerals | 1 | 1 | 111 | 63 | 154 | 81 |
| Iron and Steel | -11 | -11 | 22 | -12 | 32 | -26 |
| Metal Smelting | 11 | 10 | 135 | 48 | 203 | 89 |
| Mineral Mining | 6 | 5 | 144 | -17 | 188 | -56 |
| Paper Manufacturing | 7 | 0 | 213 | 59 | 220 | 22 |
| Other Manufacturing | -35 | -35 | 97 | 8 | 152 | 28 |
| Agriculture | 3 | 3 | 149 | 141 | 218 | 208 |
| Waste | -1 | -1 | -169 | -168 | -260 | -258 |
| Electricity | -814 | -815 | -1,516 | -1,643 | -2,384 | -2,584 |
| Petroleum Refining | -34 | -34 | -131 | -148 | -312 | -340 |
| Petroleum Crude Ext. | -26 | -29 | 58 | -544 | 206 | -781 |
| Natural Gas Ext. | -53 | -57 | -389 | -653 | -654 | -992 |
| Coal Mining | -8 | -8 | 13 | 8 | 15 | 7 |
| Ethanol | 0 | 0 | 3 | 3 | 19 | 19 |
| Biodiesel | 0 | 0 | 78 | 77 | 151 | 148 |
| **Total** | **-2,890** | **-2,912** | **-7,136** | **-9,119** | **-11,588** | **-14,635** |

Table 46 shows the direct average annual payments made for emissions by all sectors. These revenues are recycled as described earlier. The amounts involved are considerable, rising to $50–53 billion in 2020. 10% of the metal smelting sector's carbon charges are returned to maintain output at 2008 levels in the "Canada goes further" scenario.

**Table 46: Average annual emissions charge costs ($2005 millions, GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 0 | 0 | 1,393 | 1,393 | 1,477 | 1,477 |
| Commercial | 0 | 0 | 1,556 | 1,556 | 1,791 | 1,791 |
| Personal Trans. | 0 | 0 | 9,056 | 9,056 | 8,241 | 8,240 |
| Freight Trans. | 0 | 0 | 5,189 | 5,189 | 8,890 | 8,864 |
| Chemical Products | 0 | 0 | 586 | 553 | 854 | 795 |
| Industrial Minerals | 0 | 0 | 836 | 775 | 1,375 | 1,235 |
| Iron and Steel | 0 | 0 | 664 | 656 | 1,070 | 1,035 |
| Metal Smelting | 0 | 0 | 500 | 443 | 709 | 622 |
| Mineral Mining | 0 | 0 | 292 | 271 | 458 | 408 |
| Paper Manufacturing | 0 | 0 | 257 | 253 | 320 | 310 |
| Other Manufacturing | 0 | 0 | 1,186 | 1,179 | 2,050 | 2,032 |
| Electricity | 0 | 0 | 5,504 | 5,453 | 7,796 | 7,693 |
| Petroleum Refining | 0 | 0 | 1,091 | 1,089 | 1,703 | 1,695 |
| Petroleum Crude Ext. | 0 | 0 | 5,652 | 5,338 | 11,105 | 10,271 |
| Natural Gas Ext. | 0 | 0 | 2,591 | 2,511 | 3,411 | 3,225 |
| Coal Mining | 0 | 0 | 115 | 114 | 186 | 183 |
| Ethanol | 0 | 0 | 2 | 2 | 8 | 8 |
| Biodiesel | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **0** | **0** | **38,484** | **35,830** | **53,463** | **49,884** |

Table 47 describes the impact of the increased production costs on physical output in each sector (note this is physical output, not gross output in dollar terms). The most heavily impacted sectors are industrial minerals (-4 to -14% relative to BAU) and the fossil fuel sectors, notably petroleum refining (-18 to -19%) and natural gas extraction (-15 to -20%). Electricity production increases somewhat (6 to 8% by 2020) to accommodate fuel switching.

**Table 47: Annual % reduction in physical output from BAU to Policy (GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 0% | 0% | -3% | -3% | -4% | -4% |
| Commercial | 0% | 0% | -4% | -4% | -5% | -5% |
| Personal Trans. | 0% | 0% | -1% | -1% | -1% | -1% |
| Freight Trans. | -6% | -6% | -6% | -6% | -6% | -7% |
| Chemical Products | 0% | 0% | -2% | -4% | -2% | -6% |
| Industrial Minerals | 0% | 0% | -3% | -11% | -4% | -14% |
| Iron and Steel | 0% | 0% | -1% | -3% | -1% | -5% |
| Metal Smelting | 0% | 0% | -1% | -4% | -2% | -6% |
| Mineral Mining | 0% | 0% | -1% | -3% | -1% | -4% |
| Paper Manufacturing | 0% | 0% | -1% | -4% | -2% | -5% |
| Other Manufacturing | 0% | 0% | 0% | -1% | 0% | -1% |
| Electricity | 0% | 0% | 4% | 3% | 8% | 6% |
| Petroleum Refining | -2% | -2% | -10% | -10% | -18% | -19% |
| Petroleum Crude Ext. | -1% | -1% | -5% | -11% | -7% | -14% |
| Natural Gas Ext. | -1% | -1% | -9% | -12% | -15% | -20% |
| Coal Mining | -5% | -5% | -11% | -12% | -17% | -19% |
| Ethanol | 2% | 2% | 174% | 176% | 856% | 869% |
| Biodiesel | -3% | -3% | 324% | 321% | 450% | 443% |
| **Total** | **-0.4%** | **-0.4%** | **-2.9%** | **-3.9%** | **-3.7%** | **-5.1%** |

To provide perspective, Table 48 provides the change in physical output from 2005 to 2020 in the policy cases. Except for the petroleum refining and natural gas extraction sectors, whose outputs each decrease by approximately 9% and 13–19% respectively, no sector actually reduces output from 2005 levels in 2020. In the metal smelting sector, a rebate of 10% of its carbon charge costs in the "Canada goes further" scenario prevents physical output from falling significantly below the 2005 level.

Again, in an environment where all of North America is reducing emissions, there is some uncertainty that Canada's natural gas output will fall. The price of natural gas, based on its relatively low GHG intensity and utility for making electricity, could stay high enough to maintain Canadian production.

**Table 48: Projected increase in physical output from 2005 to 2020 in the policy case (GOVT)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 8% | 8% | 12% | 12% | 18% | 18% |
| Commercial | 12% | 12% | 20% | 21% | 32% | 32% |
| Personal Trans. | 14% | 14% | 24% | 24% | 37% | 37% |
| Freight Trans. | 12% | 12% | 25% | 25% | 38% | 37% |
| Chemical Products | 6% | 6% | 11% | 8% | 17% | 13% |
| Industrial Minerals | 8% | 8% | 15% | 6% | 23% | 10% |
| Iron and Steel | 4% | 4% | 9% | 7% | 14% | 10% |
| Metal Smelting | 6% | 6% | 4% | 1% | 5% | 1% |
| Mineral Mining | 6% | 6% | 9% | 7% | 10% | 7% |
| Paper Manufacturing | 2% | 2% | 4% | 1% | 8% | 4% |
| Other Manufacturing | 13% | 13% | 27% | 26% | 42% | 41% |
| Electricity | 5% | 5% | 17% | 16% | 29% | 27% |
| Petroleum Refining | 0% | 0% | -3% | -3% | -6% | -6% |
| Petroleum Crude Ext. | 22% | 22% | 41% | 32% | 65% | 52% |
| Natural Gas Ext. | 2% | 2% | 3% | -1% | -12% | -17% |
| Coal Mining | 3% | 3% | 5% | 3% | 9% | 6% |
| Ethanol | 395% | 395% | 1917% | 1932% | 9503% | 9633% |
| Biodiesel | 2501% | 2501% | 26025% | 25896% | 49136% | 48512% |
| **Total** | 10% | 10% | 17% | 16% | 26% | 24% |

One of the key emissions reduction actions is decarbonization of electricity, and increasing electricity demand by fuel switching to electricity from other fuels. Figure 10 provides the BAU and policy electricity generation mix for "OECD acts together", and Figure 11 for "Canada goes further".

As noted earlier, there were some key changes in the electricity sector for this analysis compared to previous analyses done with CIMS.

- Updates were made in this analysis to nuclear generation costing. The cost of refurbishing an existing reactor was set at 12.6 ¢/kwh, while the cost of building a new reactor was set at 20.9 ¢/kwh. Based on literature, we also included a 4.0 ¢/kwh liability insurance charge to capture the implicit government insurance subsidy on nuclear power.[21] These charges made nuclear sufficiently expensive to prevent new capacity from being purchased in the policy case although there was some delayed decommissioning of existing generating capacity.

- The cost of CCS was raised significantly to reflect recent cost estimates (i.e., post combustion CCS has been raised from a cost upwards of \$50/tonne $CO_2$e to \$75–\$150 /tonne $CO_2$e).

- Reflecting recent experience with wind power in other jurisdictions (e.g., Spain, Portugal, Germany and Denmark), we had previously reduced near term constraints on wind to a maximum of 15% of generation by 2020 assuming no emissions charge revenues are used to upgrade electricity transmission systems. In this analysis, we assume some of the emissions charge revenues to fund transmission upgrades. To reflect this, we raised the constraint on wind to a maximum of 25% of generation nationally by 2020. As a result, under the GOVT target, wind capacity rose to 18% of generation in 2020.

In the "OECD acts together" scenario (Figure 10) total generation is 53 TWh greater in 2020 than BAU, while in the "Canada goes further" scenario (Figure 11) total generation is 44 TWh greater. Of the increase in 2020 production relative to BAU, small and large hydro took 7 to 10 TWh, wind took 80 to 85 TWh, nuclear 2 TWh, and coal and natural gas with CCS 15 TWh. Coal and natural gas without CCS lost about 60 TWh of generation share.

[21] The insurance charge is from Heyes, A. and C. Heyes, "An empirical analysis of the Nuclear Liability Act (1970) in Canada" *Resource and Energy Economics* 2000, 22(1):91-101.

**Figure 10: Electricity production and mix "OECD acts together"[22] (GOVT)**

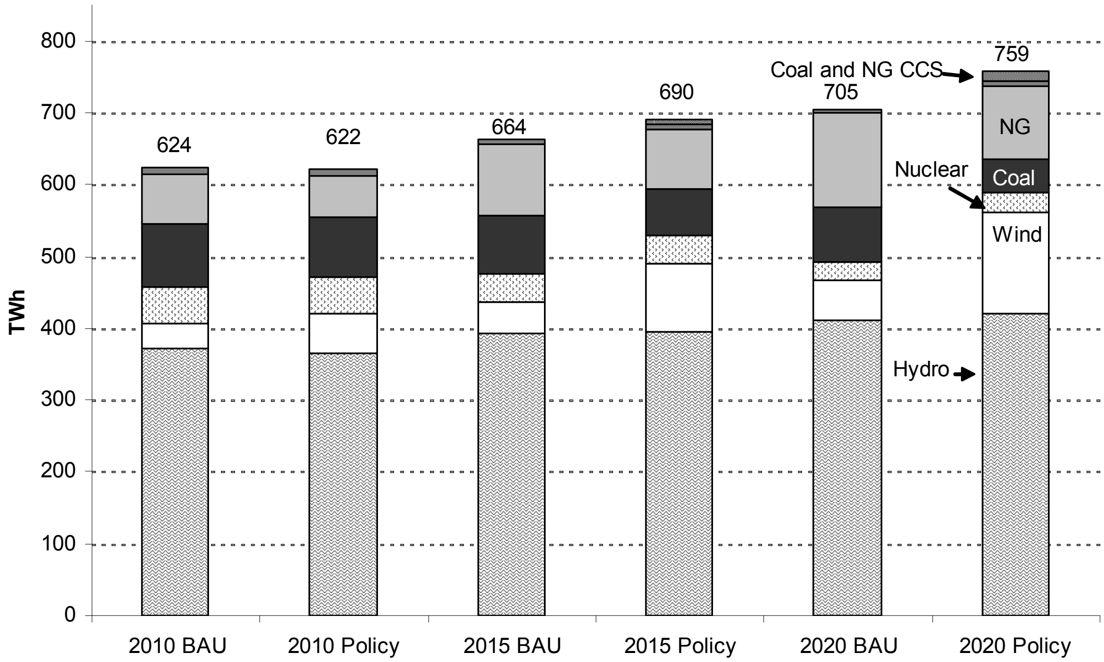
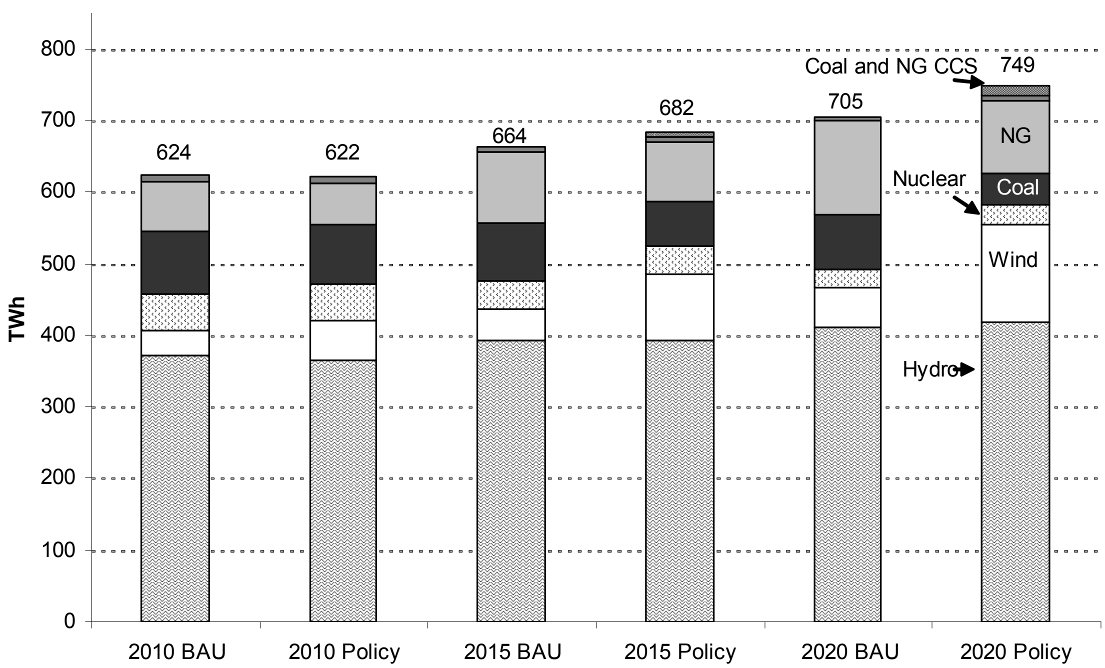



**Figure 11: Electricity production and mix GOVT "Canada goes further"**




[22] The near term BAU projections for elelc are based on economic forecasts

Table 49 summarizes the net financial effects that come out of CIMS. It adds the changes in annual capital, energy, and labour costs. Emissions costs are not included as they are transfers to the rest of the economy.

