

**metro**vancouver

# **Carbon Neutral 2050**

## **Policy & Modelling Report**

**Version 4.2**

July, 2021

LICKER  
GEOSPATIAL  
CONSULTING CO.



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## List of Abbreviations

<b>Abbreviation</b>	<b>Definition</b>
ADU	Accessory Dwelling Unit
AL	Alaska
ALR	Agricultural Land Reserve
BAP	Business As Planned
BC	British Columbia
CAC	Criteria Air Contaminant
CARB	California Air Resource Board
CC	Carbon capture
CH <sub>4</sub>	Methane
CHE	Cargo Handling Equipment
CNS	Carbon Neutral Scenario
CO <sub>2</sub>	Carbon dioxide
COP	Coefficient of Performance (as it relates to buildings' energy)
CoV	City of Vancouver
DAC	Direct Air Capture
DPM	Diesel Particulate Matter
GHG	Greenhouse gas
GHGI	Greenhouse gas intensity
GJ	Gigajoule
GWh	Gigawatt hours
H <sub>2</sub>	Hydrogen
HDV	Heavy duty vehicle
hp	Horsepower
ICE	Internal Combustion Engines
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
LCFS	Low Carbon Fuel Standard
LDV	Light duty vehicle
MDV	Medium duty vehicle
MSC	Marine Stewardship Council
MT	Megatonne
mtCO <sub>2</sub> e	Million metric tonnes of carbon dioxide equivalents
MV	Metro Vancouver
N <sub>2</sub> O	Nitrous oxide
NFSE	Non-Forest Sensitive Ecosystems
NR	Non-road
OR	Oregon
SEI	Sensitive Ecosystem Inventory

PJ	Petajoules
R100	R100 Renewable Natural Gas
RE	Renewable energy
RNG	Renewable natural gas
RT	Rapid transit
tCO2e	Metric tonnes of carbon dioxide equivalents
TAZ	Traffic Analysis Zone
VKT	Vehicular kilometres travelled
WA	Washington
WTE	Waste-to-energy
ZEV	Zero emission vehicle

## Introduction

The goal of this project is to understand and quantitatively evaluate the impact of a set of policies to reduce greenhouse gas emission activity across the region in accordance with IPCC 1.5°C climate stabilization targets adopted by the Metro Vancouver Board: a 45% reduction by 2030 from a 2010 base year, and a carbon neutral region by 2050.<sup>1</sup>

The policies and activities are intended to inform a series of *Climate 2050* issue area roadmaps being developed under the *Climate 2050 Strategic Framework* and other policy and planning initiatives in the region. It will also inform the development of policies and actions in the *Clean Air Plan*, Metro Vancouver's 10-year air quality and greenhouse gas management plan. This report details the policies, performance assumptions and results in a deep emission reduction future as well as a business as planned future.

### Metro Vancouver Context

#### *General Context*

Climate change profoundly affects the planet and the region. Without strong action and decisive leadership, warming trends will accelerate and cause irreversible changes to the environment with immense consequences to public and personal property and infrastructure, regional prosperity, and ecosystem functionality including water accessibility and agricultural productivity. Impacts will have profound social implications, compromising human health and exacerbating inequity. In response, Metro Vancouver has declared a climate emergency and set an ambitious goal to achieve carbon neutrality by 2050. Metro Vancouver's *Climate 2050 Strategic Framework* has begun to articulate next steps across key sectors.

This project aims to identify, test and evaluate a suite of achievable and aggressive actions that can assist the region with meeting its targets. To this end, a model was developed to understand the Business-As-Planned (BAP) future, and evaluate the effect of various regional policies under a "Carbon Neutral Scenario" (CNS) to meet 2030 and 2050 targets.

#### *Current Emission Activity*

Regional emission activity in the 2010 baseline model is dominated by transportation (41%, including rail, aviation and marine), followed by buildings (31%), industry and non-road (8%), and then smaller shares of agriculture and waste (3% each) (Figure 1). The vast majority of emissions are energy related, resulting from fossil fuel combustion that generates carbon dioxide (CO<sub>2</sub>). Agriculture and waste emissions include methane (CH<sub>4</sub>) from livestock digestive systems (mostly cattle) and decomposition of organic waste in landfills in the absence of oxygen. The largest sector, transportation, is heavily dominated by light duty

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<sup>1</sup> Metro Vancouver. (2019) *Climate 2050*. A climate strategy for the Metro Vancouver Region. Accessed: <http://www.metrovancouver.org/climate2050>



vehicles (i.e. passenger cars and light trucks/vans/SUVs), followed by medium and heavy duty vehicles (long haul and intraregional), as well as, marine, rail, and aviation emissions. In order to maintain consistency with the data and methods used for the modelled scenarios, this baseline differs slightly from the 2010 backcast in the Metro Vancouver 2015 emissions inventory.

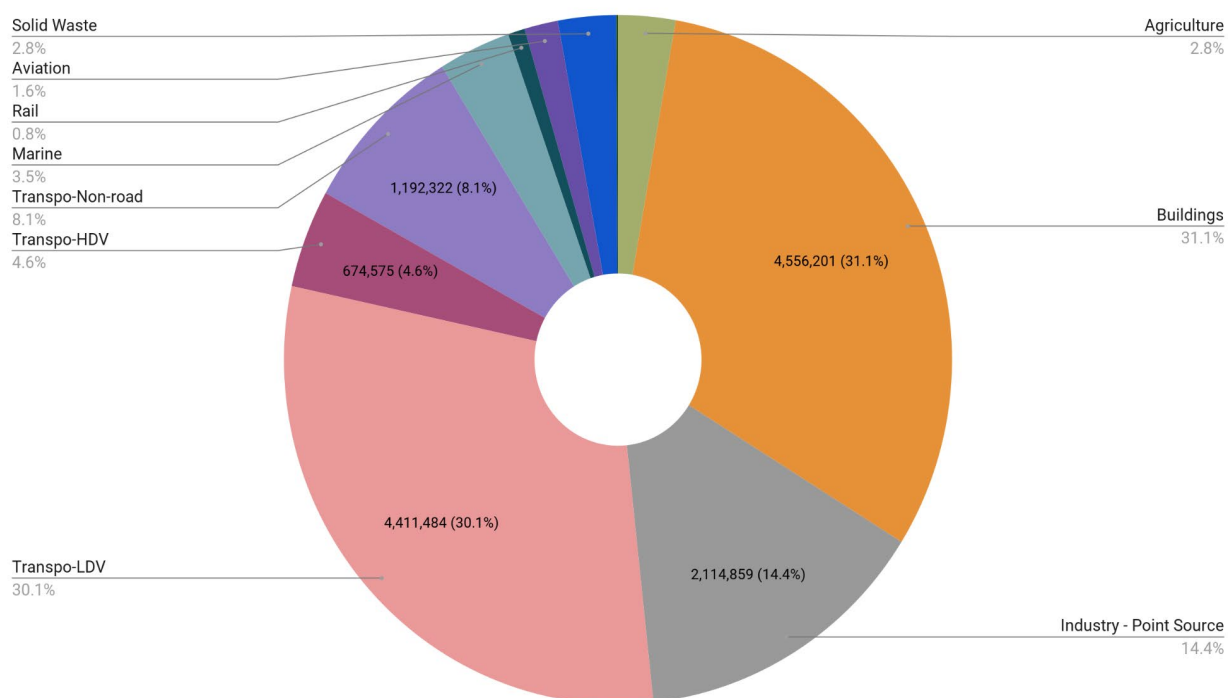


Figure 1. 2010 Base Year Emission By Sector Profile for Metro Vancouver Regional District

### Future Scenarios Overview

A *Business As Planned (BAP)* scenario out to 2050 was developed based on policies and plans currently existing or in advanced states of development by all orders of government with authority and influence over emission activity. Due to updates in data sources, evolving emissions accounting methods and updates to diverse regional trends, including new policies, the BAP scenario may slightly differ from Metro Vancouver's forecasts in the 2010 emissions inventory.

A *Carbon Neutral Scenario (CNS)* out to 2050 was shaped by a set of policies, actions and measures (referred to as Policies within this report) developed for each sector. These Policies were informed by technology currently available in the market or expected in the near future, as well as policies in leading jurisdictions in B.C., Canada, across North America, and Europe. Market transformation was contextualized for Metro Vancouver with an appreciation of the distinct authority and influence of municipal, regional, provincial and federal governments. A set of policies with performance assumptions was developed by the modelling team and the policy makers and practitioners with deep sectoral knowledge in Metro Vancouver and relevant agencies from provincial and federal governments. The

nature and intensity of these Policies were defined by an “aggressive and achievable” principle, meaning that the policies modelled are technologically achievable and may require aggressive action by policy makers. The policies modelled reduce emissions by decreasing overall energy demand and transitioning from fossil fuels to zero and low carbon energy sources.

This modelling also estimates regional ecosystem carbon sequestration to assess sequestration potential to contribute to the regional goal of carbon neutrality by 2050. Large emitter carbon capture and utilization or storage is explored through industry sector modelling. Direct air capture is not explored in this modelling.

## Methods Summary

### Description of model(s)

Modeling for this project was completed by an interdisciplinary team operating in a coordinated modeling framework. Given the extremely wide range of emissions modeled and the large geographic context, modeling was completed with an aim towards transparency, reproducibility, cross-platform functionality and simplicity. Overarching assumptions and scenario inputs for modeling were developed in conjunction with Metro Vancouver staff and stakeholders and applied to the model activity outlined below:

- **Land Use:** The modelling of future land use was based around Metro Vancouver's 2050 household and employment projections at the neighbourhood level, which guides how much floor area is created in a particular area. In turn, typologies of floor area constructed were guided by neighbourhood archetypes, which were assigned based on the floor area that currently exists in a neighbourhood. To model the Carbon Neutral Scenario, the same logic was used except that employment and household projections were updated to reflect an intensification of growth in sustainable and walkable areas. This component of the modelling incorporated spatial modelling and datasets.
- **On-road Transportation:** Including light duty (LDV) and medium/heavy duty vehicles (HDV), the modelling of on-road transportation is largely characterized by growth in vehicle stock, driving activity, engine efficiency, fuel use and the move to zero emission vehicles, typically through electrification. While there are Federal and Provincial policies driving this change, there are also economic factors that will heavily influence the rate and scale of this transition.
- **Buildings:** The modeling of buildings energy and emissions was done using a modified version of BC Hydro's Excel based Policy Impact Estimator (PIE 2018) software. This model uses building archetypes by sector, with policy reductions applied year by year to determine changes in consumption. The baseline year is calibrated with utility data to ensure alignment with actual energy consumption.

- **Industry:** Modelling of the industry sector was performed using Metro Vancouver's industrial emitters inventory, compiled based on air quality permits used to manage air emissions from large industrial and commercial emitters. Sector and facility growth projections are based on historical production data collected from annual reporting completed as a permit requirement, and from industry economic growth projections.
- **Non-road:** Modelling was based on a national emissions simulation and forecast completed by ECCC for Metro Vancouver using the US EPA NONROAD emissions model, allocated to the Metro Vancouver region. The simulated rates of growth were retained, although growth from 2035 to 2050 was reduced by 25% based on expectations of Metro Vancouver and the Project team.
- **Agriculture:** Modeling for the agriculture sector was completed using Metro Vancouver 2015 emissions inventory as a basis and updated with forecasts for growth in the livestock and greenhouse agricultural sub-sectors.
- **Marine:** Modelling for this sector is based on updated information from the Environment and Climate Change Canada (ECCC) national marine emissions inventory for the 2015 year (with forecasts), allocated to the Metro Vancouver region. The ECCC model results were supplemented with data from the Port of Vancouver model for cruise ship activity and for forecasted rates of cargo growth for the dominant cargoes in the region (cruise, container, bulk). The Port of Vancouver data was also used to refine the impacts of select policies in this sector (e.g., use of shore side power for berthing).
- **Rail:** Rail modelling was based on the existing Metro Vancouver inventories, which in turn stem from the port's 2015 emissions inventory and forecasts for cargo-based rail in the Lower Fraser Valley. Passenger rail estimates are also consistent with Metro Vancouver, which were produced from a Railway Association of Canada inventory for 2015, scaled for future years based on Diesel demand projections from the National Energy Board
- **Aviation:** Modeling utilized the Metro Vancouver inventories, with the forecasted rates of growth to 2035 extended out to 2050.
- **Waste:** The waste sector was modeled using population-based forecasts of liquid and solid waste production, which were allocated to waste handling facilities that produce point-source emissions. Facility emissions were estimated based on a combination of emissions factors for each waste stream, and in the case of landfills, first-order decay modelling of methane production from organic carbon sources. Emissions attributed to solid waste sent to out of region facilities were captured using appropriate emissions factors.

