BC hydro

Integrated Resource Plan

Appendix 6B-1

Greenhouse Gas Reduction Scenarios for the Western Interconnection: (2010-2050)

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Scenario Development and Methodology Report for BC Hydro 2011 Integrated Resource Plan

January 2011

Energy+Environmental Economics

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1 Overview

In 2008, Energy and Environmental Economics (E3) assisted the British Columbia Transmission Corporation (BCTC) in developing scenarios for the “Section 5” Long-Term Electricity Transmission Inquiry conducted by the British Columbia Utilities Commission. The purpose of the inquiry was to consider a 30-year provincial perspective on the need for electricity transmission infrastructure. The inquiry considered future demand for electricity; expected resource opportunities; renewable electricity potential in British Columbia and opportunities to optimize the provincial benefit from the potential to develop renewable, low carbon electricity, including an assessment of the external market for this electricity.

As part of the Section 5 work, E3 developed three scenarios: 1) A “Baseline” scenario, 2) A Low Greenhouse Gas (GHG) Reductions Scenario, reflecting a 30% reduction in GHG emissions by 2050 across the Western Interconnection, and 3) A High GHG Reductions Scenario, reflecting an 80% reduction in GHG emissions by 2050 across the Western Interconnection.

These three scenarios have been updated for the purposes of informing the BC Hydro 2011 Integrated Resource Plan (IRP).[1] This report describes how GHG emissions and electricity demand for each of the Greenhouse Gas Scenarios

[1] Note that all years referenced in the report are in calendar years, not fiscal years.

were developed. In addition, the Scenario results are compared to other studies that have forecast the future impacts of GHG reduction policies in Canada and the United States. The greenhouse gas scenarios are based on a forecast of energy demand in the Western Interconnection through the year 2050.

1.1 Background and Purpose of the Analysis

BC Hydro is in the process of developing a long-term resource plan, known as the 2011 Integrated Resource Plan. As part of the resource planning process, BC Hydro is interested in reflecting the potential impacts of current and future greenhouse gas reduction legislation on the need for new demand-side management efforts and new electric infrastructure. The future impact of electrification on the BC Hydro system, as part of a greenhouse gas reduction effort, is of particular interest to BC Hydro. British Columbia legislation (Bill 44, 2007) requires a provincial-wide reduction in greenhouse gas emissions to 33 per cent below 2007 levels by 2020 and a reduction to 80 per cent below 2007 levels by 2050.

In the United States, and in Canada as a whole, there remains significant uncertainty about whether federal greenhouse gas reductions policies will be enacted. In 2008, when the Section 5 scenarios were under development, a federal proposal in the U.S. House of Representatives, the “Waxman-Markey” bill (HR 2454), would have required a reduction in emissions of 83 per cent below 2005 levels by 2050. Today it appears far less certain that comprehensive greenhouse gas legislation will pass in the United States. However, emission reductions are being pushed forward through other means, including through regulatory measures by the Environmental Protection Agency. It remains possible that some form of emission reductions measures could still affect electricity sector resource planning across Canada and the United States in coming years.

Yet even if the legislative targets for greenhouse gas reductions in Canada and the United States were clear, there would still remain substantial uncertainty about how and when greenhouse gas reductions would be achieved. Given that the future impacts of both provincial and federal greenhouse gas (GHG) reduction policy on the BC Hydro electric system are uncertain, it is appropriate for the BC Hydro 2011 Integrated Resource Plan to use a scenario-based approach to assess different futures for resource planning. For these purposes, BC Hydro retained E3 to update the British Columbia Utilities Commission Section 5 analysis that E3 performed.

1.2 Description of Scenarios

The Section 5 analysis considered three scenarios for future demand for low-carbon electricity and, hence, transmission and generation infrastructure requirements within BC. These scenarios differed primarily in the level of economy-wide GHG emission reductions that would be achieved in the Western Interconnection by 2050. The three Scenarios discussed in this report are summarized below:

- Scenario 1 does not include a binding North American wide, GHG emissions target, so it does not include overall emission reduction measures or specific assumptions about the use of offsets.

- Scenario 2 assumes that a future North American emission reduction policy achieves a 30 per cent reduction in GHG emissions by 2050 relative to 2008 emissions levels. Under Scenario 2, 10 per cent of the total required emission reductions in 2050 may be met with offsets. The remaining per cent emissions reductions must be met with reductions in fossil fuel use (using some combination of conservation and energy efficiency, fuel substitution, electrification and low-carbon electricity generation). While the total offsets amount is capped for the Western Interconnect as a whole, individual states and provinces may use different shares of offsets. British Columbia, for example is assumed to exceed the North American GHG target, achieving a 50 per cent reduction in GHG emissions relative to 2008 by 2050. For British Columbia, 35% of total 2050 emissions savings come from offsets in 2050.
- Scenario 3 assumes that a future North American emission reduction policy requires an 80 per cent reduction in GHG emissions by 2050 relative to 2008 emissions levels. Scenario 3 is inspired by the emission reduction targets in the BC “Greenhouse Gas Reduction Targets Act” of 2007 and the proposed (but never passed) “Waxman-Markey” Act bill in the United States. Scenario 3 allows 30 per cent of the total required emission reductions in 2050 to be met with offsets. The remaining reductions must be met with reductions in fossil fuel use. Like Scenario 2, while the total offsets amount is capped for the Western Interconnect as a whole, individual states and provinces may use different shares of offsets. In Scenario 3, British Columbia, for example, meets the Scenario 3 overall GHG target with 35% of total 2050 emissions savings coming from offsets.

1.3 Scope of Emission Reductions Included in the Analysis and the Treatment of Offsets

Each of the three Scenarios considered in this analysis assumes a different level of GHG emissions across the Western Interconnection. To develop these Scenarios, a forecast of CO_2 emissions resulting from the combustion of fossil fuels is developed for each Scenario. For the purposes of this analysis, only CO_2 emissions from the combustion of fossil fuels are considered, rather than total GHG emission reductions. The sources and sinks of GHG emissions that are not explicitly included in this analysis include non-fossil fuel emissions from forestry, agriculture and cement, methane, nitrous oxide and certain man-made gases, such as refrigerant gases. These non-fossil fuel emissions constitute only a small percentage of total GHG emissions in North America.[2]

Reductions in non-fossil fuel emissions, as well as all GHG reductions outside the Western Interconnection, are defined as an “offset” for the purposes of this analysis. More specifically, offsets are treated as any form of GHG reduction that does not originate from one of four main emission reduction measures evaluated and applied within the zones of the Western Interconnection: energy efficiency & conservation, fuel switching (biofuels and natural gas vehicles), electrification and low-carbon electricity. For example, reductions in non-fossil fuel combustion GHG emissions, such as a reduction in agricultural emissions due to improved, no-till farming practices, would be counted as an “offset.” In contrast, consumer demand response to higher fuel prices, resulting in lower

[2] According to the U.S. Environmental Protection Agency GHG emissions inventory, CO2 emissions from fossil fuels represented 94 per cent of total United States emissions in 2007 (net of all sources and sinks). US EPA (April 2009), 2009 US Greenhouse Gas Emissions Inventory.

energy consumption and lower GHG emissions would be categorized as a form of conservation.

1.4 Geographic Zones, Economic Sectors & Fuels Included in Analysis

The geographic scope of the Scenario analysis includes British Columbia, Alberta, and the Western United States. This region is known as the Western Interconnection. This geographic scope was originally chosen because it is the feasible electricity trading area for British Columbia. The Western Interconnection is modeled as 11 zones based largely on the topology of the western transmission system: British Columbia, Alberta, and nine other North American zones which roughly correspond to state boundaries. Oregon, Washington and Northern Idaho are modelled as one zone, the “Northwest”.

In each Scenario, a consistent share of CO_2 emission reductions is assumed to be achieved in all zones with the exception of British Columbia’s electricity sector. British Columbia’s electricity sector CO_2 emissions are currently very low due to the large numbers of hydroelectric and other renewable generation facilities in British Columbia. As a result, it is assumed that British Columbia does not need to further reduce CO_2 emissions in its electricity sector to the extent of the rest of the zones. In addition, electric energy efficiency measures do not reduce GHG emissions in B.C. because the electricity sector is already assumed to be decarbonized.

Energy demand and CO_2 emissions are calculated for each zone by sector. The two primary sectors in the analysis are the electricity sector and a sector for all other fuel use outside of the electric sector. Electricity use and fuel use are tracked for the residential, commercial, industrial and transportation sectors. Sub-sectors in the transportation sector include light-duty vehicles, heavy-duty vehicles, and energy use by ships in port. Energy use from aviation and ships that are not in port is excluded from the analysis.[3]

Emission reduction measures are applied to each zone and each sector separately for each of the years in the analysis. The zones, sectors and fuels in the analysis are listed in the tables below.

Table 1. Zones Included in Analysis

Zones
Arizona-Southern Nevada
California
Colorado
Montana
New Mexico
Nevada
Northwest (Oregon, Washington & Northern Idaho)
Utah-Southern Idaho
Wyoming
Alberta
British Columbia

[3] 70% of "Other Petroleums" category of the transportation fuels is included in the baseline analysis to exclude the estimated 30% of aviation petroleum included within this category. Two per cent of the "Heavy Fuel Oil" category under the transportation fuels is included in the baseline to adjust for fact that the analysis only includes heavy fuel oil used for ships in port, not energy used by ships while at sea.