**Table 49: Annual net financial costs by sector ("+" = costs, "-" = gains, $2005 millions, GOVT. Sum of annual capital, labour related to energy use, and energy costs, relative to BAU.**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | OECD acts together | Canada goes further | OECD acts together | Canada goes further | OECD acts together | Canada goes further |
| Residential | 317 | 313 | 3,160 | 3,078 | 4,123 | 3,999 |
| Commercial | 15 | 13 | 632 | 571 | 1,463 | 1,337 |
| Personal Trans. | 0 | 0 | -13,597 | -13,599 | -14,721 | -14,723 |
| Freight Trans. | -3,112 | -3,108 | -12,341 | -12,349 | -14,869 | -15,134 |
| Chemical Products | 7 | 4 | 164 | -191 | 207 | -216 |
| Industrial Minerals | 1 | 1 | 73 | -88 | 149 | 11 |
| Iron and Steel | -10 | -8 | 14 | -176 | -24 | -263 |
| Metal Smelting | 10 | 7 | 68 | -142 | 150 | -43 |
| Mineral Mining | 5 | 0 | -20 | -559 | 91 | -390 |
| Paper Manufacturing | 10 | -1 | 29 | -568 | 170 | -257 |
| Other Manufacturing | -35 | -35 | 82 | -45 | 154 | 6 |
| Agriculture | 6 | 6 | 165 | 158 | 303 | 293 |
| Waste | 0 | 0 | 132 | 133 | -103 | -101 |
| Electricity | 415 | 403 | 6,954 | 5,642 | 7,218 | 6,334 |
| Petroleum Refining | -79 | -79 | -466 | -488 | -869 | -909 |
| Petroleum Crude Ext. | -174 | -180 | -1,085 | -3,881 | -935 | -4,371 |
| Natural Gas Ext. | -268 | -273 | -1,761 | -2,652 | -2,121 | -3,082 |
| Coal Mining | -38 | -38 | -78 | -101 | -102 | -127 |
| Ethanol | 0 | 0 | 9 | 9 | 68 | 69 |
| Biodiesel | -2 | -2 | 545 | 541 | 944 | 927 |
| **Total** | **-2,933** | **-2,977** | **-17,322** | **-24,708** | **-18,704** | **-26,640** |

Table 50 interpolates the financial impacts of "OECD acts together" between 2010, 2015 and 2020, and adds net foreign permit purchases. Table 51 shows the assumed schedule of foreign permit purchases, which rise in price from $25/tonne in 2010 to $75/tonne in 2020 for "OECD acts together", and to $50/tonne for "Canada goes further." Total payments are $14–25 billion by 2020; the annual payment in 2020 is $2.8–5.5 billion. Emissions costs are not included as they are transfers to the rest of the economy. The summed impacts over time in the "OECD acts together" scenario, *which are not discounted*, are a net *reduction* in expenditure on capital, labour and energy of $126 billion. If the transportation impacts are removed, the summed impacts are a net *increase* in expenditure of $102 billion. In the "Canada goes further" scenario (Table 52) the total including transportation is a reduction in expenditure of $198 billion, while excluding transportation the net increase in financial costs is $30 billion. These values do not necessarily represent net benefits to society; these are usually calculated as changes in consumer surplus or welfare.

**Table 50: Annual net financial costs by sector ("+" = costs, "-" = gains, $2005 billions, GOVT "OECD acts together"). Sum of annual capital, labour related to energy use and energy costs, relative to BAU.**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | ∑ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential | 0.3 | 0.9 | 1.5 | 2.0 | 2.6 | 3.2 | 3.4 | 3.5 | 3.7 | 3.9 | 4.1 | 29.1 |
| Commercial | 0.0 | 0.1 | 0.3 | 0.4 | 0.5 | 0.6 | 0.8 | 1.0 | 1.1 | 1.3 | 1.5 | 7.6 |
| Trans. Personal | 0.0 | -2.7 | -5.4 | -8.2 | -10.9 | -13.6 | -13.8 | -14.0 | -14.3 | -14.5 | -14.7 | -112.1 |
| Trans. Freight | -3.1 | -5.0 | -6.8 | -8.6 | -10.5 | -12.3 | -12.8 | -13.4 | -13.9 | -14.4 | -14.9 | -115.6 |
| Chem. Products | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 1.5 |
| Ind. Minerals | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.8 |
| Iron and Steel | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Metal Smelting | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.8 |
| Mineral Mining | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 |
| Paper Man. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.7 |
| Other Man. | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.8 |
| Agriculture | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 1.8 |
| Waste | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | -0.1 | -0.1 | 0.3 |
| Electricity | 0.4 | 1.7 | 3.0 | 4.3 | 5.6 | 7.0 | 7.0 | 7.1 | 7.1 | 7.2 | 7.2 | 57.7 |
| Pet. Refining | -0.1 | -0.2 | -0.2 | -0.3 | -0.4 | -0.5 | -0.5 | -0.6 | -0.7 | -0.8 | -0.9 | -5.2 |
| Crude Oil Ext. | -0.2 | -0.4 | -0.5 | -0.7 | -0.9 | -1.1 | -1.1 | -1.0 | -1.0 | -1.0 | -0.9 | -8.8 |
| NG Ext. | -0.3 | -0.6 | -0.9 | -1.2 | -1.5 | -1.8 | -1.8 | -1.9 | -2.0 | -2.0 | -2.1 | -16.0 |
| Coal Mining | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.8 |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 |
| Biodiesel | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 0.9 | 5.6 |
| International Permit Payments | 0.1 | 0.4 | 0.7 | 1.0 | 1.4 | 2.0 | 2.5 | 3.2 | 3.9 | 4.6 | 5.5 | 25.2 |
| **Total** | **-2.8** | **-5.5** | **-8.0** | **-10.6** | **-13.0** | **-15.4** | **-15.1** | **-14.7** | **-14.3** | **-13.8** | **-13.2** | **-126.3** |

**Table 51: Schedule of international permit payments ($2005 millions, GOVT)**

| | OECD acts together | | | Canada goes further | | |
|---|---|---|---|---|---|---|
| | Price ($/tonne $CO_2$e) | Mt | Payments | Price ($/tonne $CO_2$e) | Mt | Payments |
| 2010 | 25 | 5 | $125 | 25 | 5 | $125 |
| 2011 | 30 | 11.8 | $354 | 27.5 | 10 | $278 |
| 2012 | 35 | 18.6 | $651 | 30 | 15 | $456 |
| 2013 | 40 | 25.4 | $1,016 | 32.5 | 20 | $660 |
| 2014 | 45 | 32.2 | $1,449 | 35 | 25 | $889 |
| 2015 | 50 | 39 | $1,950 | 37.5 | 31 | $1,144 |
| 2016 | 55 | 45.8 | $2,519 | 40 | 36 | $1,424 |
| 2017 | 60 | 52.6 | $3,156 | 42.5 | 41 | $1,730 |
| 2018 | 65 | 59.4 | $3,861 | 45 | 46 | $2,061 |
| 2019 | 70 | 66.2 | $4,634 | 47.5 | 51 | $2,418 |
| 2020 | 75 | 73 | $5,475 | 50 | 56 | $2,800 |
| **Total** | | | **$25,190** | | | **$13,984** |

**Table 52: Annual net financial cost ("+" = costs, "-" = gains, $2005 billions) (sum of annual capital, labour related to energy use and energy costs, relative to BAU) GOVT "Canada goes further"**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | ∑ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential | 0.3 | 0.9 | 1.4 | 2.0 | 2.5 | 3.1 | 3.3 | 3.4 | 3.6 | 3.8 | 4.0 | 28.3 |
| Commercial | 0.0 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 0.7 | 0.9 | 1.0 | 1.2 | 1.3 | 6.9 |
| Trans. Personal | 0.0 | -2.7 | -5.4 | -8.2 | -10.9 | -13.6 | -13.8 | -14.0 | -14.3 | -14.5 | -14.7 | -112.2 |
| Trans. Freight | -3.1 | -5.0 | -6.8 | -8.7 | -10.5 | -12.3 | -12.9 | -13.5 | -14.0 | -14.6 | -15.1 | -116.5 |
| Chem. Products | 0.0 | 0.0 | -0.1 | -0.1 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -1.6 |
| Ind. Minerals | 0.0 | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 | 0.0 | 0.0 | -0.4 |
| Iron and Steel | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -0.3 | -1.7 |
| Metal Smelting | 0.0 | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | -0.8 |
| Mineral Mining | 0.0 | -0.1 | -0.2 | -0.3 | -0.4 | -0.6 | -0.5 | -0.5 | -0.5 | -0.4 | -0.4 | -4.0 |
| Paper Man. | 0.0 | -0.1 | -0.2 | -0.3 | -0.5 | -0.6 | -0.5 | -0.4 | -0.4 | -0.3 | -0.3 | -3.6 |
| Other Man. | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -0.3 |
| Agriculture | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 1.7 |
| Waste | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | -0.1 | -0.1 | 0.4 |
| Electricity | 0.4 | 1.5 | 2.5 | 3.5 | 4.6 | 5.6 | 5.8 | 5.9 | 6.1 | 6.2 | 6.3 | 48.4 |
| Pet. Refining | -0.1 | -0.2 | -0.2 | -0.3 | -0.4 | -0.5 | -0.6 | -0.7 | -0.7 | -0.8 | -0.9 | -5.4 |
| Crude Oil Ext. | -0.2 | -0.9 | -1.7 | -2.4 | -3.1 | -3.9 | -4.0 | -4.1 | -4.2 | -4.3 | -4.4 | -33.1 |
| NG Ext. | -0.3 | -0.7 | -1.2 | -1.7 | -2.2 | -2.7 | -2.7 | -2.8 | -2.9 | -3.0 | -3.1 | -23.3 |
| Coal Mining | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -1.0 |
| Ethanol | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.3 |
| Biodiesel | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.8 | 0.9 | 5.5 |
| International Permit Payments | 0.1 | 0.3 | 0.5 | 0.7 | 0.9 | 1.1 | 1.4 | 1.7 | 2.1 | 2.4 | 2.8 | 14.0 |
| **Total** | **-2.9** | **-7.0** | **-11.2** | **-15.4** | **-19.5** | **-23.6** | **-23.7** | **-23.8** | **-23.8** | **-23.8** | **-23.8** | **-198.4** |

## *Government Target – Trade-off between Carbon Price and International Permit Purchases*

Under the price path used in this study to meet the GOVT target, Canada still purchases international emissions permits to make up the difference between that target and domestic emissions reductions. For the "Canada goes further" scenario, if the carbon price reaches 100 $/t$CO_2$e by 2020, 56 Mt of purchases are required in that year. To avoid purchasing international permits, the carbon price must rise substantially. At a price of 145 $/t$CO_2$e in 2020, domestic emissions fall to the 570 Mt target and no international permits are used. All carbon prices start at 40 $/t$CO_2$e in 2011 and increase linearly between 2011 and 2020.

**Table 53: Domestic carbon price in 2020 and associated international permit purchases, GOVT target, "Canada Goes Further"**

| Carbon Price in 2020 ($/tCO2e) | Canadian GHG Emissions in 2020 (Mt CO2e) | Purchase of International Permits in 2020 (Mt) |
|---|---|---|
| 100 | 626 | 56 |
| 120 | 601 | 31 |
| 145 | 570 | 0 |

### CIMS – Effect of Complementary Regulations and Spending Policies

Table 54 shows the incremental emissions reductions that the GHG price, complementary regulations and spending programs achieve under the ENGO and GOVT price paths for the "Canada Goes Further" Scenario. Under both price paths, carbon pricing is the single most effective policy, reducing emissions by an additional 87 to 149 Mt. The regulations and spending (including agricultural offsets), when added up individually, reduce emissions by another 107 Mt from carbon pricing alone for the ENGO target and 111 Mt for the GOVT target. The regulations all reduce emissions by 2020 except the appliance standards which have little effect in the near term horizon, partly due to fuel switching and electricity decarbonization. Upstream oil and gas regulations as well as landfill gas regulations provide significant abatement of 39 Mt and 23 Mt respectively.