- **Nature and Ecosystems:** This sector incorporated information from the MVRD Regional Carbon Storage Dataset and applied a spatial modelling approach to determine annual regional carbon sequestration. The modelling of future sequestration rates for forests was performed using age-over-height curves as an estimate of total carbon per hectare (tC ha<sup>1</sup>) per tree species. The MVRD Regional Carbon Storage Dataset was used to calculate current tree age, which are then projected forward appropriately. Future tC ha<sup>1</sup> is calculated for projected years and considers impacts on sequestration from future land use developments. Soil sequestration rates are considered stable unless disturbed by future land use development impacts. Non-forested sensitive ecosystem sequestration rates were estimated through literature reviews and assigned to Metro Vancouver's Sensitive Ecosystem Inventory areas.

## Data Sources

Key data sources for the modeling included:

<b>Metro Vancouver</b>	land use data, regional carbon storage dataset and sensitive ecosystems inventory data, regional emissions inventory, industrial emitters inventory, buildings data, regional climate projections data, on-road transportation calibration data, on-road fleet makeup data, liquid and solid waste data production, energy recovered from waste facilities
<b>TransLink</b>	vehicle/passenger kilometers travelled data, vehicle count data, transit system data
<b>Province of British Columbia</b>	GHG emissions factors, GHG emissions calculation methodologies, utility-measured buildings energy demand, energy utilities data for buildings, vehicle data, building data
<b>Vancouver Fraser Port Authority</b>	port emissions inventory (which includes port related shipping, off road and rail estimates), performance of shore power systems
<b>Vancouver International Airport</b>	aviation emissions inventory
<b>Environment &amp; Climate Change Canada</b>	marine emissions inventory
<b>Natural Resources Canada</b>	Landsat satellite imagery

*Table A. Key data sources*

All input data for the modeling was considered for quality, completeness and utility in the modeling before any forecasting was completed.

### **Base Datasets**

Metro Vancouver produces an inventory of air contaminants (including greenhouse gas emissions) every five years. Metro Vancouver's 2015 emissions inventory data provided the basis for 2010 base year emissions. This inventory includes community emission inventory activity for all sectors modelled in this project. This comprehensive inventory reflects Metro Vancouver's delegated authority for managing and regulating air emissions in the Metro Vancouver region. Additional datasets that informed the inventory were used as model inputs and calibration points for each sector as appropriate.

### **Common Air Contaminants (CACs) Estimation Method**

CACs were calculated using activity-based (i.e., fuel combustion or vehicle operation) methods with generally accepted emissions factors. For the most part CAC calculations were aligned and/or calibrated with Metro Vancouver projections, unless otherwise noted.

### **Greenhouse Gas Emissions Scope Assumptions**

This project covered direct (scope 1) and some indirect (scope 2, i.e., electricity) energy and emission activities across the Metro Vancouver region. As per a standard local government inventory, all transportation activity for vehicles registered in Metro Vancouver and solid waste generated in Metro Vancouver is accounted for in this project. Passthrough trips (i.e., trips that originate from outside Metro Vancouver) are excluded. Upstream and embodied emissions were excluded.

## **Results Overview**

### **BAP Overview**

#### *Overarching Assumptions*

The Business as Planned scenario (BAP) assumes patterns of projected development and policies continue across all sectors. These sectors are interrelated and influenced by contextual changes. Regional population projections suggest that population, households, and employment will increase, which in turn will result in new development. This growth will impact various sectors such as buildings and transportation.

Regional industrial sectors are also projected to continue to grow. Additionally, as time passes, technologies are expected to improve. Aging technologies become less efficient when compared to the new products replacing them. Buildings, cars and trucks have an assumed replacement cycle, with new product efficiencies improving over time.

Policies that are already in place, such as the BC Energy Step Code and the *BC Zero-Emissions Vehicles Act* (ZEV Act) are incorporated in the modeling for the BAP scenario, as well as more sector specific considerations that are discussed in their respective sections further in this report. The federal carbon price was not modelled as an influence to the BAP scenario due to uncertainties with regards to elasticities in price response. As such, BAP modeling does not reflect the updated federal carbon price policy, which will rise to \$170/tonne by 2030 and will have a potential impact on emissions in the medium term.

#### *Land Use Assumptions*

The BAP land use scenario was developed by Metro Vancouver and reflects the Regional Growth Strategy (*Metro 2040*) in its current implementation, extended to 2050 using population growth projections out to 2050. Growth is strategically allocated to areas identified in the Regional Growth Strategy, concentrated in urban areas well served by infrastructure and transit connections with access to multiple employment nodes. Less than a quarter of growth in the BAP (22%) is being directed towards less well served areas outside of urban centers. Employment growth will follow a similar pattern to that of the residential sector with slightly less employment projected for Urban Centres (38%), and slightly more projected for areas outside of urban centers or frequent transit areas (25%). Detailed expected growth percentages of Metro Vancouver's Urban Centres is provided in the table below.

<b>BAP 2016-2050 Projected Growth Pattern</b>		
Geography	Residential	Employment
All Urban Centres (UC)	<b>41%</b>	<b>38%</b>
Frequent Transit Development Areas (FTDA)	<b>37%</b>	<b>37%</b>
General Urban Outside UC or FTDA	<b>21%</b>	<b>25%</b>
Rural, Ag, Con/Rec	<b>1%</b>	<b>0%</b>

*Table B. Business as Planned 2016-2050 projected residential and employment growth.*

Under the BAP land use scenario, no changes are envisioned to the Urban Containment Boundary nor the Agricultural Land Reserve. The locations of major industrial areas do not change. Development in suburban areas such as northeast Coquitlam, rural areas in Surrey and Langley, and areas in the upper levels of West Vancouver will continue to proceed at current levels. Based on the above assumptions, the modeling assumed a region of 3.7 million persons and 1.4 million dwellings and 1.8 million jobs in the region in 2050. These growth allocation assumptions are incorporated into the BAP estimates of carbon sequestration in regional ecosystems.

### *BAP Land Use Outcomes*

Land use is not discussed as an independent sector in this report, but establishes the foundation for much energy and emission activity in the region, profoundly shaping transportation activity, housing form, and carbon sequestration through growth patterns.

The BAP land use scenario assumed a compact and connected future for the region as a result of a strong regional and municipal land use approach. The BAP land use scenario results in the following outcomes by 2050:

- Nearly 47% of new growth will occur within 1 km of existing or proposed SkyTrain stations
- 95% of growth will be built within 5 km of existing employment clusters
- 286 hectares (ha) of undeveloped land will be developed as residential housing or business areas (greenfield development), compared to 4,116 ha that is redeveloped from previous uses (infill development). Accordingly, greenfield development accounts for 9% of development area compared to 93% of development area for infill.
- 30% of new residential development will be single detached type housing, compared to 38% townhomes and 32% low- and high-rise apartments.
- 16% of existing buildings (built by 2020) will be replaced
- New construction results in a regional net forest land disturbance of 1.9%, after new tree planting on new development sites has been considered. Net forest land disturbance within the urban containment boundary is 8.9% overall.

### *BAP Results*

The Business as Planned scenario results in a **6%** emission increase by 2030 and a **7%** reduction by 2050, relative to 2010. Emissions in most sectors remain stable or rise. Passenger light duty vehicles achieve significant GHG reductions, attesting to the power of existing regulations such as the *ZEV Act*, and also the frequency with which light duty vehicles are replaced (14 years on average). Buildings also have a strong regulation in place limiting emissions from new buildings, the *BC Step Code*, but buildings have an average life of several decades. Most building emissions in 2050 under the BAP will be from buildings standing today. This is reflected in the relatively stable emissions from buildings. Other significant sources of emissions, industry and non-road, are projected to increase emissions, and offset emissions reductions from light duty vehicles. Other transportation sectors also increase emissions in the BAP scenario.

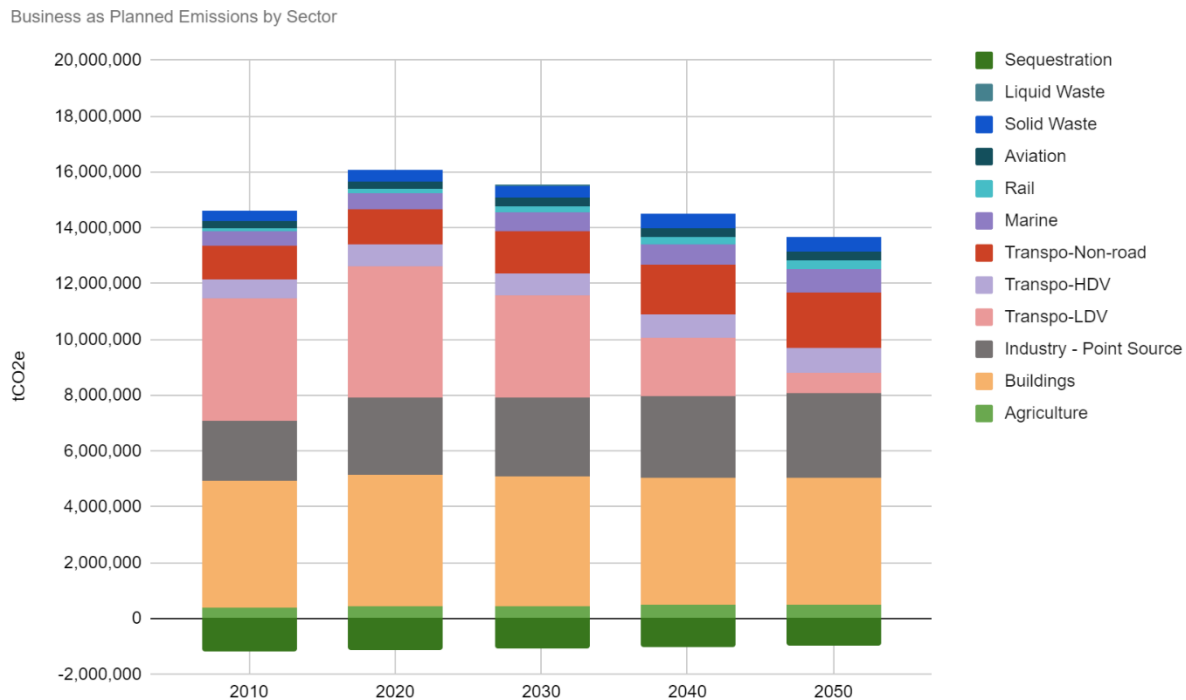


Figure 2. Business as planned emissions by sector 2010-2050.

GHG activity is primarily driven by the quantity and type of fuel used across the region. Under the BAP, the primary energy types are natural gas, electricity, diesel and gasoline. Other fuels types include coal, pet coke, marine fuels, and a small quantity of renewable biofuels. Fuel type consumption under the BAP is detailed in Figure 3. In 2010, 75% of energy came from fossil fuels and 25% came from renewables, in 2030 the balance was 73% and 27% respectively. In 2050, 67% is from fossil fuels and 33% is from renewables. In spite of increasing population and economic activity, overall energy demand decreases slightly from 2020 to 2050 as a result of efficiency improvements in key sectors, including significant decreases in gasoline use in light duty vehicles.