Table 2. Fuels Included in the Analysis by Sector

Sectors	Fuel Types by Sector
Electricity	Coal, natural gas, low-carbon generation
Fuel (non-electric)	
Residential	petroleum, natural gas, coal, bio-gas
Commercial	petroleum, natural gas, coal, bio-gas
Industrial	petroleum, natural gas, coal, bio-gas
Light-Duty Transportation	motor gasoline, bio-diesel, natural gas, LPG
Heavy-Duty Transportation	diesel, ethanol
Ships in port	bunker fuels

2 Methodology

2.1 Summary of Approach

Each Scenario requires that CO_2 emissions and demand for low-carbon electricity in North America be forecast for the period 2010 through 2050. These are estimated through a multi-step process:

- First, a baseline energy demand and CO_2 emissions forecast is established for the Western Interconnection as a whole, as well as for each sub-region.
- Second, CO_2 emission reduction measures are applied to reduce CO_2 from the baseline forecast to meet the GHG reduction target for a given Scenario. For each Scenario, options to reduce CO_2 emissions from fossil fuel combustion include:
  - *Conservation and efficiency:* Conservation and efficiency means reducing energy consumption. This can be achieved for example by driving less, changing the thermostat, or investing in more energy-efficient vehicles, appliances or buildings. Conservation and efficiency can result from consumers' price response to higher fuel prices, or due to specific programs to encourage conservation and efficiency. Energy efficiency is applied first in the emission reduction "loading order" as it is generally the most cost-effective source of emissions savings.

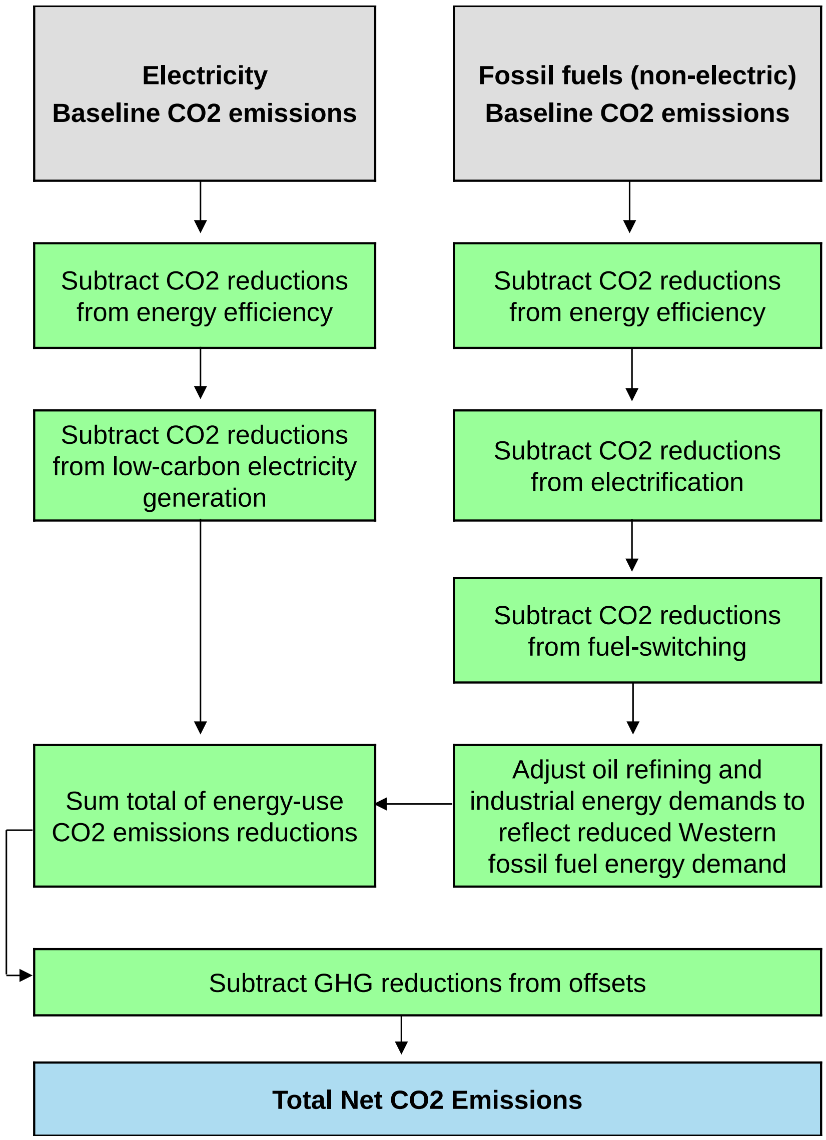
- *Fuel substitution:* Fuel substitution means replacing fossil fuels with low carbon fuels such as biofuels or hydrogen, or switching from conventional vehicles to natural gas vehicles. Fuel substitution can be the result of technology innovation, price response or other incentives to encourage fuel switching. Fuel switching is assumed to be relatively limited in both Scenarios 2 and 3, given current projections of high-costs associated with zero-carbon biofuels or hydrogen fuels. Fuel switching in the form of natural gas vehicles is also fairly limited because the GHG emissions savings from these vehicles are not very large.
- *Electrification:* Electrification means replacing fossil fuels with electricity generated from low-carbon resources, such as with plug-in hybrid-electric cars and trucks, electric water heaters or electric space heaters. Electrification can be the result of technology innovation, price response or other incentives. Electrification is used as the "swing" emissions reduction resource, used to ensure that Scenarios 2 and 3 achieve the GHG emissions target set for each scenario.
- *Low-carbon electricity:* Low-carbon electricity means replacing electricity generators that burn fossil fuels, such as coal and natural gas, with low-carbon generation technologies such as renewable power, large hydroelectric power, nuclear power or fossil generation with carbon capture and sequestration. Low-carbon generation can be developed as a result of technology innovation, price response or other incentives. Greenhouse gas emissions reductions from low-carbon electricity are assumed to be equivalent to the total GHG reduction targets set in Scenarios 2 and 3, respectively.
- *Offsets:* Offsets are other sources of emission reductions which are not included in the categories above, and which may come

from GHG reductions outside of the fossil fuel and electricity sectors. Examples of offsets include emission reduction measures achieved in the forestry sector through forest management techniques, in the agriculture sector through no-till farming practices, or in any other sector outside the Western Interconnection.

+ The demand for energy associated with fossil fuel extraction and oil refining in the non-B.C. industrial sectors is also proportionally reduced, to reflect reduced end-use demand for fossil fuels in the transportation, residential and commercial sectors. This final step reflects the feedback loop on fossil fuel energy demand that would be expected to occur under a Western Interconnection-wide greenhouse gas reduction strategy. As the West shifts away from fossil fuel use, it is expected that upstream oil refining and other industrial fossil fuel extraction energy demands would be proportionally affected, reducing demand for these products. However, we do not assume that British Columbia production of natural gas would be reduced by policies to cut GHG emissions. This is because B.C.'s natural gas production is relatively low-carbon compared to other fossil fuels, and natural gas itself is a relatively low-carbon fuel. B.C.'s natural gas production is assumed to displace the use of coal or other higher-carbon fuels in other regions of the Western Interconnection or the world.

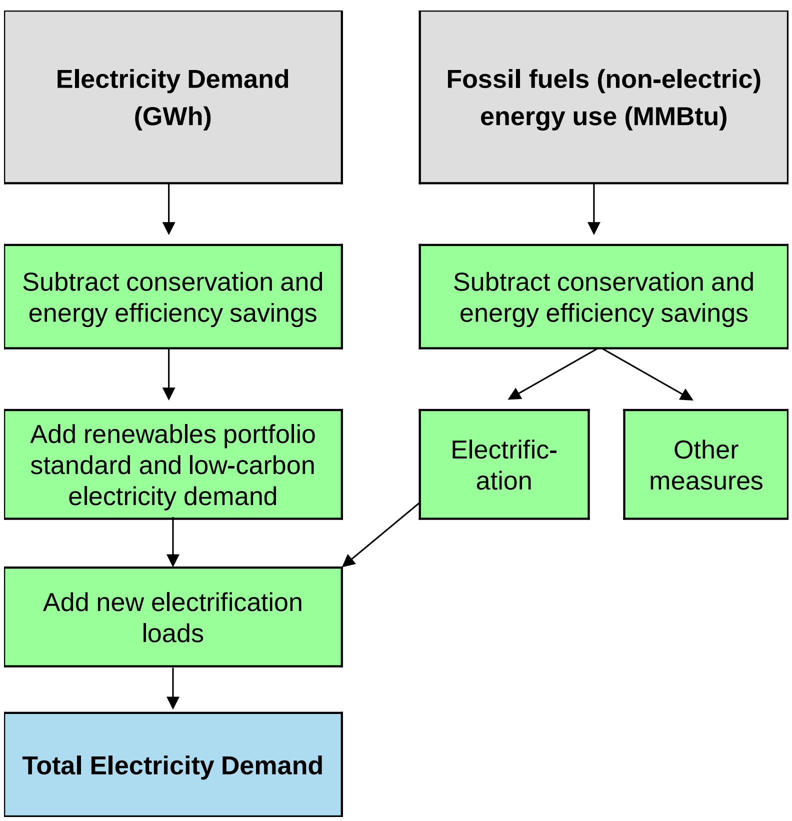
The steps involved in calculating CO_2 emissions from the electricity sector and from fossil fuel use, for each Scenario, are shown in Figure 1.