**Table 54: Incremental effect of the individual policies, "Canada Goes Further", ENGO Target and GOVT Target**

| | GOVT: Incremental effect of policy (Mt CO2e) | ENGO: Incremental effect of policy (Mt CO2e) |
|---|---|---|
| Carbon price plus all regulations and spending | 223 | 335 |
| Carbon price | 87 | 149 |
| Agricultural offsets | 3.6 | 5.1 |
| Upstream oil and gas regulations | 39 | 39 |
| Land fill gas capture regulation | 23 | 23 |
| Carbon capture regulation | n/a | 7.8 |
| Vehicle emissions standards | 6.0 | 5.1 |
| Appliance standards | 0.0[b] | 0.0[b] |
| Residential building efficiency standards | 5.7 | 4.0 |
| Commercial building efficiency standards | 8.6 | 6.1 |
| Electric heating requirement for new buildings (BC, MB, QC) | 8.3 | 5.2 |
| Urban transit spending | 0.8 | 0.7 |
| Intercity transit spending | 1.9 | 1.6 |
| Electricity transmission spending | 14.1 | 9.0 |

[a]The incremental effect of a policy is measured by calculating the difference between the effect of all policies and all policies except the one in question. Thus, the incremental effect only accounts for the emissions reductions that are additional to all other policies. Because any overlapping emissions reductions are not included here, the sum of the incremental effects is less than the effect of the entire policy package.

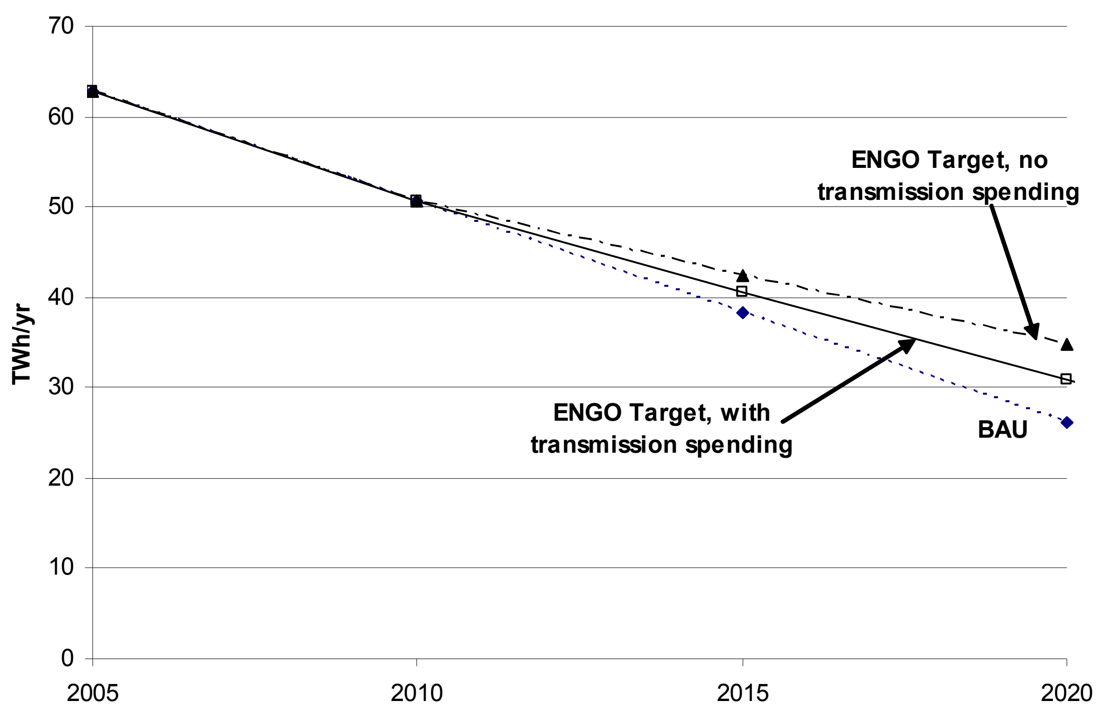
[b]The effect of the appliance standard is greater than zero, but less than one tenth of a $MtCO_2e$.

The complementary regulations and spending policies yield greater reductions under the lower GHG prices imposed under the less stringent government target. For example, under the ENGO price path, the investment choices induced by GHG pricing considerably reduce the emissions per kilometre travelled. This in turn reduces the effect of lowering the total number of vehicle kilometres travelled through transit improvements. A lower GHG price does not decarbonize personal transportation to the same extent. Therefore, using transit to limit vehicle kilometres travelled achieves larger emissions reductions when the GHG price is lower.

Similarly, the electricity transmission spending policy also has a larger effect under a lower GHG price. In regions without access to hydroelectric potential, this spending policy encourages a switch from natural gas fired power plants to wind turbines. At higher GHG prices much of this natural gas capacity would have had CCS. At lower prices much less CCS is used, therefore the effect of increased wind capacity is more noticeable. For both targets the effect of the transmission spending is significantly reduced in regions where new hydroelectricity capacity can be built. Rather than replacing thermal plants, wind energy tends to displace new hydro developments.

The transmission spending has an additional effect on the future of nuclear energy in Canada. The simulations indicate that under carbon pricing, the decommissioning of nuclear plants could be delayed, notably in Ontario. The extent of this delay is sensitive to the amount of wind energy that can be integrated into the grid. In the absence of the transmission spending, less wind energy is used, and nuclear generation is 12% higher in 2020 than it is with the spending (Figure 12, 31 TWh vs. 35 TWh). Upgrades to the electricity transmission system are therefore important to reducing the amount of nuclear energy used in Ontario.

**Figure 12: Canadian Electricity Generated with Nuclear Energy, "Canada Goes Further", ENGO Target**



### *R-GEEM - Macroeconomic Impacts*

R-GEEM was used to model the macroeconomic impacts of the ENGO and GOVT targets under the "OECD Acts Together" and "Canada Goes Further" scenarios, specifically:

- regional and national welfare based on consumption and leisure ("equivalent variation"), as well as compensation of households' carbon charges and increased energy costs (excluding transportation);
- uses, and regional sources and destinations, of carbon revenues;
- regional and national jobs, wage rates, salaries and changes in effective personal income tax rate as a result of carbon revenue recycling;
- regional changes in capital investment; and
- total and per capita regional and national GDP.

#### *Overall Changes in Welfare*

Macroeconomic models like R-GEEM provide a key overarching measure of changes to household "welfare," which is derived from a composite of goods consumption and leisure. The theory behind this measure is that households possess capital (savings and investments) and time, neither of which is directly useful. They need to be converted to goods and leisure to produce welfare. Households therefore typically sell or lend all their capital to firms to produce goods for domestic use and export, in return for interest, dividends, etc. They also sell some of their time to firm to produces wages (i.e., they provide labour) so that they may consume the goods produced by firms. Finally, they keep some of their time for themselves, i.e., they "consume" leisure. Table 55 shows how overall welfare fares under the GOVT and ENGO targets and the two international scenarios.[23]

**Table 55 Overall change in welfare ("equivalent variation") from consumption and leisure relative to BAU by region, 2020**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Average Canada |
|---|---|---|---|---|---|---|---|---|
| ENGO OAT | -2.1% | -7.8% | -5.2% | -0.1% | -1.7% | -1.4% | -1.9% | -2.4% |
| ENGO CGF | -2.1% | -7.7% | -5.3% | 0.2% | -1.5% | -1.3% | -1.9% | -2.3% |
| GOVT OAT | -0.9% | -4.2% | -2.6% | 0.3% | -0.9% | -0.7% | -0.6% | -1.2% |
| GOVT CGF | -0.8% | -4.6% | -2.8% | 0.6% | -0.6% | -0.4% | -0.4% | -1.0% |

Overall Canadian welfare based on consumption and leisure falls ~2.4% from BAU in the ENGO case, and ~1.1% in the GOVT case. There are significant regional differences, however, with Alberta experiencing reductions of ~7.8 % in the ENGO case and ~4.4% in the GOVT case, while Ontario experiences reductions of ~1.6% and ~0.8% respectively.

[23] This measure is derived from a dollar amount by which households would have to be compensated to return them to their pre-policy welfare levels (i.e., "equivalent variation" in economic parlance)

The welfare changes include the effect of the carbon revenue returned to households. The carbon costs associated with heating fuels, as well as the increases in electricity and heating fuel costs relative to BAU, are returned to all households by an equal per capita lump sum payment (Table 56).

**Table 56 Annual household compensation per capita 2020 ($2005)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada Average |
|---|---|---|---|---|---|---|---|---|
| ENGO OAT | 66.87 | 920.39 | 721.22 | 33.55 | 92.97 | 29.86 | 259.28 | 192.98 |
| ENGO CGF | 68.02 | 939.67 | 737.09 | 41.80 | 92.57 | 30.44 | 196.41 | 191.25 |
| GOVT OAT | 38.47 | 501.03 | 372.27 | 22.22 | 56.97 | 20.99 | 153.83 | 109.39 |
| GOVT CGF | 41.84 | 564.74 | 436.65 | 25.74 | 62.35 | 22.36 | 166.77 | 122.10 |

Table 57 shows the sources of carbon revenues by region: under the ENGO target, ~$23 billion comes from Alberta, ~$21 billion from Ontario, and ~$10 billion from Québec.

**Table 57 Regional sources of carbon revenue 2020 ($2005 billions)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | 7.28 | 23.71 | 3.84 | 1.76 | 20.72 | 9.90 | 4.74 |
| ENGO CGF | 7.35 | 21.84 | 3.74 | 1.79 | 21.04 | 10.10 | 4.81 |
| GOVT OAT | 4.27 | 17.18 | 2.49 | 1.02 | 12.06 | 5.74 | 2.79 |
| GOVT CGF | 3.76 | 15.50 | 2.24 | 0.90 | 10.63 | 5.02 | 2.57 |

Table 58 details how the carbon revenue, ~$70 billion in the ENGO case and ~$40 billion in the GOVT case, is redistributed. For example, in the case of ENGO "Canada goes further":

- $6.0 billion is used to purchase international permits;
- $1.0 billion is used to purchase verifiable and additive domestic agricultural offsets;
- $1.8 billion is refunded to the metal smelting sector to maintain output at 2008 levels;
- $9.0 billion is used to fund improvements to the electricity transmission grid and to improve transit;
- $7.1 billion is sent back to households to compensate them for their carbon charges and increased energy costs for heating and electricity;
- $8.0 billion is used to make up for reduced corporate taxes;
- $4.6 billion is used to make up for reduced excise taxes and royalties; and
- finally, $33.2 billion is used to reduce personal income taxes.

**Table 58 Uses of carbon revenue 2020 ($2005 billions)**

| | Carbon revenues[24] | Inter-national permits | Agric-ultural offsets | Subsidies to maintain 2008 output | Elec. & transit subsidies | Household comp-ensation | Direct & indirect personal income taxes | Direct & indirect corporate taxes | Sum of other flows[25] |
|---|---|---|---|---|---|---|---|---|---|
| E-OAT | 71.95 | -10.01 | -1.02 | 0.00 | -9.05 | -7.16 | -31.88 | -8.21 | -4.62 |
| E-CGF | 70.68 | -5.93 | -1.02 | -1.76 | -9.05 | -7.09 | -33.15 | -8.03 | -4.64 |
| G-OAT | 40.61 | -5.43 | -0.36 | 0.00 | -9.05 | -4.06 | -14.53 | -5.08 | -2.10 |
| G-CGF | 45.53 | -2.80 | -0.36 | -0.08 | -9.05 | -4.53 | -21.16 | -5.34 | -2.21 |

The model incorporated a single national government for this analysis, which collects all indirect and direct personal and corporate taxes, sales taxes, and royalties at starting regional (i.e., provincial) rates calculated from the 2005 Statistics Canada Input Output tables (corporate and income taxes adjust endogenously within the model based on returns on capital and the revenue recycling provisions). Furthermore, it was assumed that regions were reallocated carbon revenues, net of international permit purchases and domestic uses of carbon revenue listed above, according to:

- the premise that national government spending, with the exception of the climate policies, is to remain constant;
- compensation for regional reductions in revenues from direct and indirect personal and corporate taxation;
- compensation for regional reductions in sales tax revenues; and
- compensation for regional reductions in resource royalties.

The regional return of carbon revenues was calculated and is illustrated in Table 59. In practice, if the federal government were to collect all revenue under a carbon pricing policy, the regional return of carbon revenues would involve federal-provincial transfers.

**Table 59 Regional destination of carbon revenue 2020 ($2005 billions)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | 9.19 | 19.30 | 2.50 | 0.91 | 14.91 | 9.76 | 4.29 |
| ENGO CGF | 9.68 | 19.18 | 3.00 | 1.09 | 16.25 | 10.23 | 4.25 |
| GOVT OAT | 6.25 | 12.32 | 1.28 | 0.50 | 6.38 | 5.93 | 2.58 |
| GOVT CGF | 7.12 | 14.23 | 1.78 | 0.73 | 9.10 | 6.93 | 2.86 |

Other recycling mechanisms, e.g. output-based or corporate tax recycling, could have significantly different revenue, sector, GDP and welfare impacts.

### *Employment*

The following tables outline the changes in employment, salaries and changes in wage rates. Table 60 provides numbers of jobs in 2010 and 2020 in the reference case (BAU),

[24] R-GEEM tracks only fossil fuel combustion emissions, while CIMS tracks all emissions. Carbon revenues in R-GEEM are therefore somewhat under-estimated. The numbers in Tables 57-59 are based only on carbon revenues from fossil fuel combustion.

[25] Changes in sales taxes, other excise taxes, royalties of all types, etc.

and jobs in 2020 under the four scenarios. A key caveat of these results is that RGEEM does not allow inter-regional migration as a response to policy. If this were the case more workers would leave the West, especially Alberta, and move to Manitoba and especially Ontario and Québec. Table 60 shows how the number of jobs is expected to increase from 2010 to 2020 under all scenarios. Employment in all regions continues to grow from 2010 to 2020 under all scenarios, slightly faster under the climate policy scenarios because pre-tax salaries are lower, and particularly because labour supply increases as employee take-home pay increases as a result of the recycling of carbon revenues to reduce personal income tax.