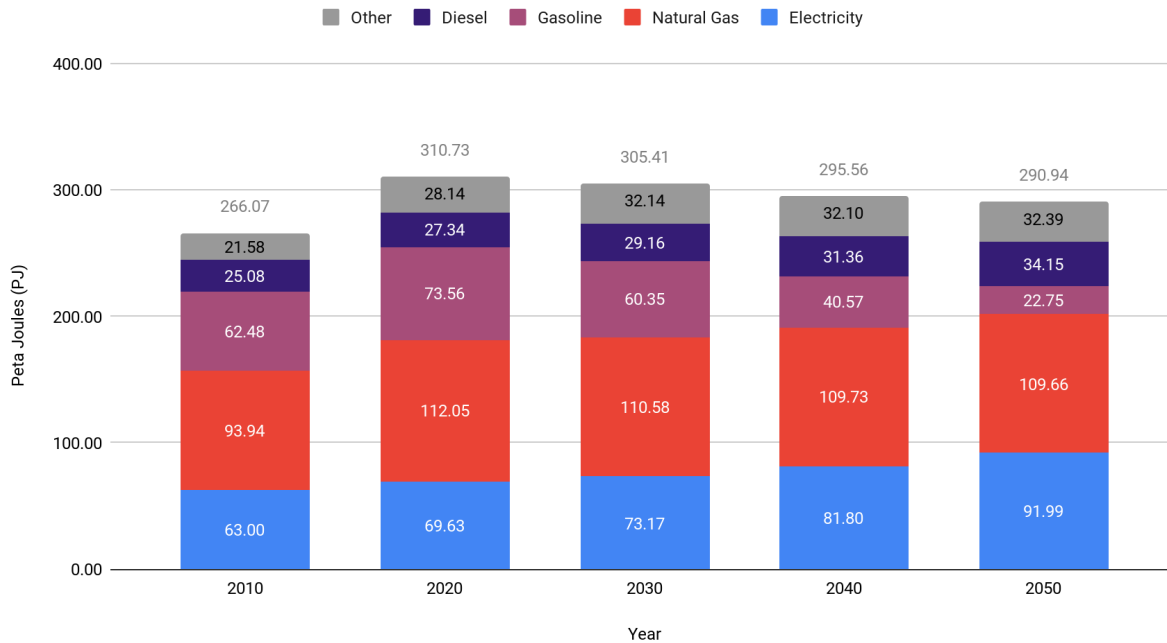


Figure 3. Total energy used under the Business as Planned scenario by decade. For reporting purposes energy (y-axis) has been converted into a standard unit of Petajoules (PJ).

Common Air Contaminants (CACs) were also modelled as part of this study for the years 2020 and 2030. The following CACs are modelled:

- Particulate Matter of 2.5 microns and smaller (PM2.5);
- Diesel Particulate Matter (DPM);
- Volatile Organic Compounds (VOC);
- Nitrous Oxides (NOx); and
- Sulfuric Oxides (SOx).

Emissions for these compounds (reported in tonnes) estimated in the BAP scenario are presented in Figure 4 below.

Modelled CAC reductions are largely a result of assuming existing trends of equipment/engine replacement continue to 2030. For example, it can be assumed that the existing relative age distribution of marine vessels or off-road equipment will persist in future years, meaning that newer equipment with lower emission rates (primarily of NOx and PM) will be introduced. The lower emission rates are well understood, since they are set through domestic and international regulations. The emissions modelling that was used for the study applies the newer emission rates in a systematic manner. This effect tends to drive down CAC emissions in the BAP more so than GHG emissions.

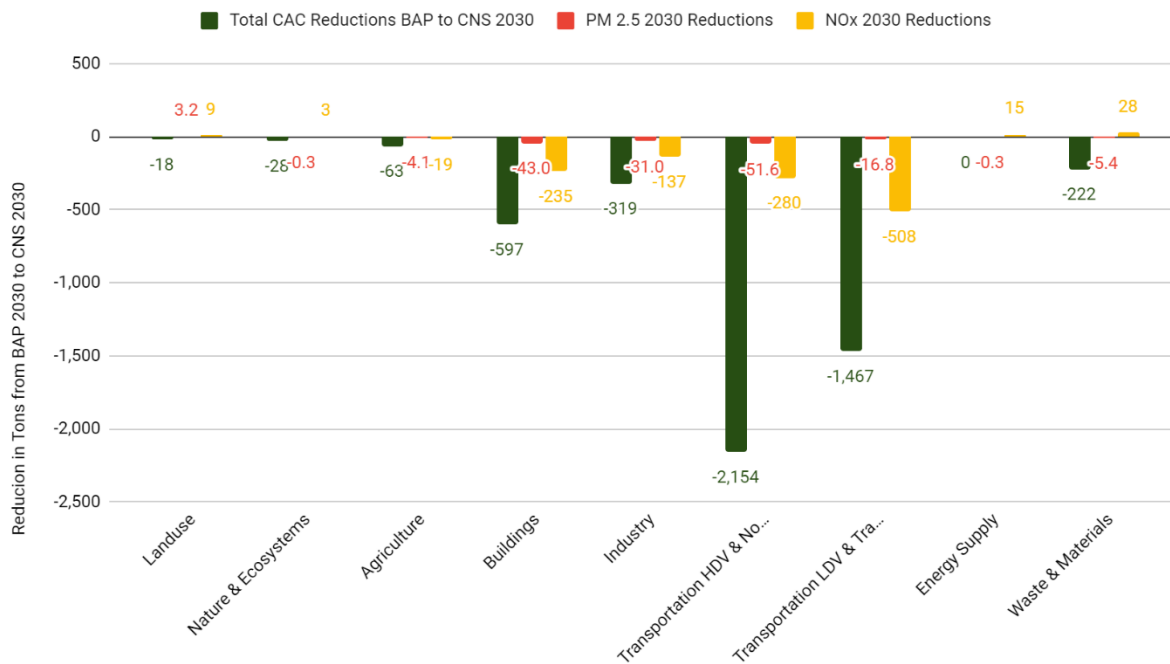


Figure 4. 2030 Annual changes relative to 2030 BAP and CNS 2030 CAC emissions.

## CNS Overview

Beyond sector-specific assumptions that are discussed at length in this report, CNS outcomes are driven by two major cross-sectoral influences, **Land Use** and **Energy Supply and Fuels**. Land use affects key sectors including on-road transportation, buildings and ecosystems and energy supply and fuels influences all sectors that use fossil fuels. The following two sections discuss these key overarching assumptions in detail:

### Key Land Use Assumptions

The CNS land use scenario was developed with Metro Vancouver and reflects a measurable enhancement beyond the BAP with regards to intensification of *Metro 2040*, the Regional Growth Strategy especially as it pertains to the co-location of residential and employment growth with frequent reliable transit in currently developed areas. The CNS land use scenario used accessibility, walkability, and flood risk as criteria to determine optimal areas for higher proportions of employment growth and household growth. Accessibility was scored based on proximity to employment, and walkability was scored based on density, land use mix and density of street intersections. Areas that were assigned high walkability and accessibility scores and low flood risk scores were overlaid with frequent transit networks, regional city centres and municipal town centres to determine locations for higher population and employment growth. This resulted in a more compact, complete land use scenario for the CNS.

The compact complete development assumed for the CNS land use scenario facilitates a number emission reduction and associated benefits across sectors by:

a. Limiting urban sprawl that:

- reduces competition for and pressure on agricultural and industrial lands
- reduces ecological disturbances caused by new development in greenfield areas
- increases redevelopment of older housing stock and commercial buildings to more efficient forms (which in turn reduces the burden to retrofit hundreds of thousands of buildings)

b. Supports residential and commercial densities that:

- can reduce travel distances and reliance on single-occupancy vehicles for daily travel
- support enhanced transit provision
- support car-sharing and other forms of shared mobility
- increase opportunities for active travel
- Reduce water demands

The following CNS growth pattern was modeled for this project.

Geography	BAP 2016-2050 Projected Growth Pattern		CNS 2016-2050 Projected Growth Pattern	
	Residential	Employment	Residential	Employment
All Urban Centres (UC)	42%	38%	54%	46%
Frequent Transit Development Areas (FTDA)	36%	37%	35%	31%
General Urban Outside UC or FTDA	21%	22%	10%	20%
Rural, Ag, Con/Rec	1%	3%	1%	3%

*Table C. Carbon Neutral Scenario 2015-2050 projected residential and employment growth.*

Under the CNS land use scenario, no changes are envisioned to the urban containment boundary or the location of major industrial areas, nor are any changes forecast for the Agricultural Land Reserve. Development in suburban areas will continue at significantly reduced levels.

## Land Use Outcomes

As in the BAP, land use is not discussed independently in this report. However, the compact land use scenario establishes the foundation for several of the aggressive transportation Policies aimed at reducing driving and mode shifting, discussed later in this report. Additionally, the CNS land use scenario impacts housing form and development patterns, as well as some carbon sequestration activity.

The CNS land use scenario builds on a highly sustainable BAP land use future. Pursuant to that future, the following outcomes result from the CNS land use growth:

- Under the CNS, nearly 57% of new growth will occur within 1 km of existing or proposed SkyTrain stations and 96% of growth will be built within 5 km of existing employment clusters, compared to 47% and 95% in the BAP respectively.
- In the CNS greenfield development will account for 4% new development compared to 9% under the BAP.
- Of new residential construction, it is expected that under the CNS 30% of new development will be single detached type housing along with 27% townhomes and 44% low- and high-rise apartments compared to 30%, 38% and 32% under the BAP.
- By 2050, it is expected that 15% of buildings built by 2020 will be replaced compared to 16% in the BAP.
- New construction under the CNS land use scenario results in a regional net forest land disturbance of 1.6%, (1.7% in the BAP) after new tree planting on new development sites has been considered. Net forest land disturbance within the urban containment boundary is 6.9% (8.9% in the BAP) for the CNS scenario.

### **Overarching Energy and Fuel Assumptions**

The CNS looks at the impact of a suite of policies designed to aggressively reduce greenhouse gas emissions through known technologies and strategies. These policies reduce emissions by switching from fossil fuels to zero and low carbon fuels, and by decreasing energy demand. These policies cover all major emissions producing sectors, and are described in more detail in subsequent sections.

As a result of the policies modelled in the CNS, significant levels of fuel switching from fossil fuels to renewable sources is projected. This study does not place a limit on the amount of electricity demand, as there is currently abundant hydroelectricity supply in British Columbia and the potential to add electrical capacity to the grid. Similarly, the study does not analyze the implications that projected biofuel demand has for supply. However, the CNS does assume a limited supply of renewable natural gas based on projections from the provincial natural gas utility, Fortis BC. Based on utility estimates, renewable natural gas available for use in the Metro Vancouver region was limited to 15 PJ in 2030 and 30 PJ in 2050. This level of use assumes a mix of renewable natural gas produced outside of the region, as well as within the region at planned waste to energy facilities. Rough estimates conducted for this project estimate that approximately 1.2 PJ in 2030 and 2.1 PJ in 2050 could be produced at regional waste facilities.

The previously stated emissions factor for BC Hydro electricity grid has declined from 25 t/GWh CO<sub>2</sub>e in 2010 to 10.67 in 2014, which was driven by grid decarbonization under the 2010 Clean Energy Act. As such, for modeling purposes it was assumed that the previously low emissions factor would remain constant to 2050 at 10.67 tCO<sub>2</sub>e/GWh. It should be noted, however, that after the completion of modeling

for this project, the BC Climate Action Secretariat indicated they would be revising the electricity emissions factor to be used by local governments up to 29.9 tCO<sub>2</sub>e/GWh<sup>2</sup> for 2019, to be used for the 2020 reporting year. This value is higher than the emissions factor used for this project. As such, emissions from electricity, while still small compared to those from fossil fuels, will be understated in this report.