Figure 1. Flow Chart of CO_2 Emissions Calculation by Scenario



As part of the Scenarios modeling, we also track the impact of CO_2 emission reduction measures in each Scenario on demand for low-carbon electricity in the Western Interconnection. Specifically, in each Scenario, energy efficiency reduces electricity demand while electrification increases electricity demand. The assumption is that all incremental electrification electricity demand will be met with low-carbon generation resources. The net effect of energy efficiency and electrification generates a forecast of total low-carbon electricity demand for each Scenario. The steps involved in calculating low-carbon electricity demand are shown in Figure 2 below. Note that electrification reduces energy use from fossil fuels but results in increased demand for low-carbon electricity.

Figure 2. Flow Chart Showing Steps to Develop Estimates of Low Carbon Electricity Demand



A forecast of new electrification demand in British Columbia, including the impacts of transportation sector electrification in British Columbia, are provided to BC Hydro for the development of British Columbia domestic electricity demand for each Scenario.

2.2 Baseline Energy Demand and Greenhouse Gas Emissions

2.2.1 DATA SOURCES

Baseline United States energy demand

A baseline estimate of future energy demand by sector, fuel-type and region in the United States is developed using the United States Department of Energy, Energy Information Administration's 2010 Annual Energy Outlook.[4] The Annual Energy Outlook (AEO) provides a forecast of energy demand and CO_2 emissions for all sectors of the U.S. economy by geographic region. The AEO Reference Case forecast, published in May 2010, is used for the forecast of energy demand from 2010 through 2030. The AEO forecast is extrapolated an additional 15

[4] *Annual Energy Outlook 2010 - With projection to 2035.* Energy Information Administration; Office of Integrated Analysis Forecasting; U.S. Department of Energy: Washington, DC 20585, May 2010; DOE/EIA-0383(2010) http://www.eia.doe.gov/oiaf/archive/aeo10/index.html

years to 2050, based on the last five year trend of the forecast data through 2035.

We made one additional adjustment to the EIA energy use forecast: under the EIA's 2010 Reference case, a significant amount of "coal-to-liquids heat and power" energy use is shown coming on-line in 2033 in the U.S. Pacific Northwest. Interviews with EIA modeling staff revealed that this coal-to-liquids fuel was being "selected by their model" based on a number of economic assumptions around the cost of producing coal-to-liquids fuels. We decided to eliminate this increase in coal-to-liquids fuels in the Pacific Northwest starting in 2033, given that there is currently zero coal-to-liquids in that region and there is no evidence that it will be coming on-line in the future.

The AEO reference case forecast includes improvements in energy efficiency based on the expected natural rate of improvement in technologies. Residential energy use per capita continues declining in the AEO2010 Reference case, to 16 per cent below the 2008 level in 2035. The commercial energy use forecast includes the impact of current "American Recovery and Reinvestment Act" provisions and state energy efficiency standards. The AEO forecast includes little industrial energy efficiency; rather structural changes in the industrial sector result in declining energy demand and fuel-switching in some sectors.

In the AEO energy use forecast for the transportation sector, a combined fuel economy of 35 mpg for light duty vehicles is achieved by model year 2020. For model years 2021 through 2030, fuel economy standards are held constant at model year 2020 levels except for some small fuel economy improvements based on an economic cost-benefit analysis. Unconventional vehicle technologies approach 50 per cent of sales in 2035, with electric hybrid sales representing approximately 10% of total sales in 2035. These embedded assumptions in the AEO baseline forecast inform the amount of incremental energy efficiency and fuel-switching that is feasible to apply in Scenarios 2 & 3.

Baseline Canadian energy demand

The baseline estimate of future energy demand in British Columbia and Alberta is drawn from two data sources. The fuel use forecast (for non-electric fuels) for British Columbia and the fuel use and the electric demand forecast for Alberta are based on Canada's National Energy Board (NEB). We use the NEB's forecast 2009 Reference Case Initial Scenario: Canadian Energy Demand and Supply to 2020 – An Energy Market Assessment.[5] The NEB energy demand forecast is then extrapolated from 2020 to 2050, using the trend of the last five years of the data.

One adjustment is made to the extrapolation of Alberta commercial refined petroleum product (RPP) energy demand beyond 2020. In the NEB energy demand forecast, Alberta's commercial demand for RPP is shown growing rapidly through 2020. Rather than extrapolate the commercial RPP demand using the trend from the last five years of the forecast, which would result in high exponential growth through 2050, we instead apply the annual average growth rate of the Alberta commercial energy demand as a whole to the RPP forecast.

[5] *2009 Reference Case Initial Scenario: Canadian Energy Demand and Supply to 2020*. National Energy Board (Canada): Calgary, Alberta, July 2009, NE23-153/2009E-PDF; ISBN 978-1-100-13235-8

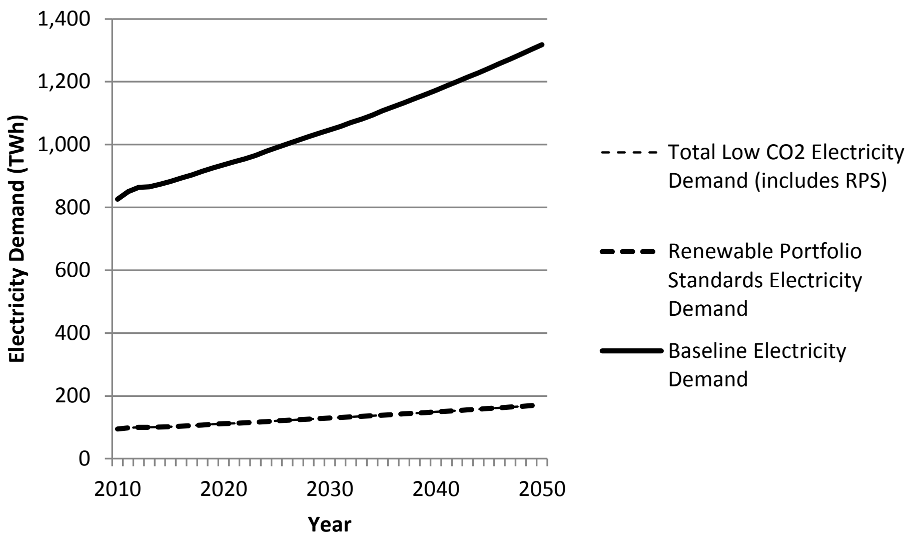
The NEB baseline forecast includes assumptions about the expected trajectory of energy efficiency within the Alberta and British Columbia economies. The residential energy forecast includes policies to slow growth in stand-by power use and other policies which affect consumer purchasing decisions. The commercial energy forecast includes provincial building codes primarily related to insulation and heating, ventilation and air conditioning minimum standards. The industrial energy forecast includes historical rates of improvements to efficiency of oil sands extraction and limited fuel switching. The transportation energy forecast includes the historical rate of adoption of hybrid vehicles. Plug-in hybrid-electric vehicles are not included in the forecast. These assumptions about energy efficiency embedded in the NEB forecast inform the amount of incremental energy efficiency and fuel switching which are applied in Scenarios 2 and 3.

In British Columbia, the electricity demand forecast from the BC Hydro December 2010 load forecast, plus Fortis BC loads, was used. The 2010 Power Smart demand-side management forecast was used for the electric energy efficiency assumptions for BC. These forecasts were extrapolated to 2050 using the growth trend between 2024 and 2029.

Total Western Interconnection electricity demand

Electricity demand forecasts for the U.S. regions, British Columbia, and Alberta are summed together to create a baseline electricity demand forecast for the Western Interconnection, shown in Figure 3 below.

Figure 3. Scenario 1: Western Interconnection Electricity Demand

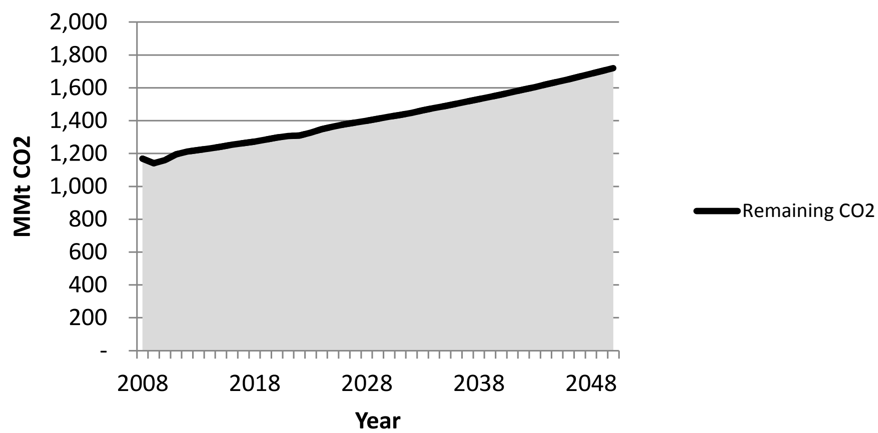


2.2.2 RESULTS OF BASELINE GREENHOUSE GAS EMISSIONS FORECAST

The energy demand forecast for each zone in the Western Interconnection is used to develop a forecast of CO_2 emissions resulting from the combustion of fossil fuels. To develop this forecast, an emissions intensity factor is applied to the fuel use forecast for each fuel type, by sector. The emissions intensity factors applied to U.S. energy demand are from Appendix H of the instructions to Form EIA-160. The emissions intensity factors applied to Canadian energy demand are from the Stats Canada catalogue no. 57-003-x.[6]

In addition, the 2008 emissions intensity of electricity for each zone in the analysis is applied to the baseline electricity demand forecast to generate a forecast of CO_2 emissions from the electricity sector that reflects the current electricity mix. This assumption of a constant emissions intensity in the electricity sector results in a baseline electricity sector CO_2 forecast that is reflective of a world that looks similar to today. The sum of CO_2 emissions from the electricity sector and the fossil fuel sectors results in the total baseline CO_2 forecast through 2050, shown in Figure 4 below.