**Table 60 Jobs 2020 (1000s)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU 2010 | 2,353 | 2,043 | 517 | 615 | 6,724 | 3,896 | 1,207 | 17,354 |
| BAU 2020 | 2,600 | 2,245 | 564 | 664 | 7,702 | 4,136 | 1,247 | 19,156 |
| ENGO OAT | 2,608 | 2,177 | 563 | 674 | 7,774 | 4,176 | 1,238 | 19,211 |
| ENGO CGF | 2,605 | 2,176 | 560 | 673 | 7,776 | 4,177 | 1,244 | 19,211 |
| GOVT OAT | 2,614 | 2,211 | 567 | 671 | 7,751 | 4,163 | 1,242 | 19,219 |
| GOVT CGF | 2,617 | 2,207 | 566 | 673 | 7,773 | 4,178 | 1,247 | 19,260 |

**Table 61 Jobs expressed as a percentage increase from 2010 to 2020**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU 2020 | 11% | 10% | 9% | 8% | 15% | 6% | 3% | 10% |
| ENGO OAT | 11% | 7% | 9% | 10% | 16% | 7% | 3% | 11% |
| ENGO CGF | 11% | 6% | 8% | 9% | 16% | 7% | 3% | 11% |
| GOVT OAT | 11% | 8% | 10% | 9% | 15% | 7% | 3% | 11% |
| GOVT CGF | 11% | 8% | 10% | 9% | 16% | 7% | 3% | 11% |

Table 62 shows the average pre-tax salary by region. Under the climate policy scenarios, pre-tax salaries climb in most regions more slowly than under BAU

**Table 62 Pre-tax annual salaries 2020 ($2005)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| BAU | 53,746 | 65,890 | 48,612 | 49,949 | 57,453 | 51,175 | 55,908 |
| ENGO OAT | 52,204 | 57,959 | 45,640 | 50,281 | 56,509 | 50,202 | 53,319 |
| ENGO CGF | 52,020 | 57,860 | 45,131 | 50,134 | 56,529 | 50,177 | 53,678 |
| GOVT OAT | 53,541 | 61,821 | 47,801 | 50,690 | 57,321 | 51,029 | 54,940 |
| GOVT CGF | 53,269 | 61,014 | 47,185 | 50,623 | 57,289 | 50,969 | 54,880 |

Table 63 provides wages from the perspective of firms (i.e., the cost of labour), while Table 64 provides wages from the perspective of employees (i.e., take home pay after taxes). Take home pay per hour has increased under all climate policy scenarios, because of the recycling of carbon revenues to reduce personal income tax. Effective personal income tax rates fall 11.6% in the ENGO OAT scenario, 10.9% in ENGO CGF, 3.9% in GOVT OAT, and 7.9% in GOVT CGF.

**Table 63 Average hourly wage rate excluding direct taxes 2020 (% of BAU) "cost of labour to firms"**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | -2.9% | -12.0% | -6.1% | 0.7% | -1.6% | -1.9% | -4.6% |
| ENGO CGF | -3.2% | -12.2% | -7.2% | 0.4% | -1.6% | -1.9% | -4.0% |
| GOVT OAT | -0.4% | -6.2% | -1.7% | 1.5% | -0.2% | -0.3% | -1.7% |
| GOVT CGF | -0.9% | -7.4% | -2.9% | 1.4% | -0.3% | -0.4% | -1.8% |

**Table 64 Average hourly wage rate including direct taxes 2020 (% of BAU) "employee take home pay"**

| | BC | AB | SK | MB | ON | QC | ATL & RoC |
|---|---|---|---|---|---|---|---|
| ENGO OAT | -1.0% | -10.4% | -4.1% | 2.9% | 0.5% | 0.7% | -2.5% |
| ENGO CGF | -1.2% | -10.4% | -5.0% | 2.8% | 0.7% | 0.8% | -1.7% |
| GOVT OAT | 0.3% | -5.5% | -0.9% | 2.3% | 0.5% | 0.6% | -1.0% |
| GOVT CGF | 0.5% | -6.1% | -1.4% | 3.0% | 1.3% | 1.5% | -0.3% |

Finally, there is significant shift away from capital intense (e.g. fossil fuel) to labour intense (manufacturing and services) industries in all regions.

### *Changes in Capital Investment*

R-GEEM, as a static CGE model with fixed and flexible capital, operates with the assumption that Canadian savings will support a given amount of capital investment between 2010 and 2020, to both replace worn out stock and make new investments. In the case of 2020, using Informetrica's economic forecast, the total capital stock available is $510 billion. Table 65 details how this capital is allocated in the BAU and policy scenarios in 2020. The new, flexible portion of this is free to migrate to whichever sectors and regions in the country that offer the highest returns. No *net* foreign capital is assumed to be available, i.e. all investment must be funded in the long run from Canadian sources. Table 66 illustrates the change in capital investment under the policy scenarios. $12–15 billion less is invested in Alberta, and is instead invested in other regions, mainly Ontario and Québec. However, the total amount of capital investment does not change, which reflects the assumptions of the model.

**Table 65 Capital investment 2020 ($2005 billions)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU | 63.4 | 113.4 | 19.7 | 15.8 | 175.2 | 88.9 | 33.8 | 510.1 |
| ENGO OAT | 63.3 | 98.9 | 18.9 | 17.2 | 184.2 | 92.6 | 35.1 | 510.1 |
| ENGO CGF | 62.6 | 100.4 | 18.1 | 17.0 | 184.0 | 92.6 | 35.3 | 510.1 |
| GOVT OAT | 63.9 | 101.8 | 19.4 | 16.6 | 182.0 | 91.4 | 35.0 | 510.1 |
| GOVT CGF | 63.9 | 99.9 | 19.0 | 16.7 | 183.1 | 92.2 | 35.3 | 510.1 |

**Table 66 Absolute change in capital investment 2020 ($2005 billions relative to BAU)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU | -0.1 | -14.5 | -0.8 | 1.4 | 9.0 | 3.7 | 1.3 | 0.0 |
| ENGO OAT | -0.8 | -13.0 | -1.6 | 1.2 | 8.8 | 3.7 | 1.6 | 0.0 |
| ENGO CGF | 0.5 | -11.6 | -0.3 | 0.8 | 6.8 | 2.5 | 1.2 | 0.0 |
| GOVT OAT | 0.5 | -13.5 | -0.7 | 0.9 | 7.9 | 3.3 | 1.6 | 0.0 |
| GOVT CGF | -0.1 | -14.5 | -0.8 | 1.4 | 9.0 | 3.7 | 1.3 | 0.0 |

### *Changes in Absolute and Per Capita GDP*

Table 67 provides 2005 actual GDP at basic prices, our 2010 and 2020 projected GDP, and GDP under the four climate policy scenarios by region and for Canada. Table 68 provides relative changes in GDP from BAU to the policy scenarios. Overall Canadian GDP falls ~3.1% under the ENGO scenario, and ~1.5% under the GOVT scenario. Regional differences are marked, however, with 2020 GDP in Alberta falling ~12% under ENGO and ~8% under GOVT, while Ontario experiences no net impact.

The economy grows under all scenarios (Table 67 and Table 69): without climate policy the overall economy grows 27% from 2010–2020, and ~23–25% under the climate policy scenarios. Alberta's economy grows 57% without climate policy, and 38–45% with climate policy.

GDP per capita also (Table 70 and Table 71) grows under all scenarios and in all regions: without climate policy Canada's GDP per capita grows 24% from 2010–2020, and ~20–22% under the climate policy scenarios. Alberta's GDP per capita grows 42% without climate policy, and 25–32% with climate policy. However, a caveat of these results is that the model does not allow population to vary from the BAU forecast. In reality, population growth, especially migration from other regions, is tied to economic performance. Alberta's population growth is likely to be lower in the climate policy scenarios than under BAU, resulting in a GDP per capita in 2020 higher than shown below.

The relative regional impacts of the "OECD Acts Together" and "Canada Goes Further" scenarios very significantly. While the differences are not large at the national level (nominal 3.0 vs. 3.2% of GDP for ENGO (Table 15)) because Canada's overall economy is dominated by the service sector and much of the country's industrial sector is only moderately carbon intensive, the relative impacts are much higher for Saskatchewan (nominal 2.8% difference) and BC, Manitoba and the Atlantic provinces (0.6%). Across the nation, there is a migration of capital and labour out of carbon and trade exposed sectors (e.g, fossil fuels) to sectors that are less carbon and trade exposed (e.g., manufacturing, services and renewable electricity).

**Table 67 Absolute GDP at basic prices 2020 ($2005 billions)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| 2005 actual | 154.9 | 163.7 | 37.9 | 39.9 | 532.6 | 270.4 | 77.3 | 1276.7 |
| 2010 projected | 171.7 | 187.9 | 42.3 | 44.7 | 569.9 | 287.8 | 83.2 | 1387.5 |
| BAU 2020 | 223.3 | 295.6 | 53.2 | 53.5 | 691.3 | 331.0 | 110.7 | 1758.6 |
| ENGO OAT | 213.81 | 260.37 | 50.68 | 54.97 | 691.27 | 326.60 | 107.89 | 1,705.60 |
| ENGO CGF | 212.50 | 259.80 | 49.20 | 54.62 | 691.15 | 326.72 | 108.57 | 1,702.55 |
| GOVT OAT | 218.28 | 273.94 | 52.59 | 54.52 | 695.22 | 328.55 | 110.11 | 1,733.21 |
| GOVT CGF | 217.81 | 270.40 | 51.69 | 54.63 | 697.33 | 330.05 | 110.59 | 1,732.49 |

**Table 68 Relative change in GDP at basic prices in 2020 from BAU (%)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| ENGO OAT | -4.2% | -11.9% | -4.7% | 2.7% | 0.0% | -1.3% | -2.5% | -3.0% |
| ENGO CGF | -4.8% | -12.1% | -7.5% | 2.1% | 0.0% | -1.3% | -1.9% | -3.2% |
| GOVT OAT | -2.2% | -7.3% | -1.2% | 1.9% | 0.6% | -0.7% | -0.5% | -1.4% |
| GOVT CGF | -2.5% | -8.5% | -2.8% | 2.1% | 0.9% | -0.3% | -0.1% | -1.5% |

**Table 69 Relative change in GDP at basic prices 2010–2020 ($2005 billions)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| 2005 actual | 154.9 | 163.7 | 37.9 | 39.9 | 532.6 | 270.4 | 77.3 | 1,276.7 |
| 2010 projected | 171.7 | 187.9 | 42.3 | 44.7 | 569.9 | 287.8 | 83.2 | 1,387.5 |
| 2020 predicted | 223.3 | 295.6 | 53.2 | 53.5 | 691.3 | 331.0 | 110.7 | 1,758.6 |
| BAU 2010-20 (+%) | 30% | 57% | 26% | 20% | 21% | 15% | 33% | 27% |
| ENGO OAT (+%) | 24% | 39% | 20% | 23% | 21% | 13% | 30% | 23% |
| ENGO CGF (+%) | 24% | 38% | 16% | 22% | 21% | 14% | 30% | 23% |
| GOVT OAT (+%) | 27% | 46% | 24% | 22% | 22% | 14% | 32% | 25% |
| GOVT CGF (+%) | 27% | 44% | 22% | 22% | 22% | 15% | 33% | 25% |

**Table 70 GDP per capita at basic prices 2020 ($2005, regional population held at BAU levels)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| 2005 actual | 36,371 | 49,951 | 38,263 | 33,983 | 42,409 | 35,589 | 28,758 | 47,495 |
| 2010 projected | 37,979 | 52,285 | 41,864 | 37,039 | 43,069 | 36,726 | 30,889 | 51,511 |
| BAU 2020 | 44,529 | 74,226 | 48,753 | 41,359 | 47,138 | 39,972 | 40,062 | 63,656 |
| ENGO OAT | 42,640 | 65,384 | 46,440 | 42,490 | 47,136 | 39,439 | 39,052 | 61,738 |
| ENGO CGF | 42,378 | 65,240 | 45,082 | 42,213 | 47,128 | 39,452 | 39,299 | 61,627 |
| GOVT OAT | 43,531 | 68,792 | 48,187 | 42,143 | 47,405 | 39,673 | 39,856 | 62,737 |
| GOVT CGF | 43,437 | 67,901 | 47,364 | 42,221 | 47,549 | 39,855 | 40,032 | 62,711 |

**Table 71 Relative change in GDP per capita at basic prices 2010–2020 (regional population held at BAU levels)**

| | BC | AB | SK | MB | ON | QC | ATL & RoC | Canada |
|---|---|---|---|---|---|---|---|---|
| BAU 2010-20 (+%) | 17% | 42% | 16% | 12% | 9% | 9% | 30% | 24% |
| ENGO OAT (+%) | 12% | 25% | 11% | 15% | 9% | 7% | 26% | 20% |
| ENGO CGF (+%) | 12% | 25% | 8% | 14% | 9% | 7% | 27% | 20% |
| GOVT OAT (+%) | 15% | 32% | 15% | 14% | 10% | 8% | 29% | 22% |
| GOVT CGF (+%) | 14% | 30% | 13% | 14% | 10% | 9% | 30% | 22% |

# Appendix – Technology Penetration in CIMS

## ENGO Target, "Canada Goes Further" Scenario

### *Wind generated electricity*

**Table 72: Annual % electricity generation from wind (TWh)**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Absolute (TWh) | 34 | 54 | 42 | 88 | 52 | 132 |
| % penetration | 5.4% | 8.8% | 6.4% | 13.2% | 7.4% | 17.7% |

Wind captures 18% of all generation by 2020 in the policy simulation. This is high, but technically and economically plausible with the upgrades proposed for the electricity transmission spending policy

Utility generation from solar is inconsequential in MW terms. There is one key caveat – feed-in tariffs like that in Ontario offer rates far above what is typically considered a least cost rate for solar power (40 cents/kwh), usually under the premise of driving down technology costs through learning and economies of scale that will "pay out" far beyond the 2020 timeframe of this report. Because of this, in reality more electricity may be generated using solar power than a pure market price might dictate, however CIMS would not show any market share for a technology that cost this much.