## Energy and Emissions Outcomes

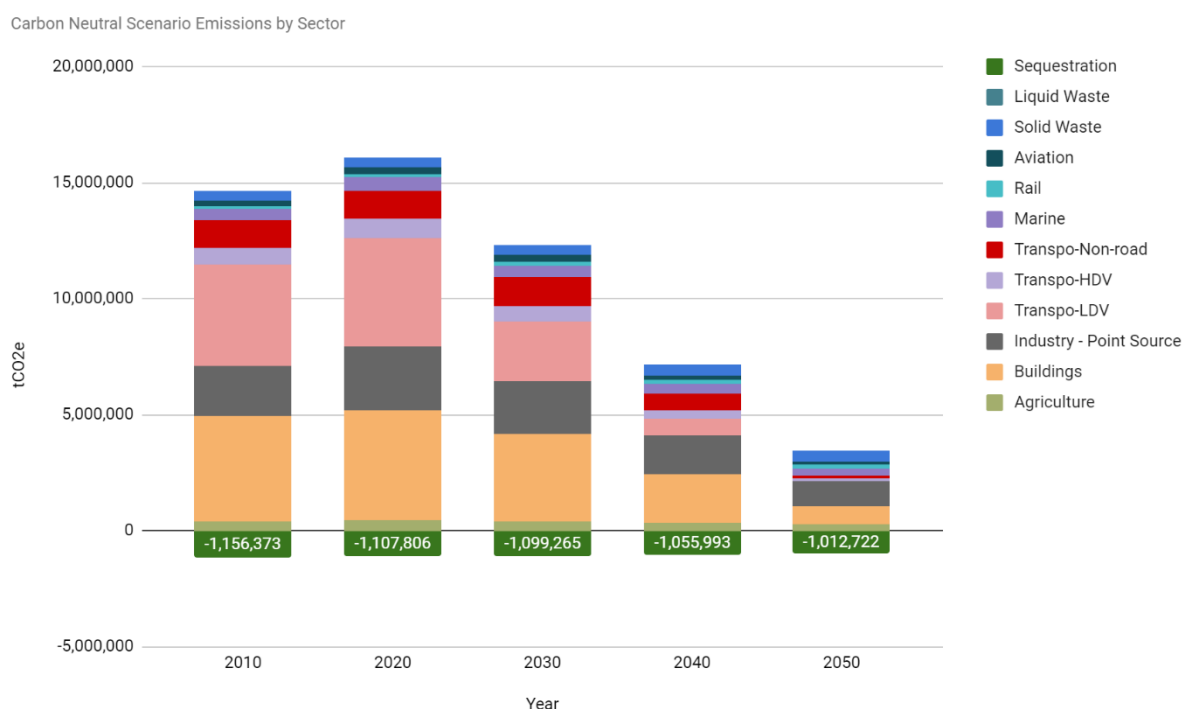


Figure 5. Emissions by sector under the CNS (tCO<sub>2</sub>e).

GHG emissions in the CNS show a sustained decline from 2020 onwards, reaching a 16% reduction in 2030 relative to 2010 emissions, and a 76% reduction by 2050. In spite of drastic emissions reductions by 2050, remaining emissions are not balanced out by annual regional ecosystem carbon sequestration. While these emissions reductions are significant, they fall short of Metro Vancouver's regional climate targets of a 45% emission reduction by 2030 and carbon neutrality by 2050.

<sup>2</sup> Government of British Columbia (Unknown Date). Electricity Emission Intensity Factors for Grid-Connected Entities. Accessed at: <https://www2.gov.bc.ca/gov/content/environment/climate-change/industry/reporting/quantify/electricity>

GHG emissions are related to the quantity and type of energy being used across the region. In contrast to the BAP, the CNS sees a shift in energy types towards electricity and other renewable sources. In 2030, 38% of energy used is from renewable sources and 62% is from fossil fuels. In 2050, 85% is renewable and 15% is from fossil fuels. Additionally, there are significant energy efficiency improvements that reduce overall energy consumption.

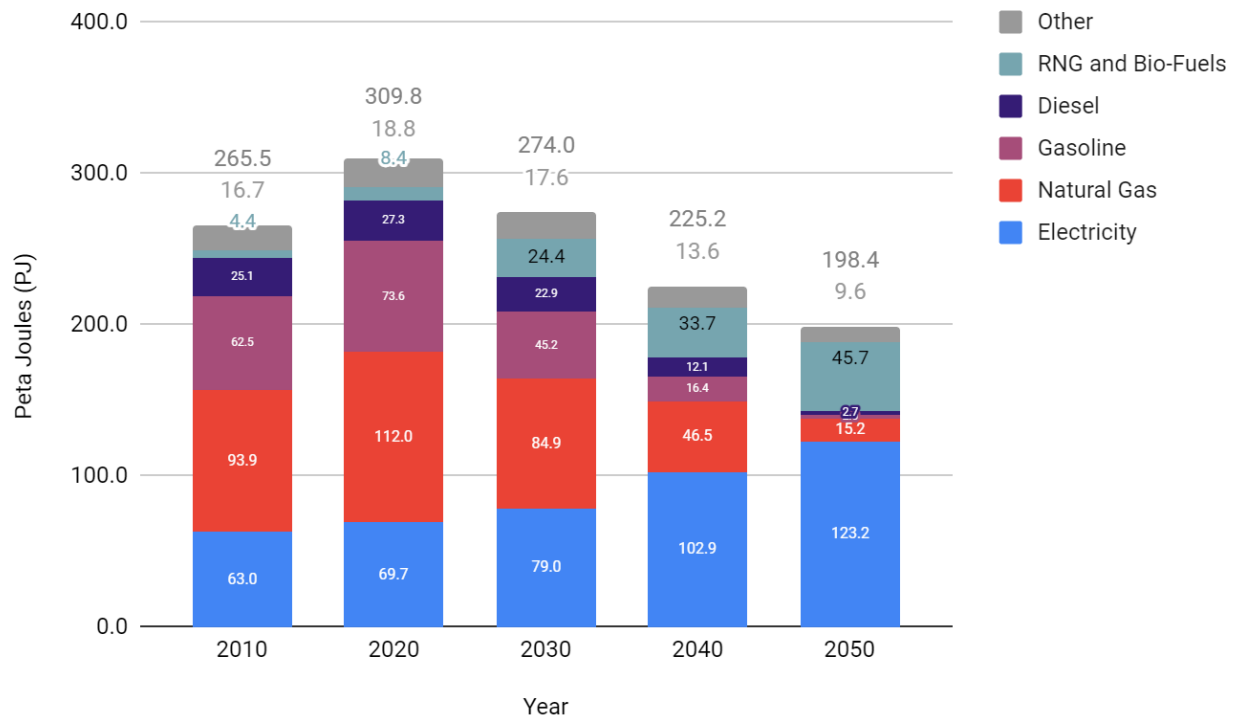


Figure 6. Total energy used under the Carbon Neutral Scenario by decade (PJ).

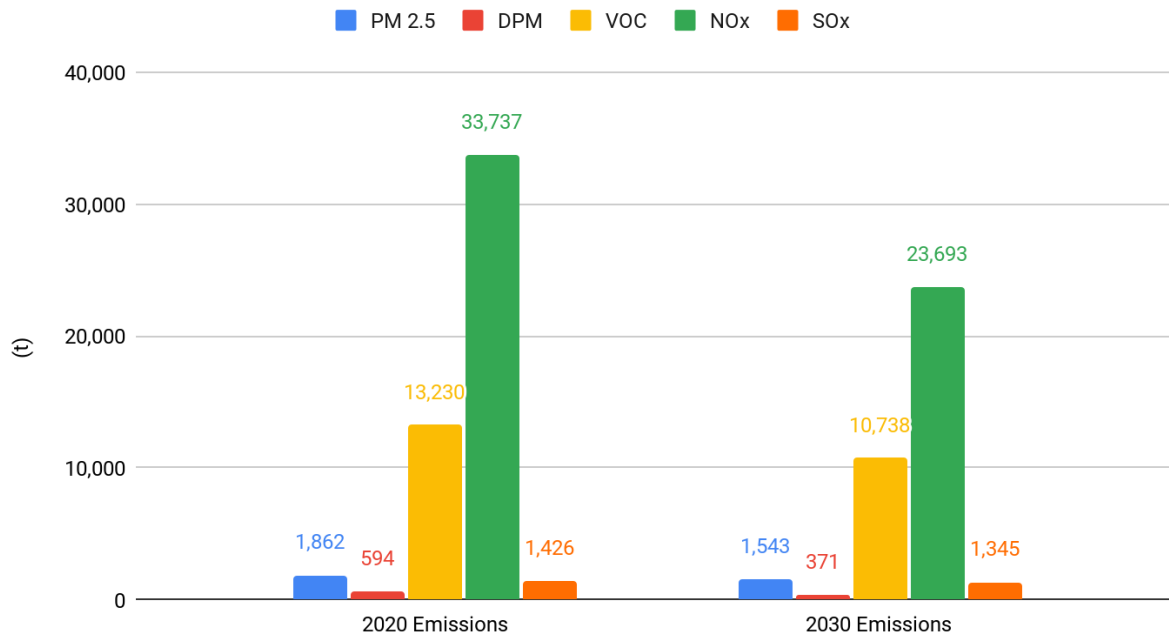


Figure 7. Total annual CAC emissions between 2020 and 2030 under the CNS (tons)

Contaminant	2020 Emissions	2030 Emissions	Percent Reduction
PM 2.5	1,862	1,543	-17.11%
DPM	594	371	-37.52%
VOC	13,230	10,738	-18.83%
NOx	33,737	23,693	-29.77%
SOx	1,426	1,345	-5.71%
<i>Total</i>	<i>50,848</i>	<i>37,690</i>	<i>-25.88%</i>

Table D. Total CAC reductions By Contaminant under the CNS.

### Comparing BAP and CNS

The BAP and CNS scenarios have dramatically different emission profiles shaped by profoundly different policies, actions and measures. Notably, from the BAP, the CNS achieves a reduction of 2.3 million tCO<sub>2</sub>e greenhouse gas emissions by 2030 and an 11 million tCO<sub>2</sub>e reduction by 2050 relative to 2010. Fundamentally, the CNS achieves 21% less emissions as compared to the BAP in 2030 and 75% in 2050, without including the effects of sequestration. This reduction is reflected in the composition of fuels between the two scenarios. By 2050 under the BAP, roughly 65% of fuels are still fossil-based in origin, whereas under the CNS 85% of fuels are renewable. This shift in energy use, along with the policies, assumptions and results that comprise the CNS are detailed sector by sector below.