Figure 4. Scenario 1: Baseline CO_2 Emissions Forecast from the Combustion of Fossil Fuels for the Western Interconnect



[6] Stats Canada: http://www.statcan.gc.ca/pub/57-003-x/57-003-x2008000-eng.pdf

2.3 Calculating Greenhouse Gas Emission Reductions and Electricity Demand

As described above, five measures broadly categorize GHG emission reduction options: conservation and efficiency (for both electricity and fuel use), fuel substitution (including natural gas vehicles), electrification, low-carbon electricity and offsets. GHG emission reduction targets are achieved in each Scenario by assuming that different levels of effort are applied in each of these five categories to achieve GHG reductions. Each emission reduction category is limited by existing infrastructure and the expected future availability of advanced technologies. For each emission reduction measure, changes to energy use by fuel type and sector is calculated, then CO_2 emissions are re-calculated based on these adjusted energy use forecasts.

2.3.1 ADOPTION CURVES AND TIMING OF EMISSION REDUCTION MEASURES

In the Scenarios, emission reduction measures are assumed to begin being deployed in different years, based on when the necessary technologies are expected to become commercially available.

For example, electricity energy efficiency is already being aggressively pursued in many regions, without the need for new technology breakthroughs. As a result, the Scenarios assume that electric energy efficiency efforts begin in the first year of the study. Likewise, renewable portfolio standards are already in place in many jurisdictions in the United States, and are currently leading to new renewable energy developments. As a result, low carbon electricity generation begins coming online immediately in the model.

In contrast, this analysis assumes that electric vehicles will not affect electricity demand prior to 2015, and widespread electrification in the residential, commercial and industrial sectors will not occur until after 2020. Currently, electrification is not being aggressively pursued; in fact, many utility programs encourage fuel switching from electricity to natural gas. In addition, some technology hurdles still exist before plug-in hybrid electric cars are likely to see widespread market penetration.

Fuel substitution, from fossil fuels to low-carbon biofuels or hydrogen fuels, also requires technological advancements. In the Scenarios, limited amounts of low-carbon biofuels become commercially available starting in 2025. Natural gas vehicles on the other hand are already a proven technology, so begin to be deployed in 2010, but only see limited adoptions overall because their CO_2 savings are limited by the carbon content of natural gas. Fuel conservation efforts are already underway in many jurisdictions, and so in this analysis, fuel conservation and energy efficiency are deployed starting in 2010.

The yearly assumptions regarding when each CO_2 emission reduction measure is modeled to come on-line for each Scenario are shown in the table below. The end year for each measure is 2060 in all cases, when 99% of the maximum achievement potential is assumed to be met, discussed below.

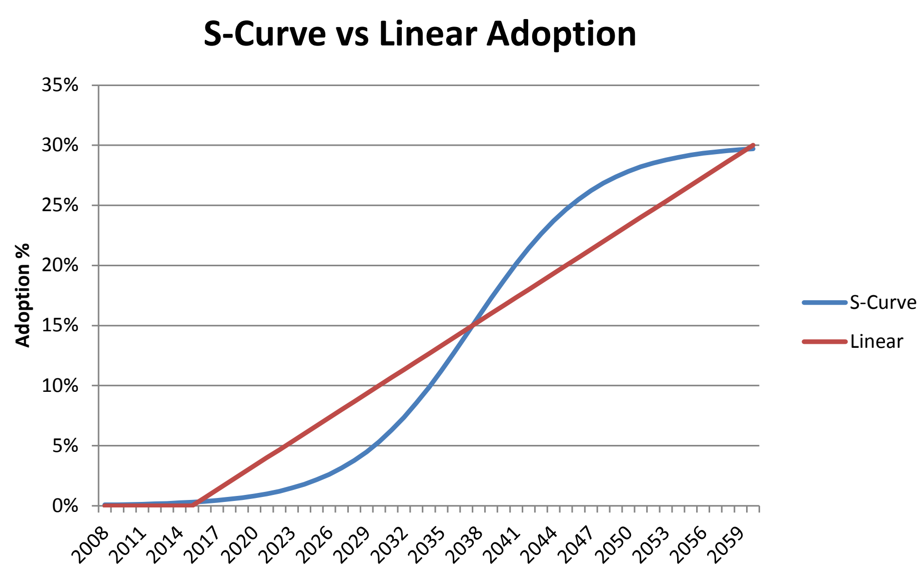
Table 3. Start Date of Emission Reduction Measures by Scenario

Sector	Scenario 1	Scenarios 2 & 3
Conservation & Efficiency	2008	2008
Renewable Portfolio Standards	2008	2008
Low carbon electricity generation to replace existing fossil generation	NA	2009
Fuel Conservation & Efficiency	NA	2010
Fuel Substitution (biofuels or hydrogen)	NA	2025
Natural gas vehicles	NA	2010
Electrification	NA	2015
Reduction in industrial refining & fossil fuel extraction energy demand	NA	2020

The result of these assumptions about the timing of emission reduction measure deployment means that electricity demand in the Western Interconnection initially climbs at about 1.3% in all scenarios, but increases rapidly after 2020 in Scenarios 2 and 3. This is because, prior to 2020, energy efficiency efforts are assumed to suppress electricity demand growth, and electrification, which would increase demand, is not yet deployed on a wide scale.

In addition to the start year of the emission reduction measure, an assumption about the rate of adoption is applied to most emission reduction measures. The rate of adoption of each emission reduction measure within a given sector is determined by a non-linear "s-curve", based on a logistic function. The s-curve is commonly used to model the saturation or penetration of new technologies into an economy.[7] In the initial stage, growth is nearly exponential, and as maturity is reached, growth slows. In our model, the s-curve is defined by three key parameters: the start-year of the emission reduction measure, the end-year at which the emission reduction measure achieves a 99% adoption, and the total, overall adoption rate in the end-state. In the example in the Figure below, the start year of the example measure is 2015, and the end year is 2060. The maximum achievable penetration level is 30% in the end state.

Figure 5. An 'S-curve" adoption rate example compared to a linear trend



While both the linear trend and the s-curve trend end-up in a similar place in 2060, the path to get to 2060 is very different in each case. Using the s-curve approach, the emissions savings are relatively low initially as emission reduction

[7] The s-curve, as applied to technology adoption and innovation is often attributed to Richard Foster in *Innovation: The Attacker's Edge*, 1986.

efforts are just beginning. The s-curve approach is applied to all of the emission reductions discussed in the next section with the exception of electric energy efficiency and de-carbonization of the electricity sector, to which linear adoption rates are applied.

2.3.2 RENEWABLE PORTFOLIO STANDARDS

Renewable portfolio standard rules stipulate that a certain percentage of a jurisdiction's retail electricity sales must be served with qualifying renewable resources. Thus, renewable electricity demand is calculated by multiplying the renewable portfolio standard target by each zone's electricity demand for a given Scenario, including the impacts of energy efficiency and new electrification load. Renewable energy demand is tracked separately from low-carbon electricity demand because current United States renewable portfolio standard policies stipulate that only certain types of renewable energy may be applied towards the renewable portfolio requirement. In particular, nuclear energy, large hydroelectric power and generation with carbon capture and sequestration do not count toward the requirement.

In Scenarios 2 and 3, renewable electricity demand resulting from a zone's renewable portfolio standard is simply a small sub-set of a zone's total low-carbon electricity demand that results from the GHG reduction targets. As a result, the renewable portfolio standard assumptions do not end up affecting the final results of the Scenarios, so we do not vary the renewables assumptions between the Scenarios. The renewable portfolio standard assumptions applied in each Scenario are shown in Table 4 below.

Table 4. Current renewable portfolio standard targets for each zone used in Scenarios 1, 2 & 3

Zone	2020, 2030 & 2040
Arizona-Southern Nevada	12 per cent
California	33 per cent
Colorado	16 per cent
Montana	12 per cent
New Mexico	16 per cent
Nevada	14 per cent
Northwest (Oregon, Washington & Northern Idaho)	16 per cent
Utah-Southern Idaho	5 per cent
Wyoming	4 per cent
United States Western Interconnection Average	*20 per cent*
Alberta	0 per cent
British Columbia	0 per cent *

*Note: Instead of a formal renewable portfolio standard, British Columbia has a requirement to generate at least 93% of the electricity in British Columbia from clean or renewable resources, based on the Clean Energy Act s.2(c), passed on June 4, 2010.

3 Scenario Results

As discussed, three Scenarios are modeled, reflecting: 1) a Baseline level of GHG emissions growth, as well as 2) Low GHG reductions, and 3) High GHG reductions. Each Scenario contains different assumptions about the deployment of low-carbon resources to reduce emissions. The Baseline Scenario is developed using forecasts of energy demand from the Energy Information Agency for the United States, and from the National Energy Board, and BC Hydro's 2011 IRP electricity demand forecast, as described above.

The High GHG Reduction Scenario is developed as a "bookend" of aggressive GHG reductions. This Scenario includes high levels of energy efficiency and conservation and fuel-switching by 2050. The remaining CO_2 savings that are needed to achieve the CO_2 reduction targets are achieved through electrification and low-carbon electricity generation. The Low GHG Reduction Scenario includes less aggressive GHG reduction measures, which are scaled back proportionally from the High GHG Reduction Scenario.