### *Coal and gas -fired electricity with CCS*

**Table 73: Coal-fired electricity with CCS (TWh)**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Absolute (TWh) | 0 | 0 | 0 | 8 | 0 | 17 |
| % penetration | - | - | - | 1.3% | 0.0% | 2.3% |
| CCS Retrofits (TWh) | 0 | 0 | 0 | 7 | 0 | 13 |
| %CCS from Retrofits | - | - | - | 86.6% | - | 73.3% |

**Table 74: Gas-fired electricity with CCS (TWh)**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Absolute (TWh) | 0 | 0 | 0 | 7 | 0 | 21 |
| % penetration | - | - | - | 1.0% | 0.1% | 2.8% |
| CCS Retrofits (TWh) | 0 | 0 | 0 | 2 | 0 | 6 |
| %CCS from Retrofits | - | - | - | 25.8% | - | 28.9% |

Coal and gas fired electricity with CCS are a fairly minor component of total generation, at 5.2% in 2020, but this a significant gain from zero market share today. Wind and especially hydro are in general more competitive across Canada, however the carbon capture regulation ensures CCS where new coal power is necessary. This creates experience and innovation that drive down the capital costs of CCS.

### *Oil sands with CCS*

**Table 75: Oil sands with CCS**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| **Synthetic[a] (1000/bbl*day)** | | | | | | |
| Production (1000/bbl*day) | 771 | 750 | 1312 | 1079 | 1931 | 1526 |
| Production w/ CCS (1000/bbl*day) | 0 | 0 | 0 | 114 | 7 | 757 |
| Market Penetration | 0.0% | 0.0% | 0.0% | 10.5% | 0.3% | 49.6% |
| Retrofits w/ CCS (1000/bbl*day) | 0 | 0 | 0 | 2 | 0 | 58 |
| % CCS from retrofits | - | - | - | 1.5% | 0.0% | 7.7% |
| **Hydrogen production (for synthetic[b])** | | | | | | |
| Hydrogen Prod. (PJ) | 104 | 101 | 177 | 145 | 260 | 205 |
| H2 prod. w/ CCS (PJ) | 0 | 14 | 11 | 93 | 11 | 181 |
| Market Penetration | 0.0% | 14.4% | 6.0% | 63.7% | 4.4% | 88.0% |
| Retrofits w/ CCS (PJ) | 0 | 0 | 0 | 13 | 0 | 24 |
| % CCS from retrofits | - | 0.0% | 0.0% | 13.9% | 0.0% | 13.5% |
| **Steam (for bitumen[c] production)** | | | | | | |
| Steam Production(PJ) | 253 | 246 | 336 | 275 | 370 | 285 |
| Steam with CCS (PJ) | 0 | 2 | 1 | 4 | 1 | 43 |
| Market Penetration | 0.0% | 0.9% | 0.4% | 1.3% | 0.3% | 15.2% |
| Retrofits w/ CCS (PJ) | 0 | 2 | 0 | 2 | 0 | 8 |
| % CCS from retrofits | - | 76.0% | 0.0% | 45.6% | 0.0% | 18.2% |

[a] Includes integrated mining and upgrading and standalone upgrading
[b] Includes all hydrogen produced for either integrated mining and upgrading or standalone upgrading
[c] Exclude bitumen produced during integrated mining and upgrading

By 2020, 50% of synthetic oil is made using CCS. This penetration of CCS applies to the steam and process heat used for integrated oil sands mining and upgrading and standalone upgrading. 88% of hydrogen for synthetic oil is made using CCS which reflects the low cost of capturing the relatively pure $CO_2$ released during production. Only 15% of steam production for bitumen extraction uses CCS in 2020. This market penetration is low compared to CCS for synthetic oil production. However synthetic oil is made in large facilities where economies of scale can be achieved with CCS, whereas bitumen production occurs at many small in-situ production facilities.

### *Public transit*

**Table 76: Urban Public transit ridership millions of pkt**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| *Millions pkt* | 17,416 | 17,563 | 19,897 | 29,172 | 20,708 | 35,872 |
| *% of Urban Travel* | 5.3% | 5.4% | 5.6% | 8.2% | 5.3% | 9.2% |

Transit ridership rises by 73% in 2020 compared to BAU, accounting for 9.2% of urban travel. The urban transit spending policy and the carbon charge contribute almost equally to this mode shift.

### *Electric vehicles*

The cost and performance of non-transit electric vehicles next to hybrids and other alternatives is uncompetitive. However, CIMS does not endogenously recognize niche markets such as municipal or courier fleets. Regardless, while these niche markets are important, they are not large enough to change national results.

### *Transport Fuels*

**Table 77: Share of liquid fuels by type, personal and freight transportation**

| | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|
| **Personal Transport** | | | | |
| Gasoline/Diesel | 100.0% | 100.0% | 99.8% | 98.1% |
| Ethanol | 0.0% | 0.0% | 0.1% | 1.3% |
| Biodiesel | 0.0% | 0.0% | 0.1% | 0.6% |
| Hydrogen | 0.0% | 0.0% | 0.0% | 0.0% |
| **Freight Transport** | | | | |
| Gasoline/Diesel | 100.0% | 99.9% | 90.2% | 81.2% |
| Ethanol | 0.0% | 0.0% | 0.0% | 0.0% |
| Biodiesel | 0.0% | 0.1% | 9.8% | 18.8% |
| Hydrogen | 0.0% | 0.0% | 0.0% | 0.0% |

**Table 78: Corn and cellulosic ethanol's share of total ethanol production**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| **Corn** | | | | | | |
| *Absolute (1000 GJ)* | 149 | 165 | 226 | 1282 | 309 | 1143 |
| *%penetration* | 100.0% | 100.0% | 100.0% | 96.3% | 100.0% | 7.1% |
| **Cellulosic** | | | | | | |
| *Absolute(1000 GJ)* | - | - | - | 49.3 | 0 | 14,998 |
| *%penetration* | 0.0% | 0.0% | 0.0% | 3.7% | 0.0% | 92.9% |

In the personal transportation fleet gasoline still has a 98% market share in 2020, but this share is within a far more efficient fleet that include more hybrid vehicles (Table 86). Almost all ethanol is corn ethanol in 2015, switching to cellulosic ethanol by 2020 (Table 87). In the freight transportation fleet, 19% of fuel needs are met by biodiesel in 2020 (Table 77). While technically feasible, the key limitation to these results will be the availability of feedstock. If cellulosic ethanol can be made commercially viable, it will largely eliminate the feedstock issues, but this technology has not yet been applied at a commercial scale.

### *Residential technologies*

**Table 79: Residential[a] Technologies**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Solar Hot Water | 0.2% | 0.2% | 0.3% | 1.8% | 0.5% | 6.0% |
| Heat Pump Hot Water | 3.8% | 3.9% | 4.4% | 14.1% | 4.9% | 27.2% |
| Air Source Heat Pump Space Heating | 3.8% | 3.8% | 4.4% | 14.9% | 3.7% | 20.3% |
| Ground Source Heat Pump Space Heating | 0.1% | 0.1% | 0.2% | 1.7% | 0.3% | 5.0% |
| Building Shell-LEED | 0.0% | 0.0% | 0.0% | 9.2% | 0.0% | 20.6% |
| Building Shell-R2000 | 1.2% | 1.2% | 1.7% | 1.2% | 2.1% | 1.1% |
| Solar PV | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

[a] Includes apartment buildings

### *Commercial and institutional building technologies*

**Table 80: Commercial Technologies**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Heat Pumps | 1.5% | 1.6% | 1.9% | 9.6% | 2.1% | 25.3% |
| Building Shell-LEED | 0.0% | 0.0% | 0.2% | 14.5% | 0.4% | 31.5% |

Solar hot water heating for the commercial sector is not currently modelled in CIMS. Further study may find applications where this technology can provide additional abatement in the commercial sector. All heat pumps simulated in the commercial sector are ground source heat pumps.

## GOVT Target, "Canada Goes Further" Scenario

### *Wind generated electricity*

**Table 81: Annual % electricity generation from wind (TWh)**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Absolute (TWh) | 34 | 54 | 42 | 92 | 52 | 133 |
| % penetration | 5.4% | 8.7% | 6.4% | 13.4% | 7.4% | 17.8% |

Wind captures 18% of all generation by 2020 in the policy simulation. This is high, but technically and economically plausible with the upgrades proposed for the electricity transmission spending policy. The penetration of wind is similar to under the ENGO target even though the carbon price is lower under the GOVT target. However, this expansion of wind power is largely driven by the electricity transmission spending policy assisted by a carbon price more so than the magnitude of carbon price. This result does not include any future advances in energy storage that could be induced by carbon pricing. Utility generation from solar is inconsequential relative to other renewable technologies.

### *Coal and gas -fired electricity with CCS*

**Table 82: Coal-fired electricity with CCS (TWh)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Absolute (TWh) | 0 | 0 | 0 | 4 | 0 | 10 |
| % penetration | 0.0% | 0.0% | 0.0% | 0.6% | 0.0% | 1.3% |
| CCS Retrofits (TWh) | 0 | | 0 | 4 | 0 | 7 |
| %CCS from Retrofits | | | | 81.6% | | 74.8% |

**Table 83: Gas-fired electricity with CCS (TWh)**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Absolute (TWh) | 0 | 0 | 0 | 2 | 0 | 6 |
| % penetration | - | - | 0.04% | 0.27% | 0.06% | 0.76% |
| CCS Retrofits (TWh) | 0 | 0 | 0 | 0 | 0 | 1 |
| %CCS from Retrofits | - | - | - | 0.5% | - | 12.1% |

Coal and gas fired electricity with CCS account for only 2% of total generation in 2020. Wind and hydro are in general more competitive across Canada and the carbon capture regulation was not used to achieve the government target.

### *Oil sands with CCS*

**Table 84: Oil sands with CCS**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| **Synthetic[a] (1000/bbl*day)** | | | | | | |
| Production (1000/bbl*day) | 771 | 768 | 1312 | 1179 | 1931 | 1696 |
| Production w/ CCS (1000/bbl*day) | 0 | 0 | 0 | 25 | 7 | 75 |
| Market Penetration | 0.0% | 0.0% | 0.0% | 2.2% | 0.3% | 4.4% |
| Retrofits w/ CCS | 0 | 0 | 0 | 2 | 0 | 9 |
| % CCS from retrofits | - | - | - | 6.9% | 0.0% | 11.7% |
| **Hydrogen production (for synthetic[b])** | | | | | | |
| Hydrogen Prod. (PJ) | 104 | 103 | 177 | 159 | 260 | 228 |
| H2 prod. w/ CCS (PJ) | 0 | 9 | 11 | 53 | 11 | 129 |
| Market Penetration | 0.0% | 8.5% | 6.0% | 33.4% | 4.4% | 56.6% |
| Retrofits w/ CCS | 0 | 9 | 0 | 32 | 0 | 72 |
| % CCS from retrofits | - | 99.0% | 0.0% | 61.1% | 0.0% | 55.7% |
| **Steam (for bitumen[c] production)** | | | | | | |
| Steam Production(PJ) | 253 | 252 | 336 | 300 | 370 | 316 |
| Steam with CCS (PJ) | 0 | 1 | 1 | 1 | 1 | 2 |
| Market Penetration | 0.0% | 0.5% | 0.4% | 0.5% | 0.3% | 0.5% |
| Retrofits w/ CCS (PJ) | 0 | 1 | 0 | 1 | 0 | 1 |
| % CCS from retrofits | - | 61.3% | 0.0% | 59.1% | 0.0% | 53.6% |

[a] Includes integrated mining and upgrading and standalone upgrading
[b] Includes all hydrogen produced for either integrated mining and upgrading or standalone upgrading

[c] Exclude bitumen produced during integrated mining and upgrading

By 2020, only 4% of synthetic oil is made using CCS under the government price path. Again, this CCS applies to the steam and process heat used for integrated oil sands mining and upgrading and standalone upgrading. 57% of hydrogen for synthetic oil is made using CCS which reflects the low cost of capturing the relatively pure $CO_2$ released during production. Less than 1% of steam production for bitumen extraction uses CCS in 2020. Again, steam for bitumen extraction is produced in small facilities, thus CCS does not achieve the same economy of scale as it does for synthetic oil production.

***Public transit***

**Table 85: Urban Public transit ridership millions of pkt**

| | 2010 | | 2015 | | 2020 | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| *Millions pkt* | 17,416 | 17,416 | 19,897 | 26,935 | 20,708 | 32,134 |
| *% of Urban Travel* | 5.3% | 5.3% | 5.6% | 7.5% | 5.3% | 8.3% |

Transit ridership rises by 55% in 2020 compared to BAU, accounting for 8.3% of urban travel. The urban transit spending policy contributes to more of this mode shift than the carbon price under the GOVT target.

***Electric vehicles***

The cost and performance of non-transit electric vehicles next to hybrids and other alternatives is uncompetitive. However, CIMS does not endogenously recognize niche markets such as municipal or courier fleets. Regardless, while these niche markets are important, they are not large enough to change national results.