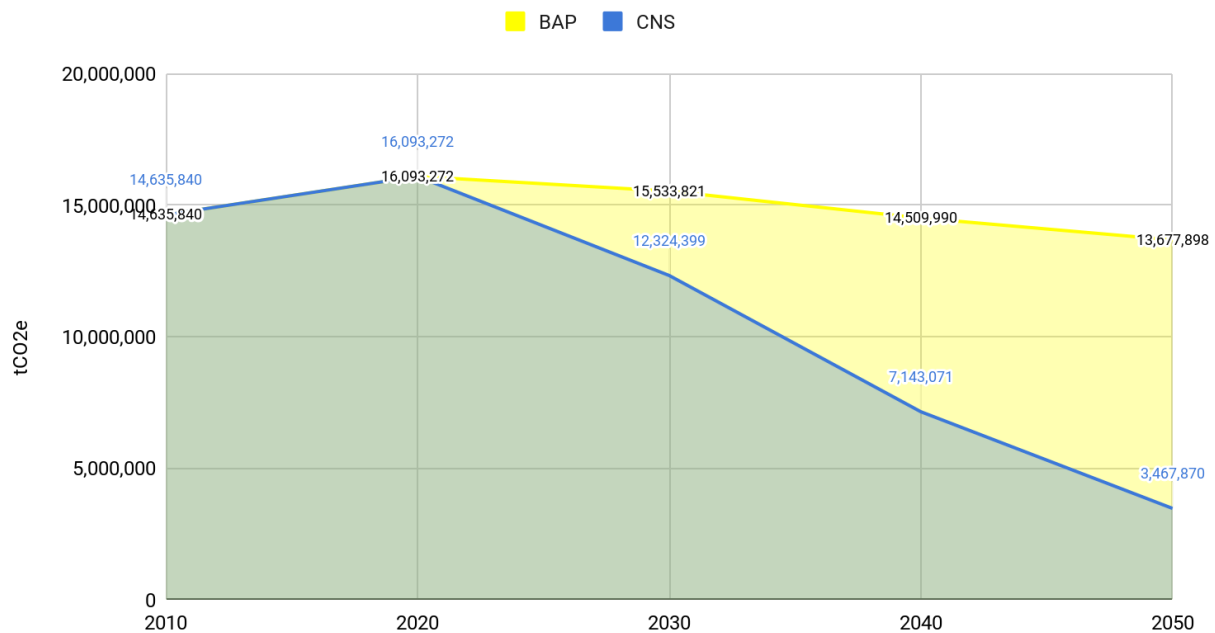


Figure 8. BAP and CNS GHG Emissions by decade (tCO<sub>2</sub>e).



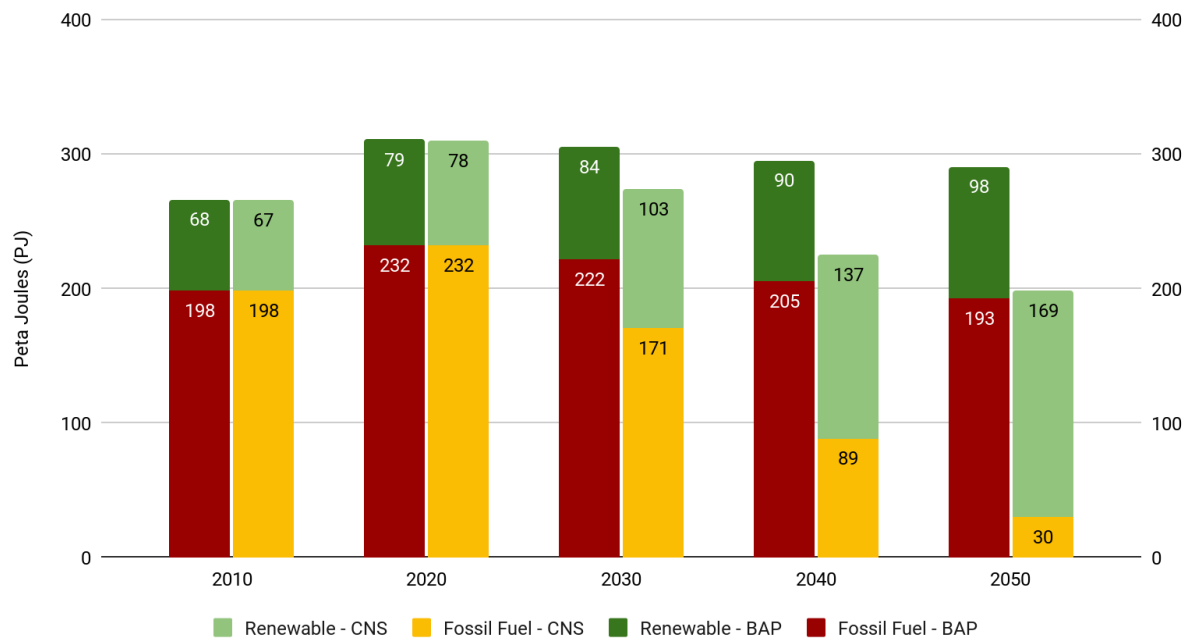


Figure 9. A comparison of Energy usage under the BAP and CNS between carbon emitting fossil fuels and renewable energy sources (PJ).

## Sector Overviews

### Buildings

Building GHG emissions in the base year (2010) comprise 31% of total GHGs across Metro Vancouver. With such low carbon in B.C.'s electricity grid (i.e., most generation is from renewable sources), these GHG emissions are overwhelmingly from natural gas combustion for space heating and hot water. While electricity makes up 45% of building energy consumption, it only accounts for 10% of GHG emissions in 2010, and less than 5% in 2020 due to grid decarbonization under the 2010 Clean Energy Act.

Single detached and small duplex/multiplex buildings account for just over half of building GHG emissions. Large residential multi-family buildings account for just 13% of 2010 GHG emissions, but are also the fastest growing sector. Commercial/institutional buildings account for one third of GHG emissions. District energy systems comprise 9% of GHG emissions from these two sectors (large multi-family and commercial/institutional).

CAC's from buildings include PM2.5, VOCs, NOx, and SOx. These are primarily produced as a result of burning natural gas and are proportional to natural gas consumption rates, with some CACs from burning of biomass.

#### *Business As Planned Future*

##### Key Assumptions

Under the BAP, it is expected that all new buildings will be constructed to increasing levels of BC Energy Step Code, with the highest levels (Step 4/5) adopted across the region by 2032. The City of Vancouver will have additional GHGi targets for new buildings, reaching 1 - 3 kg/m<sup>2</sup>/yr by 2025. There is assumed to be no significant increase in retrofits of existing buildings, although confirmed biomass plants for district energy systems at UBC and SFU will reduce the GHG emissions from those systems.

The BAP scenario incorporates confirmed and highly advanced policies with residential and commercial growth projections to predict future buildings consumption and emissions. Key trends that impact future energy and GHG emissions include population growth and associated residential and commercial construction, Step Code adoption into the building code, and a shift to multi-family residential buildings from single detached. Another significant policy impact which has already occurred since the 2010 baseline is the assumed decline in BC Hydro's electricity GHG emissions factor, though, as discussed above, new guidance may modify this factor.

The BAP scenario includes assumptions related to development, climate change and new construction policy:

- Floor area projections are based on the land-use business as planned (BAP) urban growth future. Single detached and small duplex/multiplex floor area increases by 29% from 2020, while large multi-family residential grows by more than double that, at 63%. Commercial/institutional growth is 23% over that period.
- Weather is normalized and adjusted for a warming climate based on RCP 4.5, Climate Projections for Metro Vancouver based on heating degree days (heating degree days) from 2018 onwards. Weather and energy consumption are actual for years prior to that.
- Full BC Step Code implementation (Step 4 for all Part 3 buildings, Step 5 for all Part 9 buildings) by 2032, based on direction in the provincial CleanBC climate action strategy. A more aggressive implementation schedule is assumed for buildings in the City of Vancouver, based on proposed updates to the Vancouver Building Bylaw.

## Results

Based on current trends, building emissions are expected to initially rise slightly and then decline, resulting in no significant change by 2050, at 4.56 million tCO<sub>2</sub>e. The biggest determinant of GHG emissions in this sector is the large share of existing building stock remaining by 2050 with natural gas heating systems, accounting for 81% of emissions. Projected building replacements account for a 19% drop in emissions for existing buildings. New buildings will perform considerably better both from energy and greenhouse gas intensity perspectives when compared to existing buildings. Accordingly, while new construction will account for 19% of GHG emissions in 2050, it will account for 37% of expected floor space. Large multi-family residential and commercial/institutional building GHG emissions are expected to increase by roughly 19% and 7% respectively by 2050, while single detached and small duplex/multiplex residential buildings GHG emissions are expected to decrease 13%. This is largely due to urban intensification which results in the demolition of single detached buildings and their replacement with denser and more complex structures, increasing the relative floor area of large multi-family buildings.

Simultaneously, energy use in buildings is expected to increase from 138 PJ in 2010 to 159PJ in 2050. Energy consumption increases due to ongoing building construction with increased building units and total floor space. Rising energy demand is partially offset by older and less efficient buildings being replaced by new and more efficient buildings. Although energy use increases, GHG emissions remain the same due to a slight decline in the overall share of fossil fuels and the lower GHG emissions created through electricity use.

Common Air Contaminants increase due to rising natural gas consumption. PM<sub>2.5</sub>, VOC, and NO<sub>x</sub> increase by 8-9% each from 2010 to 2030. There is a slightly higher increase of 12% in SO<sub>x</sub> due to a small amount of biomass combustion for district heating systems, although the buildings sector has fairly low total SO<sub>x</sub> emissions, about 5% of the regional total in 2030.

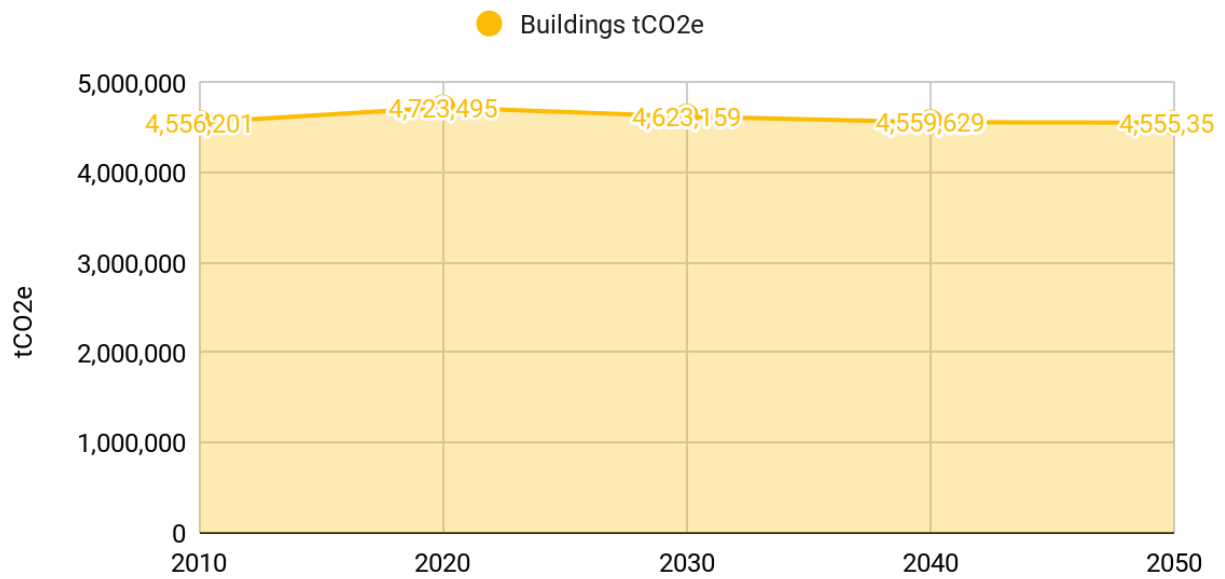


Figure 10. Business As Planned modelling of primary energy usage by buildings from 2010 to 2050 (tCO2e).