The table below presents the renewable portfolio standard and low-carbon electricity demand gaps for each of the Scenarios. The renewable portfolio standard demand gap is the difference between 2050 renewable energy demand due to current renewable portfolio standard policies and the 2008 renewable energy supply in the Western Interconnection. The low-carbon electricity gap is the amount of low-carbon electricity that is required to meet each Scenario's GHG reduction target. The renewable portfolio standard gap plus the low-carbon electricity gap results in a total low-carbon electricity gap in 2050.

Table 5. 2050 Renewable portfolio standard and low-carbon electricity demand gaps (TWh)

2050 Scenario:	Baseline	Low GHG Reductions	High GHG Reductions
Renewable Portfolio Standard Gap (TWh)	171	225	269
Low-Carbon Electricity Gap (TWh)	0	586	906
Total Low-Carbon Electricity Gap (TWh)	*171*	*811*	*1,175*

Table 5 shows that the larger the GHG reductions in a given Scenario, the larger the demand for low-carbon electricity is expected to be. This is because high levels of electrification are required to meet GHG reduction targets, offsetting the electricity savings which result from increased energy efficiency and conservation efforts. More detailed results for each of these three Scenarios are presented below.

3.1 Scenario 1: Baseline

Scenario 1 assumes that GHG reduction mandates are not established in North America through 2050, and that current commitments to reduce GHG emissions are not achieved. Therefore current energy trends continue to 2050.

Energy efficiency assumptions in British Columbia are applied that are consistent with BC Hydro's current Power Smart demand side management forecast. In the United States and Alberta, energy efficiency efforts are underway as well. However, these efforts are assumed to be largely reflected in the EIA and NEB baseline energy consumption forecasts. As a result, in Scenario 1, no additional energy efficiency achievements are included, beyond those applied in BC. Scenario 1 also includes current renewable energy standards in U.S. states. No additional emission reduction measures are implemented in this scenario.

In Scenario 1, existing renewable portfolio standards result in approximately 171 TWh of demand for renewable energy in the Western Interconnection in 2050. Since Scenario 1 does not include a North America GHG reduction target, this scenario does not include any additional demand for low-carbon electricity beyond current renewable portfolio standard requirements. The level of renewable portfolio standard electricity demand for the Western Interconnection is shown in Figure 6 and in Table 6 below.

Figure 6. Scenario 1 Western Interconnection demand for renewable electricity

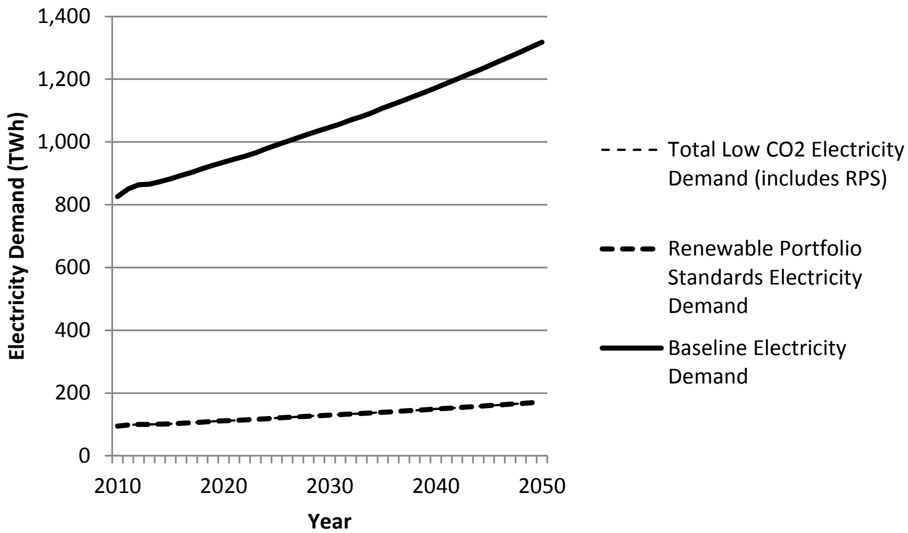


Table 6. Scenario 1: Renewable Portfolio Standards Electricity Demand

	2008	**2020**	**2030**	**2050**
Total renewable portfolio standard demand (TWh)	45	111	129	171
Low-Carbon Electricity Gap	0	0	0	0
Total Low-Carbon Electricity Gap	**45**	**111**	**129**	**171**

3.2 Scenario 2: Low GHG Reductions

Scenario 2 assumes that low GHG emission reduction targets are established for 2050. In British Columbia, the same level of energy efficiency savings are applied in Scenario 2 as in Scenario 1, at a level which is consistent with the BC Hydro's current Power Smart demand side management forecast. In the non-British Columbia zones, energy efficiency is assumed to increase relative to

Scenario 1, eliminating 20 per cent of organic[8] electricity demand growth in 2020, 50 per cent in 2030 and 85 per cent in 2050. Table 7 presents the percentage of organic electricity load growth reduction from electricity conservation and efficiency assumed for non-British Columbia zones.[9]

Table 7. Scenario 2 percentage of organic electric load growth reduction from electrical conservation and efficiency

Zone	2020	2030	2050
All non-British Columbia zones	20 per cent	50 per cent	85 per cent

In addition to energy efficiency and renewable portfolio standard targets, additional emission reduction measures are required to meet the CO_2 reduction target in Scenario 2. As a result, fuel efficiency, fuel substitution and electrification assumptions are applied to each sector and each zone.

Overall in Scenario 2, the sum of the CO_2 savings from each sector results in a reduction in fossil fuel related emissions in the Western Interconnect of 22% per cent by 2050, relative to 2008, with offsets making up the difference for a total of 30% reductions below 2008 by 2050. Offsets meet 10% of the total required reductions by 2050. Each sub-sector does not necessarily see an equal 22% per cent cut in emissions by 2050. Rather, the distribution of emission savings depends on the expected potential for reductions from each sector.

[8] As the economy grows the underlying demand for electricity increases, irrespective of policy change. This is often referred to as "organic" demand.

[9] The 2020 electric energy efficiency assumptions are benchmarked against a study that compares U.S.-wide estimates of energy efficiency potential: Sreedharan, Priya. "Energy efficiency potential in the U. S.: A review and comparison of recent estimates." Energy Policy, pending 2010. The benchmarking results show that the 20% reduction in electricity load growth for Scenarios 2 and 3 falls within the range of existing estimates of "economic potential" for energy efficiency.

For example, Scenario 2 reflects more electrification in the light-duty vehicle fleet than in any other sector, with the exception of electrification of energy use by ships that are in port. The assumption is that 100 per cent of ships' energy use, while the ships are docked in port, could be converted to electric shore power by 2050. Likewise, Scenario 2 shows only a 3% fuel substitution (conversion to biofuels or hydrogen fuel) by 2050 in the residential, commercial or industrial sectors.[10] Limited fuel substitution is seen in the transportation sectors. Table 8 presents the percentage of CO_2 emission reductions by 2050 for each sector, relative to the baseline emissions trajectory. A similar table is presented for Scenario 3 in the next section.

[10] The assumption that low-carbon biofuel potential will be relatively limited compared to other low-carbon resources is based on work by Morrow, W.R.; Balash, P. "Biomass Allocation Model – Comparing Alternative Uses of Scarce Biomass Energy Resources through Estimations of Future Biomass Energy Use for Liquid Fuels and Electricity," Office of Systems Analysis and Planning at the National Energy Technology Laboratory, U.S. Department of Energy: Pittsburg, PA, October 3, 2008, DOE/NETL2008/1302.

Table 8. Scenario 2: CO_2 emission reductions in each economic sector in 2050 relative to the baseline CO_2 forecast for each economic sector

	Per cent Reductions by 2050
Residential & Commercial	
Fuel Conservation & Efficiency	30%
Fuel Substitution (biofuels)	3%
Electrification	30%
Industrial	
Fuel Conservation &Efficiency	10%
Fuel Substitution	3%
Electrification	15%
Transportation – Light Duty Fleet	
Fuel Conservation & Efficiency	20%
Fuel Substitution (biofuels)	10%
Electrification	50%
Natural gas vehicles	5%
Transportation – Heavy Duty Fleet	
Fuel Conservation & Efficiency	20%
Fuel Substitution (biofuels)	10%
Electrification	20%
Natural gas vehicles	10%
Transportation – In-Port Shipping	
Fuel Conservation & Efficiency	5%
Fuel Substitution (biofuels)	0%
Electrification	100%
Electricity Sector CO_2 Emission Reduction Target	30%
Reduction in U.S. oil refining and fossil fuel energy demand (applied to natural gas, still gas and petroleum coke, and other industrial fossil fuel energy use)	8%
Reduction in AB oil refining and fossil fuel energy demand (applied to natural gas, still gas and petroleum coke & commercial natural gas and refined petroleum products)	10%
Percentage of total reductions in 2050 allowable from offsets	10%

Figure 7 presents the Western Interconnection CO_2 emissions forecast and the effect of the emissions reduction measures on total CO_2 emissions in Scenario 2. Each "wedge" in the chart represents the CO_2 emissions savings resulting from the emissions reduction measure. The final amount of CO_2 emissions for a given Scenario can be read off of the bottom of the lowest wedge on the chart. For example, the final CO_2 level shown in Figure 7, after calculating the effects of the emission reduction measures, is just over 800 million metric tons of CO_2 (MMt CO_2) in 2050.