***Transport Fuels***

**Table 86: Share of liquid fuels by type, personal and freight transportation**

| | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|
| **Personal Transport** | | | | |
| Gasoline/Diesel | 100.0% | 100.0% | 99.9% | 99.6% |
| Ethanol | 0.0% | 0.0% | 0.0% | 0.2% |
| Biodiesel | 0.0% | 0.0% | 0.1% | 0.2% |
| Hydrogen | 0.0% | 0.0% | 0.0% | 0.0% |
| **Freight Transport** | 100.0% | 100.0% | 100.0% | 100.0% |
| Gasoline/Diesel | | | | |
| Ethanol | 100.0% | 99.9% | 97.9% | 96.1% |
| Biodiesel | 0.0% | 0.0% | 0.0% | 0.0% |
| Hydrogen | 0.0% | 0.1% | 2.1% | 3.9% |

**Table 87: Corn and cellulosic ethanol's share of total ethanol production**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| **Corn** | | | | | | |
| *Absolute (1000 GJ)* | 149 | 152 | 226 | 624 | 309 | 2827 |
| *%penetration* | 100.0% | 100.0% | 100.0% | 99.8% | 100.0% | 94.5% |
| **Cellulosic** | | | | | | |
| *Absolute(1000 GJ)* | - | - | - | 1.0 | 0 | 164 |
| *%penetration* | 0.0% | 0.0% | 0.0% | 0.2% | 0.0% | 5.5% |

In the personal transportation fleet gasoline still holds 100% of the market share in 2020. In the freight transportation fleet, biodiesel meets 4% of fuel needs in 2020 (Table 86). The small amount of ethanol is made from mostly from corn until after 2020 (Table 87). The lower carbon price that achieves the GOVT target does not stimulate the use of liquid biofuels in the near term, nor does it spur a development of cellulosic ethanol production. However, this does not rule out the use of biofuels from 2020 onward assuming, especially if the carbon price were to continue rising.

### *Residential technologies*

Penetration of abatement technologies in the residential sector under the government target is similar to the ENGO target. The complementary regulations, used for both targets, are driving much of the adoption of new technologies in this sector, thus the technology penetrations are similar between targets.

**Table 88: Residential[a] Technologies**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Solar Hot Water | 0.2% | 0.2% | 0.3% | 1.4% | 0.5% | 4.6% |
| Heat Pump Hot Water | 3.8% | 3.7% | 4.4% | 12.8% | 4.9% | 24.8% |
| Air Source Heat Pump Space Heating | 3.9% | 3.8% | 4.6% | 16.1% | 4.0% | 22.6% |
| Ground Source Heat Pump Space Heating | 0.1% | 0.1% | 0.2% | 1.4% | 0.3% | 4.1% |
| Building Shell-LEED | 0.0% | 0.0% | 0.0% | 10.7% | 0.0% | 21.9% |
| Building Shell-R2000 | 1.2% | 1.2% | 1.7% | 1.2% | 2.1% | 1.1% |
| Solar PV | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

[a] Includes apartment buildings

There are two notable differences between the GOVT and ENGO results. First, LEED buildings have greater technology penetration under the policy package that achieves the GOVT target (Table 88, Table 89, Table 79, Table 80). The construction and retrofit of LEED buildings is driven by regulation affecting new buildings, and the growth of new buildings is slowed less under the GOVT target, thus there are more LEED buildings.

Second, the market penetration of all heat pumps is slightly higher under the GOVT target than under the ENGO target. This is because under the ENGO target, the electricity sector is induced to decarbonise sooner, making new homes built with electric baseboard somewhat more competitive relative to heat pumps or high efficiency furnaces.

***Commercial and Institutional Building Technologies***

**Table 89: Commercial Technologies**

| | *2010* | | *2015* | | *2020* | |
|---|---|---|---|---|---|---|
| | BAU | POL | BAU | POL | BAU | POL |
| Heat Pumps | 1.5% | 1.5% | 1.9% | 9.3% | 2.1% | 24.1% |
| Building Shell-LEED | 0.0% | 0.0% | 0.2% | 16.8% | 0.4% | 33.2% |

Under the GOVT target, heat pump space conditioning achieves a 24% market share and LEED shells achieve a 33% market share in the commercial sector. Similar to the residential sector, LEED shells achieve a greater market share under the GOVT target because the construction of new commercial buildings is slightly higher than under the ENGO target. Ground source heat pumps are more competitive relative to conventional electric space conditioning at the commercial scale. Therefore the more stringent ENGO target policies do not induce more conventional electric systems at the expense of the heat pump market share. Consequently, the market penetration of heat pumps is lower under the GOVT target.

Solar hot water heating for the commercial sector is not currently modelled in CIMS. Further study may find applications where this technology can provide additional abatement in the commercial sector. All heat pumps simulated in the commercial sector are ground source heat pumps.

# Appendix – CIMS

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 90. CIMS does not include adipic and nitric acid, solvents or hydrofluorocarbon (HFC) emissions. CIMS covers nearly all CAC emissions in Canada except those from open sources (e.g., forest fires, soils, and dust from roads).

**Table 90: 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.

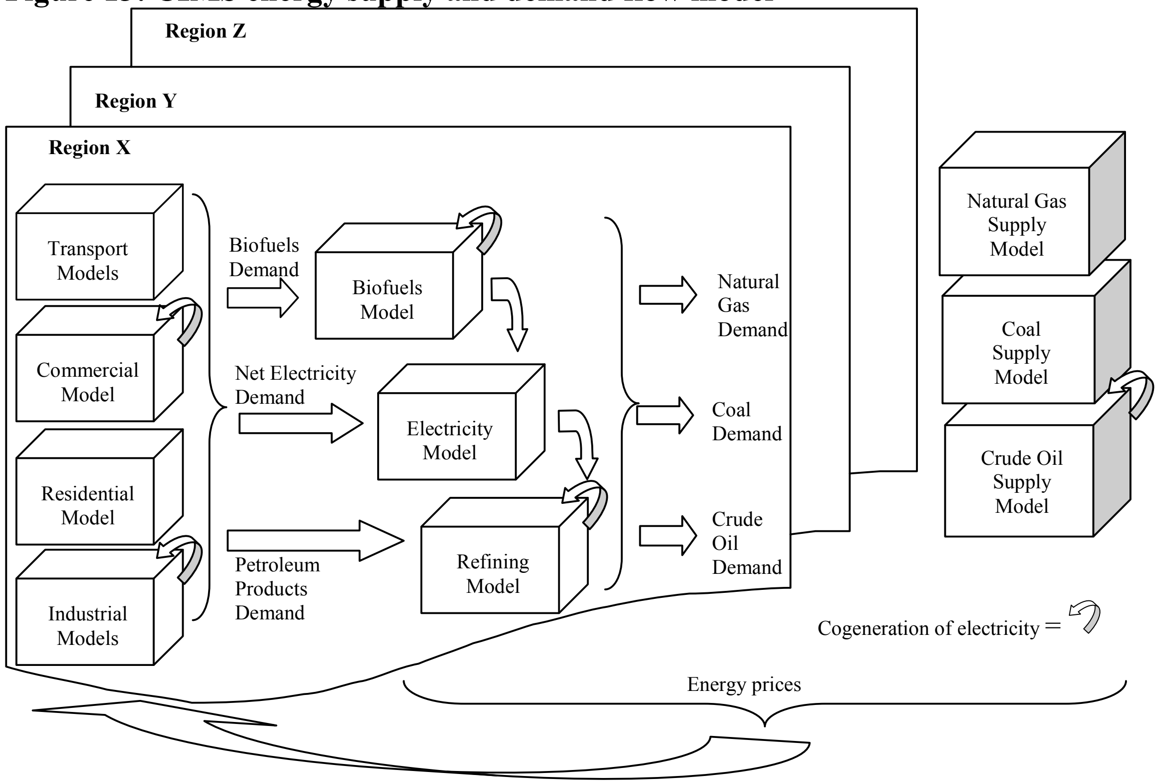
CIMS simulates the competition of technologies at each energy service node in the economy based on a comparison of their life cycle cost (LCC) and some technology-specific controls, such as a maximum market share limit in the cases where a technology is constrained by physical, technical or regulatory 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 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 13 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 13: 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).[26] Freight transportation is driven by changes in the combined value added of the industrial sectors, while personal transportation is adjusted using a personal kilometres-travelled elasticity (-0.02). Residential and commercial floor space is adjusted by a sequential substitution of home energy consumption vs. other goods (0.5), consumption vs. savings (1.29) and goods vs. leisure (0.82). If demand for any good or service has shifted more than a threshold amount, supply and demand are considered to be out of balance and the model re-runs using these new demands. The model continues re-running until both energy and goods and services supply and demand come into balance, and repeats this balancing procedure in each subsequent five-year period of a complete run.

### Empirical basis of parameter values

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

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

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

Fuel-based GHGs emissions are calculated directly from CIMS' estimates of fuel consumption and the GHG coefficient of the fuel type. Process-based GHGs emissions are estimated based on technological performance or chemical stoichiometric proportions. CIMS tracks the emissions of all types of GHGs, and reports these emissions in terms of carbon dioxide equivalents.[27]

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.

Behavioral parameters are estimated through a combination of literature review, judgment, supplemented with the use of discrete choice surveys for estimating models whose parameters can be transposed into behavioral parameters in CIMS.

### 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.

Please see the following list of publications for further information on CIMS:

Bataille, C., M. Jaccard, J. Nyboer and N. Rivers. (2006). "Towards General Equilibrium in a Technology-Rich Model with Empirically Estimated Behavioral Parameters." *Hybrid Modeling: New Answers to Old Challenges, Special Issue of the Energy Journal.*

Jaccard, M., J. Nyboer, C. Bataille, and B. Sadownik (2003). "Modeling the Cost of Climate Policy: Distinguishing Between Alternative Cost Definitions and Long run Cost Dynamics." *The Energy Journal* 24(1): 49-73.

Rivers, N. and M. Jaccard. (2005) "Combining Top-Down and Bottom-Up Approaches to Energy-Economy Modeling Using Discrete Choice Methods." *The Energy Journal* 26(1): 83-106.

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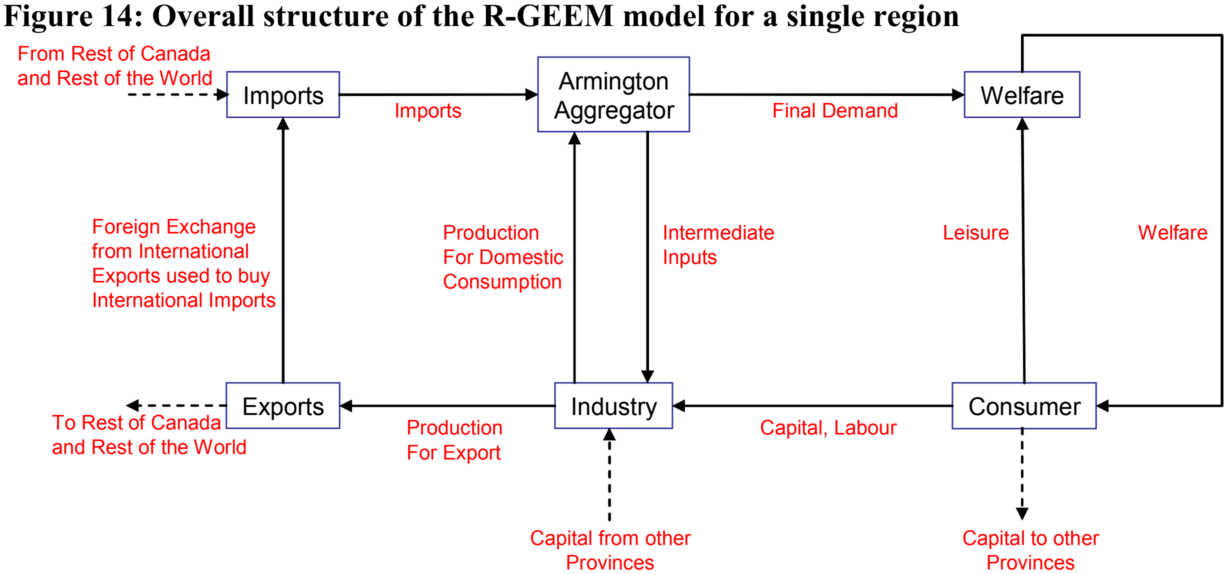
[27] CIMS uses the 2001 100-year global warming potential estimates from Intergovernmental Panel on Climate Change, 2001, "Climate Change 2001: The Scientific Basis", Cambridge University Press, UK.

# Appendix – R-GEEM

R-GEEM is a static multi-sector, open-economy computable general equilibrium model that represents BC, Alberta, Saskatchewan, Manitoba, Ontario, Quebec and Atlantic Canada as separate regions. In the current version Canadian economic activity outside Canada is included with the Atlantic provinces. In the model, a representative consumer is the owner of the primary factors (labour and capital). The consumer rents these factors to producers, who combine them with intermediate inputs to create commodities. These commodities can be sold to other producers (as intermediate inputs), to final consumers, or sold to the rest of the world as exports. Commodities can also be imported from the rest of the world. R-GEEM is a small open-economy model and it would be assumed to be a price taker for internationally traded goods. The key economic flows in R-GEEM are captured schematically in Figure 14.

**Figure 14: Overall structure of the R-GEEM model for a single region**




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

As a static model, R-GEEM does not model the accumulation and depreciation of capital, so cannot model incentives for investment. Instead, investment capital is modeled as a fixed stock; capital investment can be moved between different sectors or regions in response to a policy, but the overall level of investment remains constant.

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

The data underlying the model is derived primarily from the Statistics Canada System of National Accounts. We use a mixture of the S and M level Input, Output, and Final Demand tables to populate the model, and aggregate these somewhat to focus on sectors of primary interest.[28] Energy consumption is disaggregated using data from the CIMS model and from the Statistics Canada Report on Supply and Demand of Energy. R-GEEM is implemented in GAMS, using the MPS/GE substructure.