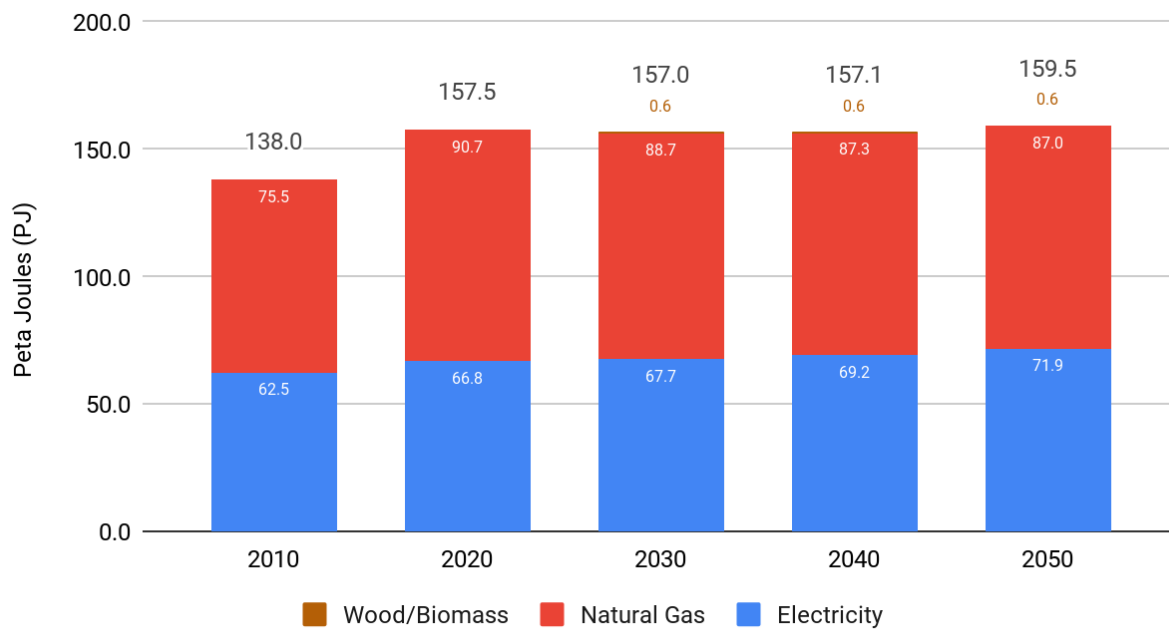


Figure 11. Business As Planned modelling of primary energy usage by building fuel type from 2010 to 2050 (PJ).

## *Carbon Neutral Scenario*

### *Policies and assumptions*

The CNS for buildings focuses on three areas - reducing carbon emissions in new construction, retrofitting existing buildings, and replacing natural gas with renewable / low carbon energy sources. Of these, building energy retrofits have the greatest potential impact, as existing buildings account for the largest share of emissions. Existing buildings, however, are also the most difficult to address. Numerous policies, summarized below, would target these three areas.

The policies modelled for buildings focus on requiring zero emissions space and water heating systems for new construction paired with modern, high-efficiency building techniques and technologies so that far less energy is needed to meet a building's space and water heating needs than in the past. These requirements could be adopted through the BC Energy Step Code that include additional GHG requirements.

The policies for existing residential buildings assume a more gradual transition primarily because space and water heating equipment are only replaced every 10 to 20 years, and even less frequently for large commercial, residential, and public sector buildings. The modeled requirements for existing buildings start in the next few years, but take longer to reduce GHG emissions because the opportunities to change equipment or building envelopes are limited in the next 30 years.

#### *New building GHG requirements (Policy #30)*

This policy reduces carbon emissions in new construction with GHG intensity (GHGI) requirements in the building code. Building code regulations will require reduced carbon emissions in all newly constructed buildings. Key performance assumptions for this policy include (1) by 2025, all buildings will be required to reach Step 4/5 of BC Energy Step Code, with an additional GHGI requirement of 1 kg CO<sub>2</sub>e per m<sup>2</sup> per year; and (2) near-zero GHGI by 2030.

This policy demonstrates the impact of incorporating GHGI requirements into the Step Code, which currently only enforces energy standards. The combination of energy and GHGI requirements will result in both higher efficiency construction and the adoption of low emission technologies such as heat pumps.

#### *District energy decarbonisation (Policy #37)*

This policy reduces GHG emissions from district energy systems. In response to municipal and/or regional requirements, district energy systems will transition to renewable energy sources, with the energy type varying based on different system characteristics. Key performance assumptions for this policy are (1) 70% of energy is from electricity or renewable natural gas by 2030; and (2) 100% by 2050 (70% renewable natural gas, 30% electricity).

While DE systems are not a large part of total buildings GHG emissions, they are some of the largest single point sources. Opportunities to decarbonize are available through switching to renewable fuels, accessing waste heat sources, or electrification through heat pumps.

#### *Deep carbon retrofits for Part 9 residential buildings (Policy #31)*

This policy evaluates the potential impact of regulatory requirements for low carbon retrofits to single detached and small residential buildings (Part 9) through a policy such as a provincial retrofit code. Provincial regulations will require that existing Part 9 buildings are retrofitted to meet GHGI requirements. This policy modelled GHG emission intensity requirements of 15 kg/m<sup>2</sup>/yr beginning in 2030, reaching 1 kg/m<sup>2</sup>/yr in 2050. As a performance-based regulation, these requirements could be met through efficiency improvements, transition to lower GHG emission technologies for space heating/cooling and water heating, and/or switching to near zero GHG emission energy sources such as electricity.

Existing buildings, built today, will comprise a much larger source of greenhouse gas emissions relative to new buildings. Placing greenhouse gas limits on retrofits for existing Part 9 buildings, the largest source of GHG emissions in buildings, is a significant opportunity to transition to zero GHG emissions buildings.

#### *Benchmarking and performance requirements (Policy #32)*

This policy evaluates the impact of coordinated region-wide regulatory requirements for existing large multi-family and commercial/institutional buildings including energy consumption benchmarking, reporting and performance requirements that must be met through retrofits. These requirements are applied to all existing commercial/institutional and large multi-family residential buildings, and would require that these buildings undertake retrofits to reduce their GHG emissions.

As a performance-based regulation, these requirements could be met through efficiency improvements, transition to electric technologies for space heating/cooling and water heating, and/or switching to low emission energy sources such as electricity or renewable natural gas. This policy modelled a phase in of GHG emission intensity requirements by building type, beginning at of 30 - 50 kg/m<sup>2</sup>/yr (depending on building type) in 2025, and reaching 1 - 5 kg/m<sup>2</sup>/yr in 2050, with additional RNG use to reduce GHG emissions to near-zero.

	<i>Modelled Benchmarking and Performance Requirements (kg CO<sub>2</sub>e/m<sup>2</sup>)</i>				
	<b>2025</b>	<b>2030</b>	<b>2035</b>	<b>2040</b>	<b>2050</b>
<i>Large Commercial (&gt;10,000m<sup>2</sup>)</i>	30	20	10	5	1
<i>Commercial</i>	50	50	25	10	5
<i>Multi-Family</i>	30	30	15	10	5

*Table E. Benchmarking and performance requirement Policy 32's GHGi Space and Water Heating Requirements*

This policy demonstrates the impact of a regulatory approach to reducing GHG emissions from existing large, complex buildings. As there is a wide range of different Part 3 building types, performance requirements offer a flexible approach that can be adjusted based on different buildings' needs. This policy also assumes that some renewable natural gas may be used as a pathway to meeting performance requirements in old, particularly complex buildings such as hospitals.

#### *Retrofit incentives, training support, and financing tools (Policy #33)*

This is a suite of policies that supports the successful implementation of aggressive buildings policies with high compliance by alleviating financial burdens and ensuring sufficient industry training to meet demand. Incentives are provided to building owners for building retrofits, to increase uptake. This policy also envisions a ramp up in industry training needed to meet demand. Strategic financing tools for building energy and emission retrofits are accessible to households and building owners, including rental properties; this could include programs such as Property Assessed Clean Energy financing. The impacts of these policies are modelled as improved compliance rates. While the baseline compliance rate is assumed to be fairly high at 88% (based on our knowledge of typical adherence to stringent building requirements), we assume this could be improved to 97% through the implementation of this suite of strong supporting policies.

#### **Carbon Neutral Scenario Results**

Emission and energy activity anticipated through the application of CNS policies for the building sector are outlined below. GHG emissions drop 17% by 2030 over 2010 and 83% by 2050. Energy use in this sector is expected to decrease from 138 PJ in 2010 to 118 PJ by 2050, after total energy consumption peaks in 2030. The drop in energy consumption is driven by increased building efficiency, and the additional decrease in greenhouse gas emissions is a result of switching to renewable and low carbon fuels.

The largest share of reductions (71% of energy and 79% of greenhouse gas emissions in 2050) come from electrification, retrofits, and fuel switching in existing buildings. This includes the use of 12 PJ of renewable natural gas in Part 3 buildings in 2050, accounting for about 40% of the reductions for Part 3 buildings. With another 1.6 PJ of renewable natural gas in district energy systems, RNG accounts for 18% of total GHG emissions reductions. Electrification, through heat pumps or direct electric heating, adds another 22 PJ of

electricity consumption above 2050 electricity use in the BAP scenario. GHG emissions reductions in Part 9 buildings are driven through efficiency improvements and electrification, as it's assumed that the limited amount of RNG available would be needed for large, complex Part 3 buildings to meet stringent GHG emissions performance requirements. Through a combination of efficiency improvements and fuel switching, fossil natural gas use in buildings decreases by 77 PJ, or 88%.

Higher standards in new construction account for 15% of total emissions reductions by 2050. This is relatively small compared to existing buildings, as new construction is already quite efficient in the BAP scenario and has less room for improvement. Its impact on energy consumption is greater, at a 24% reduction, due to the use of heat pumps in new construction rather than renewable natural gas in existing buildings as a result of the more stringent policies modelled.

With regards to the effects of land use on buildings' greenhouse gas emissions, the following factors affect the changes between the BAP and CNS

- Firstly, while demolition rates increase somewhat between the BAP and CNS (which results in fewer older buildings and more newer buildings), the effects from this change are related primarily to new construction, which only accounts for only 18% of emissions in 2050. As such, demolition rates do not have a real impact on emissions.
- Secondly, as expected, the CNS land use pattern changes the mix of buildings. Accordingly, the proportion of Part 9 residential buildings goes down by 9.5 million square meters of built area, while Part 3 residential goes up by 7.3 million. Changes in non-residential construction are minimal, so overall between the BAP and CNS there is a net reduction in floor area, which should drive greenhouse gas emissions downwards.
- However, the fundamental driver of emissions changes are anticipated code improvements covered in the BAP. Efficiency improvements through the Step Code in Part 9 residential buildings are roughly double those in Part 3 residential, as such, the new Part 3 buildings end up considerably using more energy than the new Part 9 buildings as the various steps are implemented. This effectively offsets the reduction in floor area and mutes potential emissions reductions resulting from the CNS land use scenario.

The remaining policies have a minor impact on GHG emissions reductions. In 2050, district energy decarbonization accounts for 3% of reductions driven by a combination of fuel switching to electrification and renewable natural gas. Incentives, training, and financial tools result in a 2.5% reduction. This policy, however, plays a valuable role to engage public support for other policy actions, and the implementation of stringent GHG emissions requirements such as those modelled would rely on such policies.

CACs decrease by an amount matching the reduction in total natural gas consumption. As RNG produces the same volume of CACs as fossil natural gas, the use of RNG does not result in a reduction of CACs. PM2.5, VOC, SOx, and NOx decrease by 16%, 15, 15%% and 12% respectively from 2020 to 2030. SOx



emissions decrease slightly less (3% between 2010 and 2030) than other CAC's due to biomass combustion in district heating systems, which also occurs under the BAP.

The table below projects emission reductions from modelled policies, actions and measures for this sector. For simplicity, the BAP has been included to indicate the effect of general trends against the additional effort required for deep emissions reductions.