Figure 7. Scenario 2: CO_2 emissions forecast and the effect of emission reduction measures

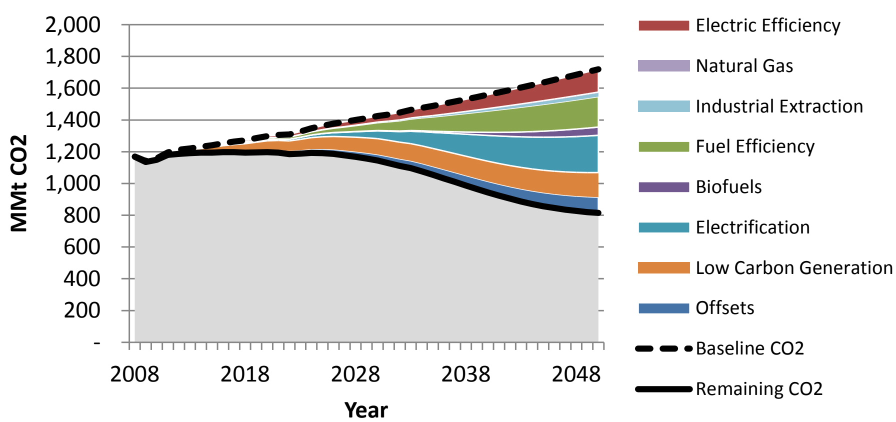


Figure 8 presents the demand for renewable energy and total low-carbon electricity demand in Scenario 2, compared to Scenario 1 total electricity demand. Table 9 below shows this information for 2008, 2020, 2030 and 2050. Table 10 presents the incremental electricity demand within British Columbia due to electrification.

Figure 8. Scenario 2: Western Interconnection demand for renewable and total low-carbon electricity.

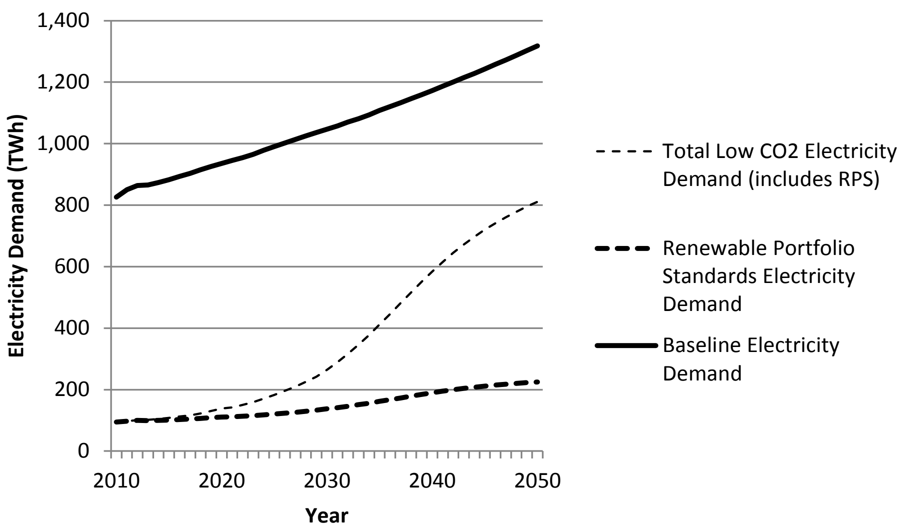


Table 9. Scenario 2: Low-Carbon Electricity Demand and Renewable Portfolio Standard Electricity Demand (TWh)

	2008	2020	2030	2050
Total renewable portfolio standard demand	45	111	138	225
Low-Carbon Electricity Gap	0	28	127	586
Total Low-Carbon Electricity Gap	**45**	**138**	**265**	**811**

Table 10. Scenario 2: Incremental electricity demand due to electrification in British Columbia (GWh)

	2020	2030	2040	2050
Residential (GWh)	152	943	2,811	3,744
Commercial (GWh)	153	1046	3,521	5,293
Industrial (GWh)	172	1123	3,860	5,697
Transportation (GWh)	380	2614	9,032	13,452
Total (GWh)	**858**	**5,725**	**19,224**	**28,185**

3.3 Scenario 3: High GHG Reductions

Scenario 3 assumes that high CO_2 emission reduction targets are established for 2050 across the Western Interconnection. Table 14 presents the percentage of organic electricity load growth reduction from electrical conservation and efficiency assumed for non-British Columbia zones. In British Columbia, energy efficiency assumptions are applied that are consistent with BC Hydro's 2011 IRP assumptions. Scenario 3 includes the same percentage savings of electric and fuel efficiency as Scenario 2 because of a "loading order" assumption which puts energy efficiency as the first priority resource for energy procurement. Furthermore, energy efficiency is generally understood to be one of the most cost-effective emission reduction measures. Therefore, it makes sense to put policies in place to achieve all possible energy efficiency first, before moving on to more expensive or less well-tested emission reduction measures. Scenario 2 includes an estimate of how much energy efficiency might be achieved under the best circumstances, so there is no need for additional energy efficiency in Scenario 3.

Table 11. Scenario 3: percentage of organic electric load growth reduction from electrical conservation and efficiency

Zone	2020	2030	2040
All non-British Columbia zones	20 per cent	50 per cent	85 per cent

Scenario 3 includes a higher GHG reduction target than Scenario 2, and as such includes more aggressive emission reduction measures. Table 15 presents the CO_2 emission reductions from the four broad categories of CO_2 emission reduction measures by 2050. Overall in Scenario 3, the sum of the CO_2 savings from each sector results in a total reduction in emissions of 42 per cent by 2050 relative to 2008, with offsets making up the remaining share of emissions reductions for a total of 80 per cent reductions below 2008 levels by 2050. However, each sub-sector does not necessarily see an equal per cent cut in emissions by 2050. Rather, the distribution of emission savings depends on the expected potential for reductions from each sector.

Table 12. Scenario 3: Emission reductions from the four broad categories of CO_2 emission reduction measures by 2050

	Per cent Reductions by 2050
Residential & Commercial	
Fuel Conservation & Efficiency	30%
Fuel Substitution (biofuels)	5%
Electrification	50%
Industrial	
Fuel Conservation &Efficiency	10%
Fuel Substitution	5%
Electrification	30%
Transportation – Light Duty Fleet	
Fuel Conservation & Efficiency	20%
Fuel Substitution (biofuels)	20%
Electrification	70%
Natural gas vehicles	5%
Transportation – Heavy Duty Fleet	
Fuel Conservation & Efficiency	20%
Fuel Substitution (biofuels)	20%
Electrification	42%
Natural gas vehicles	10%
Transportation – In-Port Shipping	
Fuel Conservation & Efficiency	5%
Fuel Substitution (biofuels)	0%
Electrification	100%
Electricity Sector CO_2 Emission Reduction Target	
Reduction in U.S. oil refining and fossil fuel energy demand (applied to natural gas, still gas and petroleum coke, and other industrial fossil fuel energy use)	10%
Reduction in AB oil refining and fossil fuel energy demand (applied to natural gas, still gas and petroleum coke & commercial natural gas and refined petroleum products)	17%
Percentage of total reductions in 2050 allowable from offsets	17%

Figure 9 presents the Western Interconnection CO_2 emissions forecast and the effect of emissions reduction measures. Figure 10 presents demand for renewable energy and total low-carbon electricity demand in Scenario 3, compared to Scenario 1 total electricity demand. This information is also presented for 2008, 2020, 2030 and 2050 in Table 11. Table 12 presents the incremental electricity demand within British Columbia due to electrification in Scenario 3.

Figure 9. Scenario 3: CO_2 emissions forecast and the effect of emission reduction measures

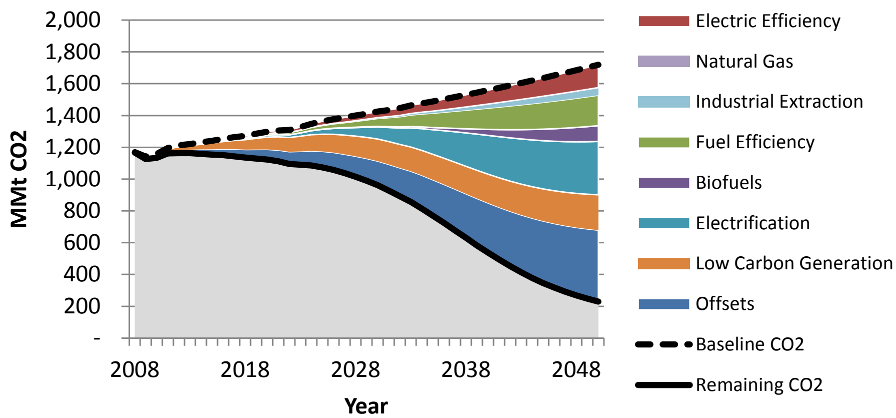


Figure 10. Scenario 3: Western Interconnection demand for renewable and total low-carbon electricity.