### Consumers

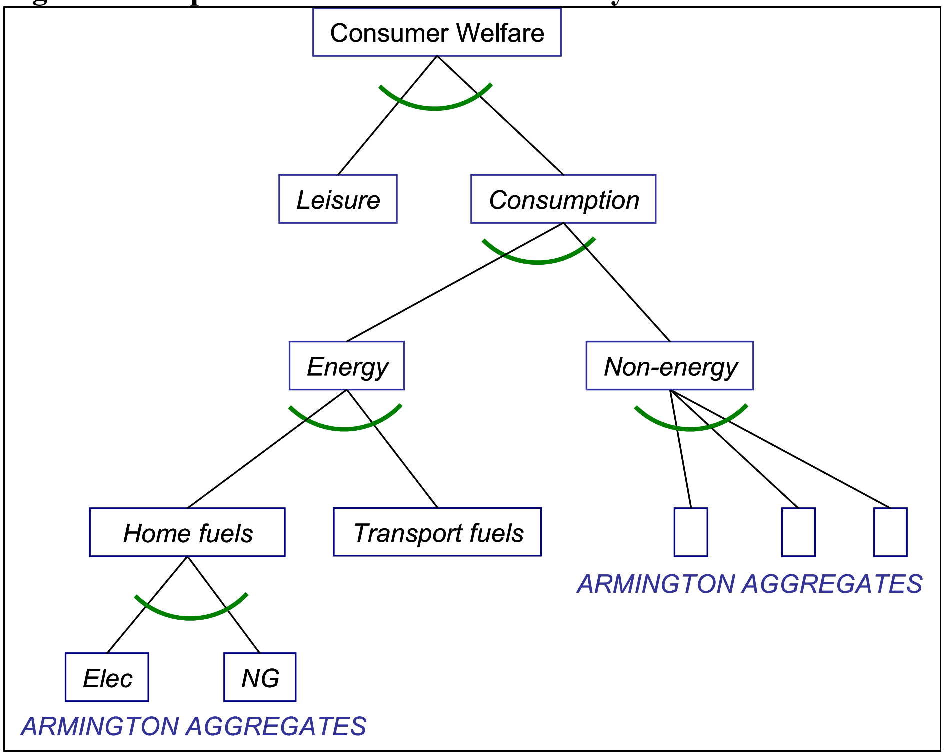
R-GEEM uses a representative agent framework, like many CGE models, where all consumers (individuals) are represented by a single representative agent. In this framework, the representative agent aims to maximize utility, where utility is a function of consumption of various commodities and leisure:

$$U^C = U^C(c_1 \ldots c_N, L) \qquad (1)$$

In R-GEEM, $U^C$ is characterized by a nested constant elasticity of substitution function, which is represented schematically in Figure 15. At the top level of the nest, the consumer chooses between leisure and consumption. Consumption is made up of energy commodities and non-energy commodities, which are nested separately. Amongst energy commodities, electricity and natural gas form an individual nest.

[28] S level has the least amount of resolution, and does not allow much differentiation of energy-intensive sectors, but is the only one available at a provincial level because of confidentiality concerns. We M level data to expand the S level data for key sectors, such as mining, crude oil, natural gas, coal mining, renewable electricity and transit.

**Figure 15: Representation of consumer utility function in R-GEEM**




The consumer faces a budget constraint, given by:

$$M^C = \sum_{i=1}^{n} (1+t_i^C) p_i c_i \qquad (2)$$

Income for the representative consumer is derived from returns to primary factors, and all taxation revenue:

$$M^C = \sum_{f=1}^{L} F_f w_f (1-t_f^F) + T \qquad (3)$$

Equations *(1)* through *(3)* are solved through Lagrangian optimization for quantities $c_i$ and $L$. These commodity (and leisure) demand equations are used in developing the general equilibrium solution.

### Producers

The R-GEEM model includes a representative producer in each of the $K$ productive sectors of the economy, which are each assumed to be perfectly competitive (i.e., no excess profits are derived by producers) except for the upstream oil and gas sector. Profits for each sector $j$ are given by:

$$\pi^j = \sum_{i=1}^{N} p_i Y_{ij} - \sum_{i=1}^{N} p_i x_{ij} - \sum_{f=1}^{F} w_f F_{fj} (1+t_f^j - s_f^j) \qquad (4)$$

Each sector makes outputs by combining primary factors and intermediate inputs in a nested *KLEM* (capital, labour, energy, and materials) production function:

$$Y_j = Y_j(F_{1j}..F_{fj}, x_{1j}..x_{Nj}) \qquad (5)$$

The specific structure of the production function $Y_j$ is given in Figure 16. In this structure, energy commodities enter in successive nests, to represent the differing capacity to switch between fuels. Once aggregated, the energy commodities can substitute for the value added aggregate, made up of capital and labour inputs. Overall industry output is made up of a combination of this energy and value added bundle with a bundle of intermediate (material) inputs. Combustion emissions from fossil fuel combustion are based on a fixed coefficient relationship with each fuel type.

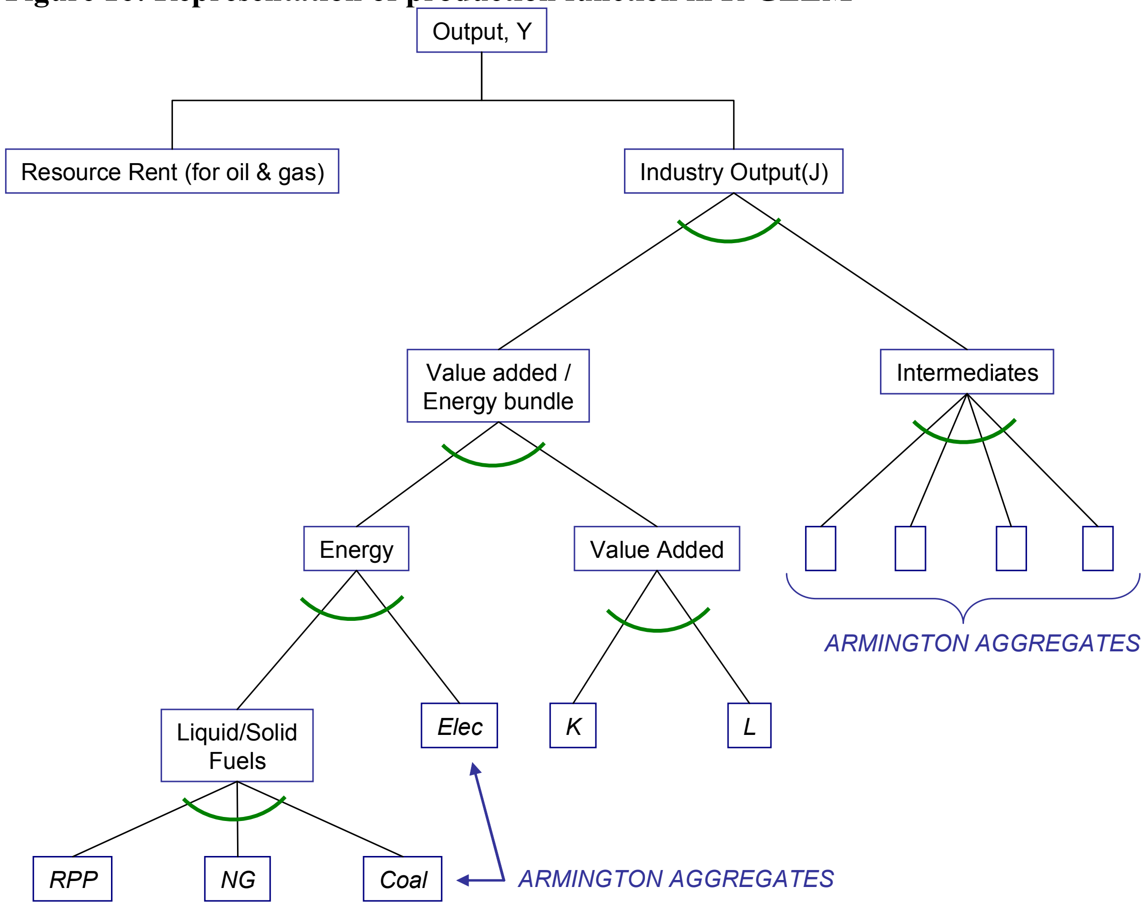
Special treatment is made for the oil and gas sector, which is assumed to earn resource rents. The presence of resource rents makes the oil and gas sector less susceptible to declines in output, as the size of rents can decline while the sector remains profitable. All output adjustments from the oil and gas sector occur as the average cost of the sector increases, and it is assumed that these increases remove marginal plants from operation. The relationship between output and cost was approximated from the relationship between oil and natural gas prices and production from National Energy Board (2009).

Total output is disaggregated into individual commodities using a constant elasticity of transformation function ($T_j$):

$$Y_j = T_j(Y_{1j}..Y_{Nj}) \qquad (6)$$

Equations *(4)* through *(6)* are solved through Lagrangian optimization for quantities $x_{ij}$ and $F_{ij}$. These equations are used in the general equilibrium conditions to solve the model.

**Figure 16: Representation of production function in R-GEEM**




For this project, represent discrete technologies using CCS in the crude oil, electricity and natural gas sectors, we borrowed a method from the MIT-EPPA model that replaces the production function approach with selections from a discrete list of technologies (McFarland et al 2004, Sue Wing 2008).

### Trade

R-GEEM models trade flows to other provinces and to the rest of the world. Imports are combined with domestically produced commodities in a constant elasticity of substitution function to produce Armington aggregate commodities, which are consumed by both producers (intermediate inputs) and consumers (final demand):

$$A_i = A_i(\hat{Y}_i, M_i) \qquad (7)$$

Production is separated into production for domestic consumption and production for export according to a constant elasticity of transformation function ($G_i$):

$$Y_i = G_i(\hat{Y}_i, \overline{Y}_i) \qquad (8)$$

Where $Y_i = \sum_{j=1}^{K} Y_{ij}$ . Overall trade flows are determined by balancing imports and exports mediated through a foreign exchange market:

$$FXX = \frac{\sum_{i=1}^{N} p_i^W \overline{Y}_i}{PFX} \quad (9)$$

$$FXM = \frac{\sum_{i=1}^{N} p_i^W M_i}{PFX} \quad (10)$$

$$FXX - FXM = BTD \quad (11)$$

Runs in R-GEEM are constrained such that the balance of trade deficit (*BTD*) that prevailed in the benchmark scenario is replicated in the counterfactual scenario. The world price is given by:

$$p_i = p_i^W (1 + t_i^x)(1 + t_i^m) \quad (12)$$

**Variable Definitions**

| | |
|---|---|
| ***Consumers*** | |
| $U^C$ | Consumer utility |
| $c_i$ | Quantity of commodity *i* consumed by consumer |
| $L$ | Quantity of leisure consumed by consumer |
| $p_i$ | Price of commodity *i* |
| $t_i^C$ | Consumption tax rate on commodity *i* |
| $t_f^F$ | Direct factor tax rate on factor *f* |
| $T$ | Sum of all direct and indirect tax revenue |
| ***Producers*** | |
| $Y_{ij}$ | Quantity of output of commodity *i* by sector *j* |
| $Y_j$ | Total output of all commodities by sector *j* |
| $x_{ij}$ | Quantity of intermediate input of commodity *i* by sector *j* |
| $\pi^j$ | Profit of sector *j* |
| $F_{fj}$ | Quantity of factor *f* required by sector *j* |
| $w_f$ | Returns to factor *f* |
| $t_f^j$ | Indirect factor tax rate on factor *f* employed by sector *j* |
| $s_f^j$ | Indirect factor subsidy rate on factor *f* employed by sector *j* |
| ***Trade*** | |
| $\hat{Y}_i$ | Production of commodity *i* for domestic consumption |
| $\overline{Y}_i$ | Production of commodity *i* for export to rest of world |
| $BTD$ | Balance of trade deficit with the rest of world |
| $FXM$ | Foreign exchange outlays for imports |
| $FXX$ | Foreign exchange receipts from exports |
| $PFX$ | Price of foreign exchange (exchange rate) |
| $p_i^W$ | World price of commodity *i* |
| $t_i^x$ | Tax on exports of commodity *i* |
| $t_i^m$ | Tax on imports of commodity *i* |

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# Appendix - The Reference Scenario

*Note to the September 2009 version of this section: The key difference between the December 2008 and September 2009 reference scenarios was adoption of CAPP's latest 2008 crude oil forecast to reflect recent investment announcement changes.*

The reference scenario described in this report is based on several external inputs showing how the economy will evolve over the coming 12 years to 2020 (CIMS typically simulates out to 2050, but we have not reported 2021 onward for this project). Many key inputs underlying the reference scenario are highly uncertain, and if the economy evolves differently than as shown in this reference scenario, energy consumption and emissions will also differ from what we show here. Credible sources have been used to guide key inputs wherever possible, but no amount of research allows perfect foresight into the future of the economy. As a result, the scenario described here should be considered 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. We begin by highlighting our key assumptions, and follow by showing the results of our forecast.

### Key economic drivers and assumptions

CIMS uses an external forecast for the economic or physical output of each economic sector to develop the business as usual forecast. For example, CIMS requires an external forecast for the number of residential households, another for the amount of cement produced in the province, and another for amount of natural gas produced as applicable. These forecasts can be internally adjusted when a policy is applied.

For all energy demand sectors, the external forecast through 2020 is based on the same data used by NRCan to develop the national energy outlook in 2006.[29]

**Table 91: Canada economic and demographic forecast**

| | *Units* | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|---|
| Gross Domestic Product | *Billion 1997$* [a] | 1,083.7 | 1,237.5 | 1,383.9 | 1,552.2 |
| Population | *Millions* | 32.2 | 33.5 | 34.7 | 35.8 |

Note: [a] Gross domestic product is presented in basic prices

While the residential, commercial and transportation sectors are not the direct subject of policy in this analysis, their demand for electricity, processed natural gas and refined petroleum products set the stage for many of the industrial sectors subject to the *Regulatory Framework*. The CIMS models for each of these sectors were updated with 2005 data to ensure their demand for energy end use commodities fits history, is reasonable, and adjusts in a credible fashion with population, economic growth and technology.