<b>Buildings</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
BAP GHG Emissions (tCO <sub>2</sub> e)	4,556,201	4,723,495	4,623,159	4,559,629	4,555,350
Landuse	0	0	1,274	2,818	4,955
Policy 30 New Building GHG Requirements	0	0	-156,960	-357,854	-584,060
Policy 37 District Energy Decarbonization	0	0	-84,358	-105,238	-112,738
Policy 31 Deep Carbon Retrofits for Part 9 Buildings	0	0	-22,729	-394,186	-1,475,990
Policy 32 Benchmarking & Performance Requirements	0	0	-484,520	-1,075,708	-1,508,829
Policy 33 Retrofit Incentives, Training Support and Financing Tools	0	0	-112,003	-541,770	-94,332
<i>Reductions</i>	<i>0</i>	<i>0</i>	<i>-859,296</i>	<i>-2,471,938</i>	<i>-3,770,994</i>
<i>Remaining Emissions</i>	<i>4,556,201</i>	<i>4,723,495</i>	<i>3,763,863</i>	<i>2,087,691</i>	<i>784,356</i>

*Table F. Greenhouse gas emissions (tCO<sub>2</sub>e) from the buildings sector, and relative changes by policy.*

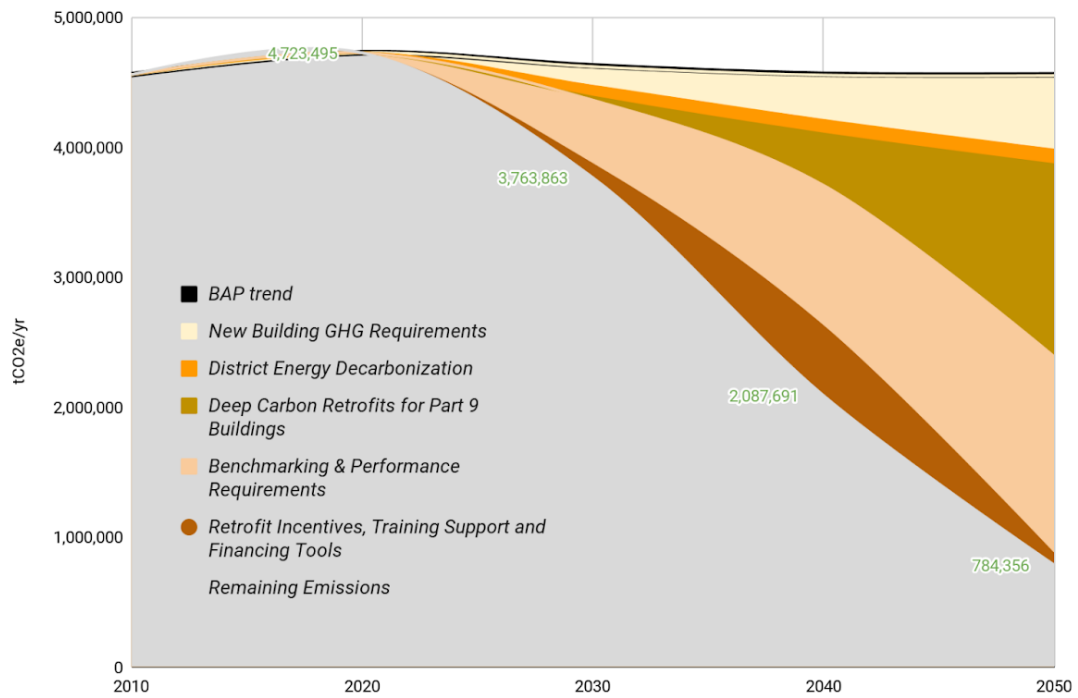


Figure 12. Building emissions reductions resulting from CNS Policies (tCO<sub>2</sub>e).

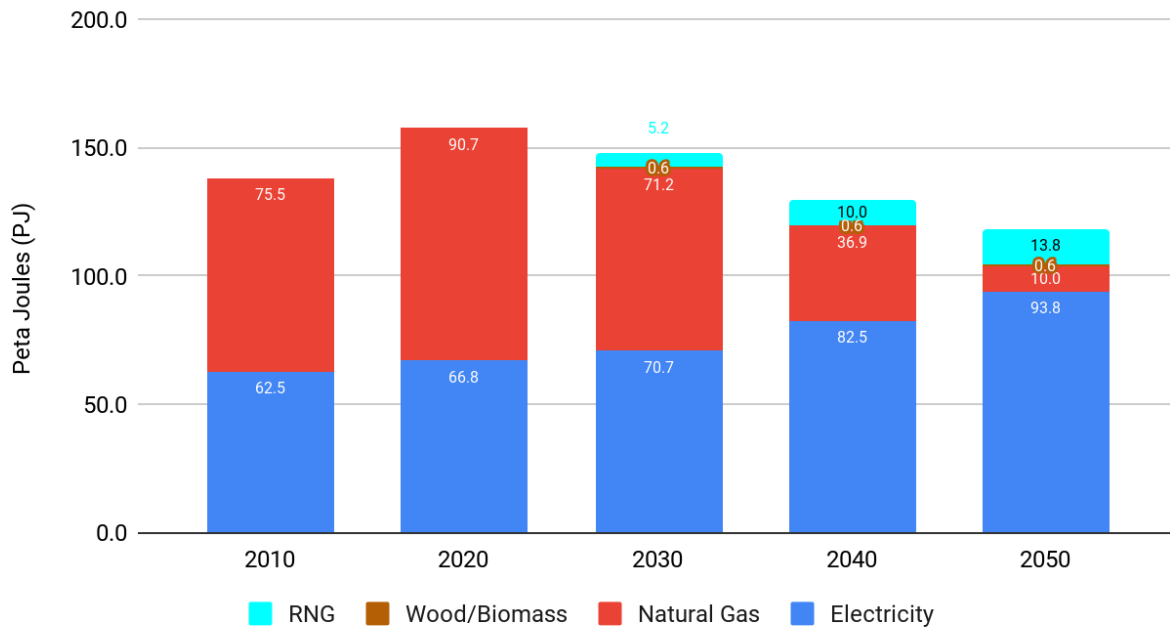


Figure 13. Building energy use (PJ) in the CNS.

### *Remaining Emissions and Further Reductions Opportunities*

Only 17% of building GHG emissions remain in 2050 relative to 2010 under the carbon neutral scenario. Of these GHG emissions, 36% are from electricity use. Although electricity has a very low GHG emissions factor, consumption increases by 50% by 2050 due to a combination of population/construction growth and a shift to electrification for space and water heating.

Almost all remaining GHG emissions are from natural gas combustion. The majority, 73%, are in single detached and small duplex/multiplex buildings. Large multi-family and commercial/institutional buildings make up a smaller share of remaining GHG emissions, as these are assumed to use RNG to reduce natural gas emissions to near-zero to comply with building performance requirements, and some are also connected to DE systems which will have achieved near-zero-emissions.

While these GHG emissions reductions are significant, deeper reductions are required to meet Metro Vancouver's 2030 and 2050 targets. The project consulting team has identified the following opportunities to explore to intensified GHG reductions:

- A combination of innovative financing, incentives, education and knowledge mobilization and workforce training can enable rapid uptake of zero GHG emission building technologies and deep retrofits. While these were included in this modelling exercise, their impact may be underestimated. Further analysis focused on the impact of these types of programs and policy may explore their full potential for GHG emission reductions.
- While the CNS land use scenario looked at the impact of more compact land use, not all potential for densification has been captured in this project. Under the CNS, density increases were modelled in corridors and nodes. However, there is further potential for gentle intensification in lower density residential areas by increasing households per dwelling unit and/or parcels with accessory dwelling units (e.g. expanding secondary suite and laneway housing options, facilitating additions, requiring secondary suites in new construction, lock off units in multi-family homes). By avoiding demand for new construction, they also reduce embodied emissions which were not part of this study. Further analysis could explore the potential emissions impact of these gentle intensification approaches.
- While embodied GHG emissions in building materials were not included in this scope of this modelling exercise, there are important GHG implications that can be explored with further analysis, notably including mass timber. The use of these materials also typically involves transitioning to more prefabricated construction which also has greater potential for improving quality and cost controls.

## On Road Transportation

On-road transportation is a large sector encompassing two diverse, vehicle categories:

- *Light Duty Vehicles* (LDVs) is comprised of cars and light trucks. The latter sub-category includes pickups, SUVs and minivans as well as trucks and other on-road vehicles weighing less than 4,536 kg. Most of these vehicles and emissions are passenger-related.
- *Medium and Heavy-Duty Trucks* (HDVs) which comprise larger commercial trucks and transit vehicles weighing more than 4,536 kg.

Modelled estimates for emission and energy consumption from on-road transportation in 2020 demonstrates the impact of this sector. In 2020, modeled estimated fuel combustion for on road transportation accounts for 37% (5.5 million tCO<sub>2</sub>e) of the region's total emissions. Most of these emissions are generated by gasoline and diesel use in light duty vehicles (4.7 million tCO<sub>2</sub>e), the region's largest emission sub-sector. The balance is from diesel consumed in large commercial trucks (0.7 million tCO<sub>2</sub>e). Virtually all of the energy consumed by on-road vehicles is gasoline or diesel, though 7.8% came from renewable gasoline or diesel as a result of Provincial and Federal requirements for renewable fuel content. Under 1% of energy use for light duty vehicles was electric. Roughly 6% of energy used for HDVs was electric, almost all of which is used by transit busses that run on electric overhead cables. CACs from on-road vehicles are primarily from fuel combustion, though some are generated from braking. Estimated emissions for CACs from on-road vehicles in 2020 account for 8% of total regional PM<sub>2.5</sub>, 12% of DPM, 37% of VOCs, 21% of NO<sub>x</sub> and 5% of SO<sub>x</sub>, produced in the region in 2020. When added together, CACs from on-road transportation account for 24% of all regional CACs.

This modelling looks at the impact of a transition to Zero Emission Vehicles (ZEVs) on emissions. The ZEV category includes battery electric vehicles (referred to as electric vehicles, EVs), hydrogen vehicles, and a limited amount of plug-in hybrid electric vehicles with a significant electric range (referred to as low emissions vehicles, LEVs). Renewable fuels are also considered, particularly for HDVs. While the modelling generally does not specify what type of renewable fuel would be used, common renewable transportation fuels include:

- Ethanol, a renewable gasoline substitute
- Biodiesel, a renewable form of diesel
- Renewable diesel, which is chemically identical to fossil diesel but produced with bio-feedstocks
- Renewable natural gas, which is identical to fossil natural gas but produced from organic materials (often waste or manure)

## *Business As Planned Future*

### Key Assumptions

For each vehicle, fuel consumption is determined by the class of vehicle and type of engine and/or fuel type, engine efficiency (typically measured as litres of fuel per 100km), and the annual distance travelled (vehicle kilometres travelled, VKT). Renewable fuel content in the fuel supply allows for an estimation of emission intensity per litre of fuel which, combined with fuel consumption, allows for an estimation of GHGs at the regional scale. Electric vehicles are assigned a CO<sub>2</sub>e intensity per km based on B.C.'s grid and engine efficiency.

Factors under the Business As Planned (BAP) future affecting these drivers and assumptions:

- *Vehicle Stock* - Stock changes over time as existing vehicles are retired and new vehicles are sold. The Provincial ZEV Act will progressively increase the share of zero emission vehicle sales to 100% by 2040. While the average LDV is on the road for 14 years, it takes 30 years for the stock to completely turn over, which leaves a sizable share of internal combustion engines on the road in 2050. Medium and heavy-duty trucks are not covered by the existing BC ZEV Act. However, under the BAP, transit buses are assumed to transition to 100% renewable energy by 2050 based on the commitments in TransLink's *Low Carbon Fleet Strategy*. These heavy-duty vehicles with high mileage, will be electrified or RNG fueled by 2050.
- *Fuel Economy and Engine Efficiency* - Engine efficiency – measured by fuel economy - is assumed to improve by 1.5% per year until 2035 for light duty vehicles, based on existing federal requirements. For medium and heavy-duty vehicles, fuel economy is expected to improve by 1.5% per year until 2025 based on existing federal requirements. However, gains in fuel economy are partially offset by increasing demand for larger vehicles as larger vehicles use more fuel per kilometer travelled than cars. Over the past 5-10 years, light duty trucks and SUVs have accounted for the majority of all new vehicles sold (approximately 75% of all new vehicles sold in 2019 were light duty trucks or SUVs).
- *VKT and Fleet Growth* - Average annual VKT per household is flattening due to diverse factors: For instance, average VKT is dropping around high density, transit-supported, mixed-use areas. This is likely supported by increased transit and active transit infrastructure, and more recently the availability of alternate mobility infrastructure such as car-share, bike-share and teleworking. However, average VKT reductions are moderated by a rising average daily commute length due to the growth in car-oriented, distributed neighbourhoods. Additionally, with a regional population increase (1.3% per year) total VKT is rising, and total vehicle stock across the region is growing at a rate faster than the population. As a result, total VKT is steadily rising.
- *Renewable fuel* - Renewable content in gasoline and diesel is currently regulated under the BC Low Carbon Fuel Standard (LCFS). The LCFS regulates the lifecycle carbon intensity of

transportation fuels, and mandates a minimum blend of 4% renewable content in diesel and 5% in gasoline. Carbon intensity requirements can be met through a combination of renewable content blending exceeding these minimums, upstream emissions reductions, or credit agreements. Estimated 2020 levels of renewable fuel content is 8% in gasoline and 6.7% in diesel. By 2030, the LCFS requires that the carbon intensity of fuels is to be reduced by 20%. For the purposes of this modelling project, it is assumed that this requirement would be met through 10% renewable content blending in both gasoline and diesel. The Federal government also has minimum fuel content requirements (5% for gasoline and 2% for diesel), but these are superseded by the BC LCFS.