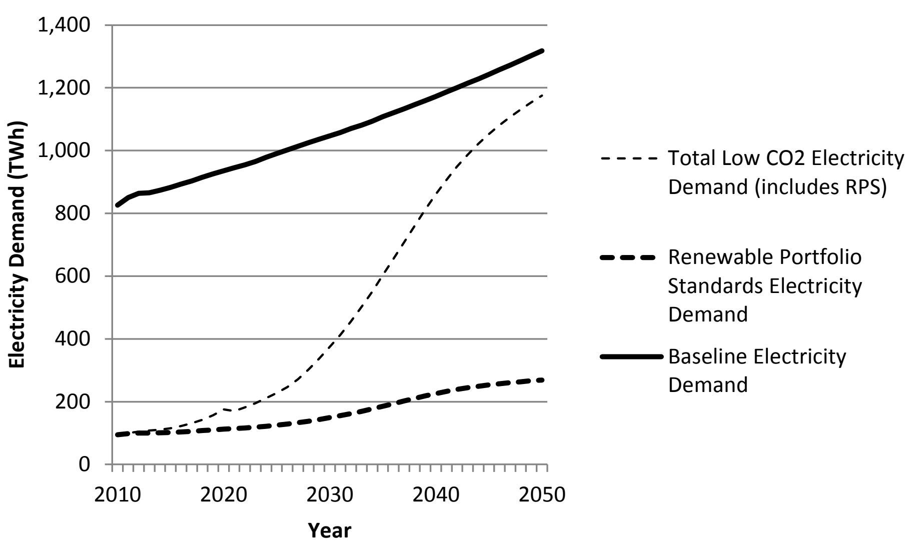


Table 11. Scenario 3: Low-Carbon Electricity Demand and Renewable Portfolio Standard Electricity Demand (TWh)

	2008	2020	2030	2050
Total renewable portfolio standard demand	45	112	149	269
Low-Carbon Electricity Gap	0	63	226	906
Total Low-Carbon Electricity Gap	**45**	**175**	**375**	**1,175**

Table14. Scenario 3: Incremental electricity demand due to electrification in British Columbia (GWh)

	2020	2030	2040	2050
Residential (GWh)	254	1570	4,653	6,127
Commercial (GWh)	256	1741	5,828	8,663
Industrial (GWh)	343	2244	7,667	11,188
Transportation (GWh)	538	3685	12,334	17,234
Total (GWh)	**1,391**	**9,241**	**30,482**	**43,212**

3.4 Electricity Demand Results for British Columbia

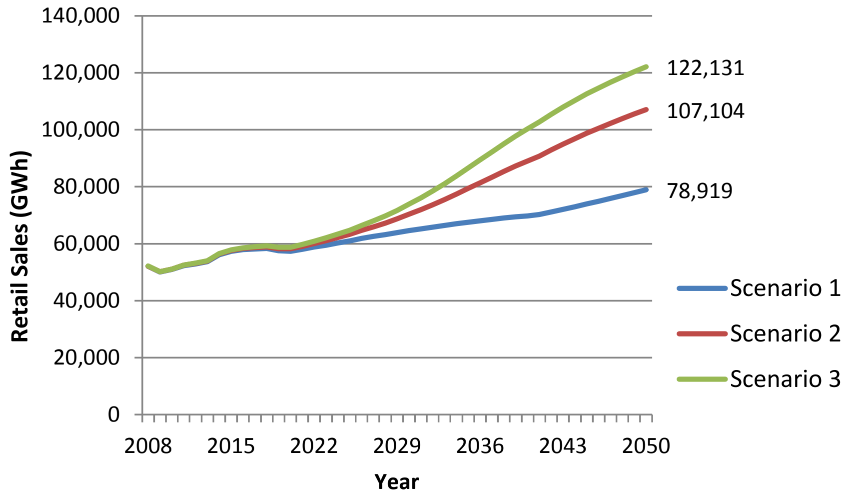
British Columbia energy and CO_2 emission reduction measures are consistent with all other zone measures with the exception of electricity energy efficiency, which is designed to be consistent with BC Hydro's current Power Smart demand side management forecast. Because British Columbia's electricity sector CO_2 emission intensity is currently much lower than many other jurisdictions, it is assumed that British Columbia does not need to reduce the CO_2 emissions associated with its electricity sector to the extent the rest of the other zones do. Furthermore, electrical energy efficiency in BC does not save

CO_2 in the model, since the province's marginal electricity generation assumed to be zero-carbon.

It is assumed, however, that British Columbia will reduce its CO_2 emissions from other sectors by the same percentage assumed in all other zones. Like other zones, in Scenarios 2 and 3, British Columbia is expected to see an increase in electricity demand due to electrification in the residential, commercial, industrial, and transportation sectors. As is the case in all zones, electricity demand growth due to electrification in British Columbia must be satisfied with low-carbon electricity resources in order to achieve CO_2 emission reduction goals.

The Figure below shows the resulting electricity demand in British Columbia under all three scenarios. The difference between the scenarios is due to the magnitude of electrification.

Figure 11. British Columbia Electricity Retail Sales by Scenario (2008 – 2050)



4 Benchmarking Results and Input Assumptions

4.1 Comparing Total Savings and Offsets Assumptions

The scenario analysis considers three Scenarios, each resulting in a different level of CO_2 emissions in the Western Interconnection. In these Scenarios, CO_2 reductions from energy efficiency and electrification result in different levels of demand for clean electricity in 2020, 2030 and 2040, both in British Columbia and in other zones in the Western Interconnection. Other recent studies have also assessed the potential impact of GHG reductions on the electricity sector through 2040. This section compares the findings of these Scenarios with two other recent GHG reduction studies:

1) "A Technology Roadmap to Low-Carbon Emissions in the Canadian Economy: A Sectoral and Regional Analysis" study of the Canadian Economy, prepared for the National Round Table on the Environment and the Economy (NRTEE), referred to here as the "NRTEE study,"[11] and

[11] Peters, J., Bataille, C., Bennett, M., Melton, N., and Rawson, B. (2008). *A technology roadmap to low GHG emissions in the Canadian economy: a sectoral and regional analysis*. Report prepared for the NRTEE. J&C Nyboer and Associates: Vancouver, British Columbia.

2) The United States Environmental Protection Agency (EPA) Analysis of the American Clean Energy and Security Act of 2009, referred to here as the "EPA study."[12]

While all of these studies consider deep reductions in GHG emissions, each study applies unique assumptions about the availability of offsets to meet these GHG reduction goals in place of reductions in fossil fuel emissions, and applies unique assumptions about the role that conservation, energy efficiency, electrification and other technologies will play in meeting long-term GHG reduction goals. As a result, the impact of GHG reduction scenarios on the electricity sector is different in each study.

However, it is not straightforward to compare the results between studies. This is because the geographic scope of each study is different: Canada, the United States and the Western Interconnection. This means that each study begins from a different baseline level and sectoral distribution of GHG emissions. In addition, while the EPA study includes a significant share of GHG savings from international and domestic offsets, the NRTEE study does not include offsets, while the BC Hydro Scenarios include a range of offsets. Other differences include the relative reliance on different technologies in each study, as well as the type and scope of GHG emissions that are included in each study. These studies are compared to current BC Hydro scenarios in Table 13:

[12] U.S. Environmental Protection Agency (EPA) Analysis of the American Clean Energy and Security Act of 2009, available at: http://www.epa.gov/climatechange/economics/pdfs/HR2454_Analysis.pdf

Table 15. Comparison of GHG Reduction Studies

Name of Study	Geographic Scope of Analysis	Emissions Reduction Target	Emissions included in analysis
NRTEE study	Canada	65 per cent reduction from 2006 by 2050	Includes most sources of GHG emissions except methane and nitrous oxide emissions from agriculture and the production of adipic and nitric acid, among other minor sectors
EPA study	United States	83 per cent below 2005 by 2050	All GHGs
BC Hydro Scenarios	Western Interconnection	Varies by Scenario: No reduction target, 30 per cent and 80 per cent below 2008 by 2050	CO_2 emissions from the combustion of fossil fuels only

Some of the other key differences between the studies are described below:

- ***Biofuels:*** In the NRTEE study, there is a higher reliance on biofuels than in the other studies. This means that in the NRTEE study more CO_2 savings can be obtained from biofuels and less vehicle electrification is needed to reduce GHG emissions than in the BC Hydro Scenarios.
- ***Offsets:*** In the EPA study, a large share of GHG reductions is met with domestic and international offsets, including “banked” offset credits. Banked credits are saved, or “banked,” from over-compliance in the early years of the cap and trade program and used in later years of the program as a credit towards emission reduction obligations. This means that fewer reductions are required from the fossil fuel sectors, especially the United States transportation sector. As a result of offsets, the transportation sector does not show large reductions in GHG emissions in the EPA study. The NRTEE study does not include offsets.

- ***Electrification:*** In the EPA study, new developments in transportation technologies are not explicitly modeled. It appears as if transportation electrification is not an emission reduction option in the macroeconomic models (ADAGE and IGEM) that are run by the EPA. Since the EPA study includes so many domestic and international offsets (2 billion metric tons of CO_2-equivalent per year plus any banked offsets from earlier compliance years), the EPA study shows that large emission reductions are not required in the transportation sector to meet the GHG target. As a result, there is little, if any electrification in the EPA study. This leads to lower electricity demand in the EPA GHG reduction scenarios relative to the EPA baseline. The opposite is true in the NRTEE and BC Hydro Scenarios, where electrification leads to higher electricity demand under the GHG reduction scenarios.

Table 14 compares the annual average growth rates in electricity demand for the three studies. The EPA study produces a GHG reduction scenario that has less electricity demand than the EPA Reference case level of electricity demand. This is because the EPA study includes high levels of energy efficiency and conservation and almost no incremental electrification.