[29] Natural Resources Canada, 2006, "Canada's Energy Outlook: The Reference Case 2006", Analysis and Modelling Division, Natural Resources Canada.

Physical output in each of the industrial sectors was also updated to reflect recently released 2005 statistics.  Energy use for each sector was also checked against Statistics Canada's *Report on Energy Supply and Demand 2005*, as well as NRCan's *Comprehensive Energy Use Database*.  2005 emissions of GHGs and CACs were calibrated against the aforementioned energy use statistics and EC's draft *GHG Inventory for 2005*.[30]

Table 92 summarizes the reference case economic output forecast that is adopted for this forecast.  As has been emphasized throughout, this forecast reflects historic and anticipated future trends, but is highly uncertain, particularly in the later years of the forecast.

[30] Environment Canada, "National Inventory Report: 1990-2005. Greenhouse Gas Sources and Sinks in Canada." November 2007.

**Table 92: Reference case forecast of physical output**[31]

| | Units | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| **Demand Sectors** | | | | | |
| Residential | *thousands of households* | 12,587 | 13,550 | 14,476 | 15,380 |
| Commercial | *million $m^2$ of floorspace* | 652 | 730 | 816 | 908 |
| Transportation | | | | | |
| Passenger | *billion passenger-km* | 616 | 702 | 774 | 851 |
| Freight | *billion tonne-km* | 864 | 978 | 1,094 | 1,210 |
| Manufacturing Industry | | | | | |
| Chemical Products | *thousand tonnes* [a] | 18,504 | 19,633 | 20,957 | 22,167 |
| Industrial Minerals | *thousand tonnes* [b] | 16,623 | 17,951 | 19,751 | 21,393 |
| Pulp and Paper | *thousand tonnes* [c] | 20,103 | 20,466 | 21,296 | 22,114 |
| Iron and Steel | *thousand tonnes* | 14,200 | 14,740 | 15,564 | 16,403 |
| Metal Smelting | *thousand tonnes* | 4,577 | 4,838 | 4,839 | 4,916 |
| Mining | *thousand tonnes* | 246,385 | 262,005 | 270,985 | 274,301 |
| Other Manufacturing | *million $2005* | 181,806 | 205,184 | 231,403 | 260,052 |
| Waste | *million tonnes of waste in place* | 658 | 683 | 708 | 732 |
| **Supply Sectors** | | | | | |
| Crude Oil (CAPP report) | | | | | |
| Conventional Light | *thousand barrels/day* | 1192 | 1133 | 883 | 676 |
| Conventional Heavy | *thousand barrels/day* | 475 | 436 | 390 | 320 |
| Synthetic | *thousand barrels/day* | 495 | 771 | 1312 | 1931 |
| Blended Bitumen | *thousand barrels/day* | 436 | 772 | 1062 | 1338 |
| Natural Gas (CIMS) | *billion cubic feet/day* | 16.8 | 17.3 | 18.9 | 17.3 |
| Coal Mining | *million tonnes* | 68 | 71 | 77 | 86 |
| Electricity Generation | *TWh* | 545 | 576 | 612 | 651 |
| Petroleum Refining | *million $m^3$* | 102 | 103 | 108 | 116 |
| Ethanol | *TJ* | 30 | 149 | 226 | 309 |

### Energy prices

CIMS also requires an external forecast for energy prices. As for sectoral output, fuel prices can change while a policy scenario is running if the policy induces changes in the cost of fuel production. Reference case prices for most fuels through 2020 are derived from the recent energy outlook published by NRCan (the industrial and electricity coal price forecasts were derived from forecasts by the U.S. Environmental Protection Agency), with some modification based on the latest NEB forecasts. Table 93 shows the fuel price forecast that was used to develop the reference case forecast in this report – the values differ slightly by province depending on supply costs and taxation; the values for Ontario are provided. Like the other forecasts that are used as inputs to CIMS, it should be recognized that the fuel price forecast adopted here is highly uncertain, particularly in

[31] Notes: [a] chemical product output is the sum of chlor-alkali, sodium chlorate, hydrogen peroxide, ammonia, methanol, and petrochemical production
[b] industrial mineral output is the sum of cement, lime, glass, and brick production
[c] pulp and paper output is the sum of linerboard, newsprint, coated and uncoated paper, tissue and market pulp production
[d] natural gas production includes coal bed methane

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.

**Table 93: Ontario reference case price forecast for key energy commodities**

| | *Units* | *2005* | *2010* | *2015* | *2020* |
|---|---|---|---|---|---|
| Crude Oil (WTI) | *$2006US / barrel* | 62.45 | 87.32 | 65.55 | 58.13 |
| Natural Gas | | | | | |
| Industrial | *2005$ / GJ* | 9.97 | 9.63 | 8.56 | 8.71 |
| Residential | *2005$ / GJ* | 13.31 | 12.62 | 11.43 | 11. 30 |
| Commercial | *2005$ / GJ* | 10.93 | 11.01 | 9.90 | 9.87 |
| Electricity Generation | *2005$ / GJ* | 10.03 | 9.00 | 8.63 | 8.89 |
| Coal | | | | | |
| Market | *2005$ / GJ* | 2.87 | 3.36 | 3.36 | 3.36 |
| Electricity Generation | *2005$ / GJ* | 2.57 | 3.00 | 3.00 | 3.00 |
| Gasoline | *2005$ / GJ* | 25.27 | 31.07 | 25.98 | 23.33 |
| Diesel (Road) | *2005$ / GJ* | 23.39 | 28.25 | 23.36 | 20.87 |
| Electricity | | | | | |
| Industrial | *2005$ / GJ* | 17.73 | 18.03 | 19.12 | 19.37 |
| Residential | *2005$ / GJ* | 24.04 | 24.72 | 25.48 | 27.39 |
| Commercial | *2005$ / GJ* | 20.74 | 21.41 | 23.15 | 25.41 |

Note: All prices in Canadian dollars.

## *Reference case energy and emissions outlook*

Based on the key economic assumptions highlighted above, we used CIMS to develop an integrated reference case forecast for energy consumption and GHG and CAC emissions through 2020.  The CIMS model captures virtually all energy consumption and production in the economy.

The reference case forecast for total energy consumption is shown in Table 94, while Tables 26 through 28 show natural gas, refined petroleum product, and electricity consumption, respectively.  The residual energy consumption of other fuel types (total minus natural gas, refined petroleum products, and electricity) is not explicitly shown in this report.

**Table 94: Reference case total energy consumption**

| | Units | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| **Demand Sectors** | | | | | |
| Residential | PJ | 1,384.35 | 1,381.04 | 1,402.70 | 1,456.88 |
| Commercial | PJ | 1,129.75 | 1,221.61 | 1,335.12 | 1,462.06 |
| Transportation | PJ | 2,619.60 | 2,753.89 | 3,043.36 | 3,355.77 |
| Manufacturing Industry | PJ | 2,298.52 | 2,347.48 | 2,428.93 | 2,519.10 |
| Waste | PJ | 69 | 71 | 73 | 75 |
| Agriculture | PJ | 209 | 201 | 196 | 197 |
| **Supply Sectors** | | | | | |
| Crude Oil | PJ | 592 | 916 | 1,381 | 1,853 |
| Natural Gas | PJ | 704.72 | 705.72 | 706.72 | 707.72 |
| Coal Mining | PJ | 21 | 22 | 23 | 24 |
| Utility Electricity Gen. | PJ | 3,675.45 | 3,688.41 | 3,760.77 | 3,850.48 |
| Petroleum Refining | PJ | 372 | 383 | 414 | 456 |
| Ethanol | PJ | 0 | 0 | 0 | 0 |
| ***Total*** | ***PJ*** | 13,075.88 | 13,692.22 | 14,764.98 | 15,957.05 |

Note: Producer consumption of energy (e.g., consumption of hog fuel in the pulp and paper sector or refinery gas in the petroleum refining sector) is included in these totals. Energy consumption in the electricity generation sector includes consumption of water, wind, nuclear, and biomass using coefficients adopted from the International Energy Agency.[32]

**Table 95: Reference case natural gas consumption**

| | Units | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| **Demand Sectors** | | | | | |
| Residential | PJ | 636 | 634 | 643 | 649 |
| Commercial | PJ | 547 | 601 | 668 | 736 |
| Transportation | PJ | 13 | 7 | 10 | 10 |
| Manufacturing Industry | PJ | 750 | 765 | 799 | 824 |
| Waste | PJ | 0 | 0 | 0 | 0 |
| Agriculture | PJ | 27 | 26 | 26 | 25 |
| **Supply Sectors** | | | | | |
| Crude Oil | PJ | 282 | 477 | 703 | 875 |
| Natural Gas | PJ | 639 | 627 | 618 | 544 |
| Coal Mining | PJ | 3 | 3 | 3 | 3 |
| Electricity Generation | PJ | 394 | 538 | 740 | 943 |
| Petroleum Refining | PJ | 66 | 70 | 79 | 90 |
| Ethanol | PJ | 0 | 0 | 0 | 0 |
| ***Total*** | ***PJ*** | **3,357** | **3,749** | **4,289** | **4,699** |

[32] 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. Nuclear electricity generation is assumed to require 1 GJ of energy for each GJ of thermal energy generated.

**Table 96: Reference case refined petroleum product consumption**

| | Units | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| **Demand Sectors** | | | | | |
| Residential | *PJ* | 108 | 68 | 32 | 19 |
| Commercial | *PJ* | 98 | 84 | 78 | 83 |
| Transportation | *PJ* | 2,603 | 2,739 | 3,022 | 3,332 |
| Manufacturing Industry | *PJ* | 157 | 144 | 144 | 155 |
| Waste | *PJ* | 0 | 0 | 0 | 0 |
| Agriculture | *PJ* | 145 | 137 | 132 | 133 |
| **Supply Sectors** | | | | | |
| Crude Oil | *PJ* | 77 | 73 | 71 | 97 |
| Natural Gas | *PJ* | 25 | 25 | 27 | 24 |
| Coal Mining | *PJ* | 8 | 8 | 8 | 8 |
| Electricity Generation | *PJ* | 130 | 105 | 81 | 57 |
| Petroleum Refining | *PJ* | 96 | 92 | 91 | 92 |
| Ethanol | *PJ* | 0 | 0 | 0 | 0 |
| ***Total*** | ***PJ*** | **3,447** | **3,475** | **3,687** | **4,000** |

**Table 97: Reference case electricity consumption**

| | Units | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| **Demand Sectors** | | | | | |
| Residential | *PJ* | 547 | 596 | 654 | 718 |
| Commercial | *PJ* | 485 | 537 | 589 | 642 |
| Transportation | *PJ* | 3 | 7 | 8 | 9 |
| Manufacturing Industry | *PJ* | 695 | 709 | 713 | 722 |
| Waste | *PJ* | 0 | 0 | -1 | -1 |
| Agriculture | *PJ* | 37 | 37 | 38 | 39 |
| **Supply Sectors** | | | | | |
| Crude Oil | *PJ* | 45 | 56 | 71 | 86 |
| Natural Gas | *PJ* | 40 | 42 | 50 | 47 |
| Coal Mining | *PJ* | 4 | 4 | 4 | 4 |
| Electricity Generation | *PJ* | 0 | 0 | 0 | 0 |
| Petroleum Refining | *PJ* | 20 | 18 | 19 | 20 |
| Ethanol | *PJ* | 0 | 0 | 0 | 0 |
| ***Total*** | ***PJ*** | **1,875** | **2,005** | **2,145** | **2,287** |

Based on total energy consumption as well as on process emissions in the industrial sector and supply sectors, we calculate the GHG emissions associated with the reference case forecast (Table 98). In the absence of new policies to control GHG emissions, emissions are expected to grow in all sectors of the Canadian economy. Especially strong growth is expected in the crude oil sector as a result of rapidly expanding output.

**Table 98: Reference case GHG emissions**

| | Units | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| **Demand Sectors** | | | | | |
| Residential | *Mt of $CO_2e$* | 41.6 | 38.6 | 39.0 | 39.6 |
| Commercial | *Mt of $CO_2e$* | 34.6 | 35.5 | 37.8 | 40.7 |
| Transportation | *Mt of $CO_2e$* | 187.8 | 199.4 | 221.7 | 246.3 |
| Manufacturing Industry | *Mt of $CO_2e$* | 85.3 | 85.2 | 87.2 | 90.0 |
| Waste | *Mt of $CO_2e$* | 24.7 | 28.5 | 29.5 | 30.5 |
| Agriculture | *Mt of $CO_2e$* | 58.8 | 51.7 | 47.0 | 48.2 |
| **Supply Sectors** | | | | | |
| Crude Oil | *Mt of $CO_2e$* | 63.9 | 94.9 | 135.2 | 162.4 |
| Natural Gas | *Mt of $CO_2e$* | 64.0 | 63.7 | 62.8 | 55.7 |
| Coal Mining | *Mt of $CO_2e$* | 2.3 | 2.2 | 2.4 | 2.6 |
| Electricity Generation | *Mt of $CO_2e$* | 130.2 | 118.8 | 112.7 | 108.5 |
| Petroleum Refining | *Mt of $CO_2e$* | 21.0 | 20.2 | 22.0 | 24.3 |
| Ethanol | *Mt of $CO_2e$* | 0.0 | 0.0 | 0.0 | 0.0 |
| ***Total*** | ***Mt of $CO_2e$*** | **714** | **738** | **797** | **848** |

Note: CIMS does not include $N_2O$ from nitric and adipic acid, $N_2O$ used as an anaesthetic and a propellant, halocarbons, forestry and land use change emissions, and “other and undifferentiated production” in Canada’s national GHG inventory, PFCs from aluminum production are included in CIMS.