The NRTEE study shows high levels of electricity demand growth in the early years of the study timeframe, at 3.3 per cent average growth per year between 2010 and 2020, and 1.9 per cent annual average growth thereafter. BC Hydro Scenarios 2 and 3 show electricity demand remaining relatively constant between 2010 and 2020 across the Western Interconnect because the effects of electric efficiency and new electrification loads are relatively small and counter-balance each other. Scenarios 2 and 3 show load growth picking up significantly across the Western Interconnect after 2020 due to increasing electrification. The NRTEE GHG reduction scenario shows higher growth rates between 2010 and 2020 compared to both Scenarios 2 and 3 between 2020 and 2040 because of NRTEE's higher reliance on efficiency and biofuels in the later years.

Table 16. Study Comparison of Electricity Annual Average Growth Rates

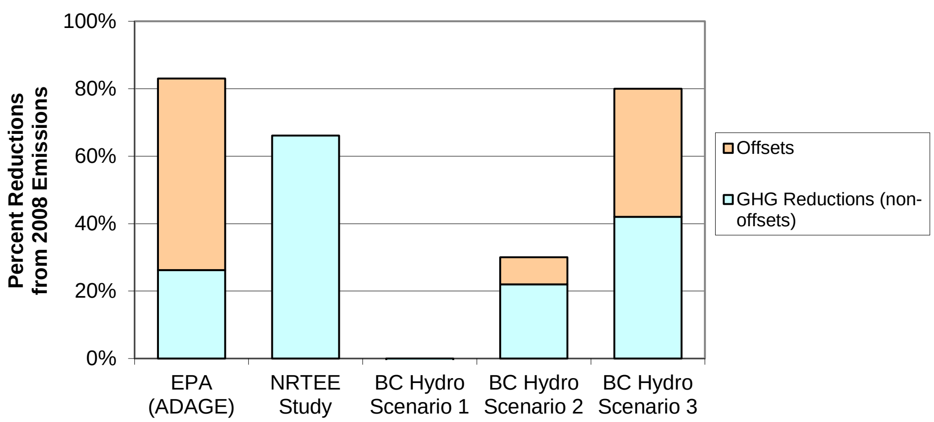
Annual average electricity growth rate	2010 - 2020	2020 - 2050
EPA Reference Case	*1.0%*	*1.0%*
EPA (ADAGE) GHG Reduction Scenario	-0.1%	0.8%
NRTEE Reference Case	*1.2%*	*1.7%*
NRTEE GHG Reduction Scenario	3.3%	1.9%
BC Hydro – Western Interconnection Baseline (Scenario 1)	*1.3%*	*1.1%*
BC Hydro Low CO2 Reductions (Scenario 2)	1.2%	1.9%
BC Hydro High CO2 Reductions (Scenario 3)	1.3%	2.5%

The figure below compares the per cent reduction in GHG emissions in 2050 relative to the 2008 baseline used in each study. The figure shows that in the EPA study (using the ADAGE model), the 2050 percentage of emission reductions, relative to 2008 GHG levels, are similar to the level of reductions shown in Scenario 3. However, only about 25 per cent of emission reductions below 2008 levels are expected to come from sources of GHG emissions which are covered under the cap and trade policy (mostly emissions from fossil fuels). The remaining emission reductions are expected to come from offsets.

The NRTEE study shows slightly lower levels of reductions in Canada as Scenario 3, reducing emissions by over 60 per cent relative to 2008 levels. However, the NRTEE study does not include offsets.

In contrast, in Scenario 1, emissions levels increase relative to the 2008 levels. In Scenario 2, emissions levels fall by 30 per cent relative to 2008 levels. In Scenario 2 only 10% of total 2050 emissions savings are allowed to come from offsets, per cent and in Scenario 3, 30% of the total 2050 emissions savings are allowed to come from offsets, which is a lower amount of offsets than the EPA scenario but a higher amount than the NRTEE study.

Figure 12. Study Comparison of Percentage Reduction in GHG Emissions in 2050 Relative to 2008 Emissions Levels



The offsets assumptions applied in the BC Hydro scenarios appear conservative when compared to existing and proposed greenhouse gas cap and trade programs:[13]

[13] Summary of information contained in the Western Climate Initiative, "Offset Limit Recommendation Paper," October 6, 2009. Available at: http://www.westernclimateinitiative.org/component/remository/Cap-Setting--and--Allowance-Distribution-Committee-Documents/Draft-Offset-Limit-Recommendations-Paper/

- Under the Western Climate Initiative (WCI), "Offset Limit Recommendations," released March 18, 2010, up to 49% of total GHG emission reductions between 2012 and 2020 may come from offsets.
- Under the Regional Greenhouse Gas Initiative (RGGI) offset use is limited on an entity-by-entity basis, but is based on the principal that offset use should be limited to 50% of the total emission reduction amount.
- In the European Union Emissions Trading Scheme (EU-ETS) offset rules vary by member state, and there is no strict policy on the total amount of offsets allowed within the trading scheme. However, it appears that the levels set for use of offsets in Phase II may allow for more than 50% of reductions to be met through offsets.

Overall, the Scenarios applied here represent an appropriate range of GHG reduction and offset use strategies, with Scenarios 1 and 3 providing useful "bookends" of future GHG emission scenarios.

4.2 Comparison to the U.S. Energy Information Agency's Scenarios

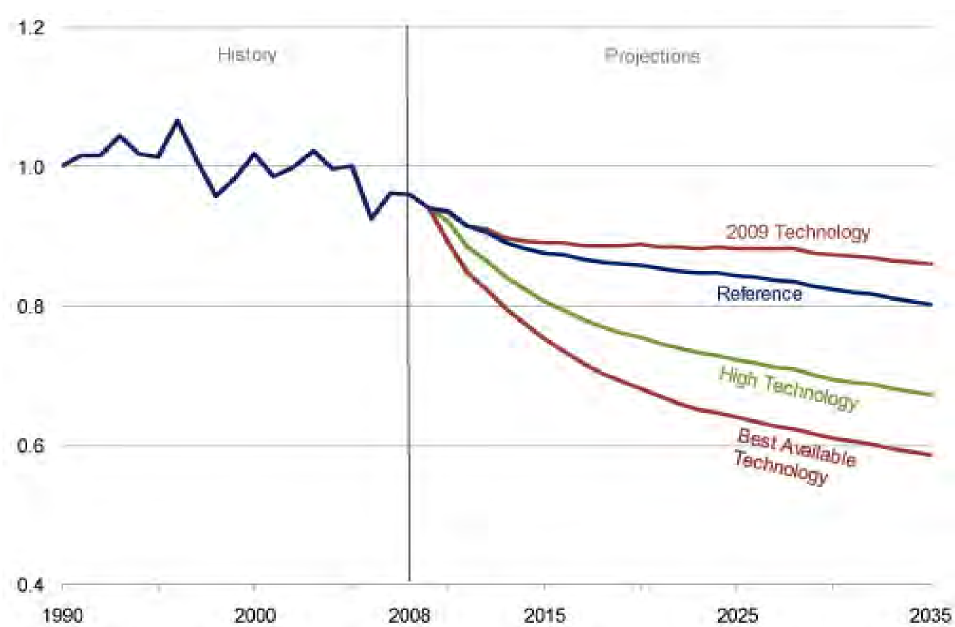
The United States' Energy Information Agency Annual Energy Outlook 2010 (EIA AEO2010) includes a number of scenarios which provide a useful comparison to the input assumptions applied in the BC Hydro scenarios. The AEO2010 includes:

- The "2009 Technology" scenario, which freezes energy use by technologies in 2009;

- The “Reference” scenario, which is the basis of the BC Hydro baseline scenario for U.S. regions;
- The “High Technology” scenario, which includes improvements to technologies beyond those considered in the Reference case; and
- The “Best Available Technology” scenario which includes an estimate of the maximum achievable improvements in energy use based on new technologies.

The figure below shows the change in residential per capita energy use under each of these scenarios.

Figure 13. Residential delivered energy consumption per capita in four cases, 1990 – 2035 (Index, 1990 = 1). Source: U.S. EIA AEO2010 Figure 42.



By comparing the change in residential per capita energy consumption between the AEO “Reference” case and the “Best Available Technology” case, we can benchmark the BC Hydro Scenario residential fuel efficiency assumptions. The EIA AEO2010 shows approximately a 25 per cent reduction in residential per capita energy consumption between the Reference Case and the Best Available Technology cases in 2035. This is compared to the 30% reduction in residential energy consumption by 2050 between the BC Hydro Baseline Scenario and Scenario 3. Given that the Scenario 3 residential fuel efficiency assumption is made over a longer time period (2050 rather then 2035) we conclude that the 30% reduction in residential fuel use by 2050 is a reasonable estimate.

We can apply a similar benchmarking logic to the commercial sector. Figure 14 below shows the four scenarios applied to commercial energy consumption in the AEO2010. It shows approximately a 20 per cent reduction in commercial per capita energy consumption in the "Best Available Technology" scenario compared to the Reference case in 2035. This is compared to the 30% reduction in commercial energy consumption by 2050 between the BC Hydro Baseline Scenario and Scenario 3. Again, given that the Scenario 3 commercial fuel efficiency assumption is made over a longer time period (2050 rather then 2035) we conclude that the 30% reduction in commercial fuel use by 2050 is a reasonable estimate.

Figure 14. Commercial delivered energy consumption per capita in four cases, 1990 – 2035 (index, 1990 = 1). Source: U.S. EIA AEO2010 Figure 42.