- Major goods movement routes, road networks, and the Provincial highway network will be largely unchanged under the BAP per current Provincial policy and TransLink's most recent 10 year-transportation plan. Under the BAP, the Millennium line will terminate at Arbutus Street, the Expo Line extension will terminate at Fleetwood, and rapid rail transportation to the Fraser Valley will not occur. Additionally, conventional bus networks will see a baseline increase in service hours by 1% per annum and no other major public transit infrastructure investments are considered. Under the BAP, the regional cycling network will be built out to TransLink's recently adopted *Regional Cycling Strategy*.

## Results

Fuel consumption and energy dynamics under the BAP are responsive to the dynamics outlined above. Fossil fuel consumption for all on-road transportation rises from 2010 to 2020 but then drops 5% by 2030, as compared to 2010. By 2050, fossil energy demands are expected to drop 67% from 2010 levels. These reductions are driven primarily by new LDV ZEV sales as a result of B.C.'s ZEV Act, as well as improving fuel economy. As a result, on-road transportation emissions are expected to decrease 68% from 2010 levels by 2050 (from 5.1 mt in 2010 to 1.6mt in 2050). This is driven entirely by emissions reductions in LDVs, as overall emissions from HDVs increase by 32% in the BAP between 2010 and 2050.

Transportation emissions remaining in 2050 are from fossil fuel-powered vehicles with a roughly even split in emissions between light and medium/heavy duty trucks, at 0.7mt of GHGs and 0.9mt of GHG respectively. Fossil fuel consumption in 2050 will be 11.5 PJ of gasoline (a 79% drop from 2010) and 10.5 PJ of diesel (largely unchanged since 2010). Reduced gasoline and diesel demand is driven by improved vehicle efficiency and LDV and bus electrification. Renewable energy consumption, i.e., electricity and renewable gasoline and diesel, increases from 3.9PJ in 2010 to 20.5 PJ in 2050. Almost all increase to renewable energy use is from increased electricity use. These increases will be driven by the provincial Low Carbon Fuel Standard and Provincial Zero Emissions Vehicles Act.

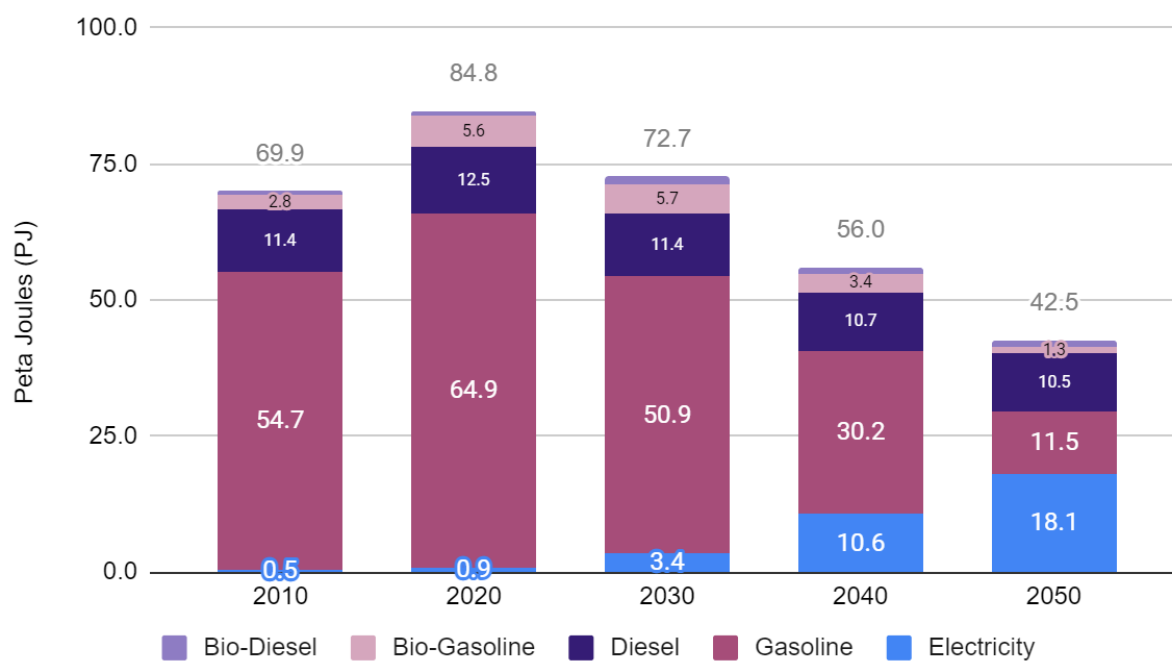


Figure 14. On road transportation fuel consumption in the BAP (PJ).

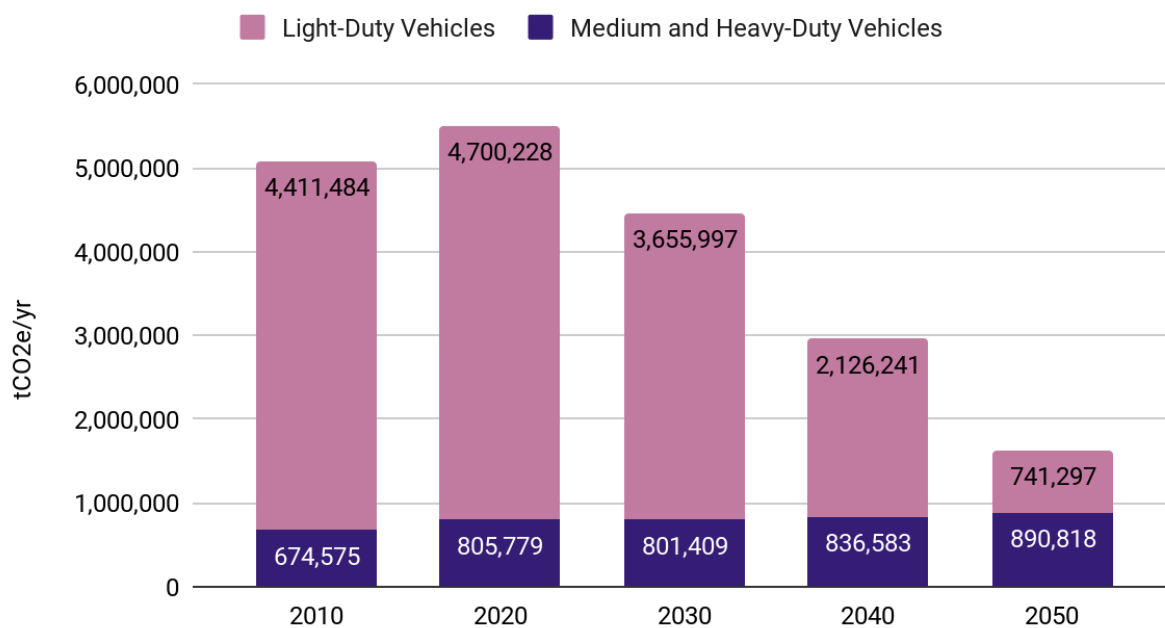


Figure 15. On road transportation emissions in the BAP (tCO<sub>2</sub>e).



Common air contaminants will drop under the BAP. By 2030 PM2.5 will be reduced by almost 50% relative to 2020. DPM will decrease by about 52% due primarily to more efficient heavy-duty vehicles and an accelerated retirement profile for heavy duty vehicles (most diesel consumption is from heavy duty vehicles). Decreases in NOX are anticipated to decrease significantly by 2030 primarily due to strict engine emission standards in both light and heavy vehicles. Reductions in VOCs and SOX follow a similar pattern to overall reductions in fossil fuel use.

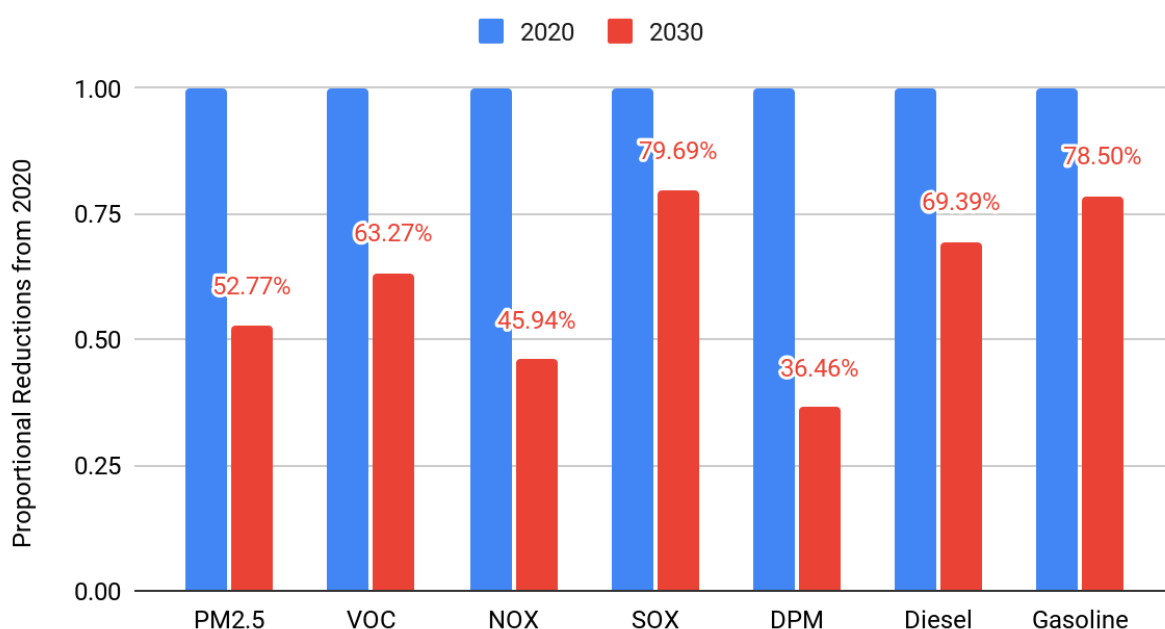


Figure 16. On-Road Reductions in fuel (Diesel and Gasoline), and related reductions in key CACs.

### Carbon Neutral Scenario

#### Policies and Assumptions

CNS on-road transportation policies focus on four main areas:

1. **Managing vehicle kilometres traveled in light duty cars and trucks** through land use change and more sustainable growth patterns which will reduce trip lengths; transit and active travel expansion; new mobility growth; reducing vehicle ownership and providing access to low-emissions vehicles; and regional road pricing.
2. **Accelerating zero emission vehicle market transformation** through an accelerated and expanded Provincial ZEV mandates.
3. **Deepening vehicle fuel efficiency** with stronger federal fuel efficiency requirements.

4. **Sustaining the growth in renewable liquid and gaseous fuels, building** on B.C.'s Low Carbon Fuel Standard, targeting rising renewable content and dropping carbon intensity targets.

Constraints to LDV emission reductions include the shift to larger, heavier light duty trucks, rising car ownership rates, growing VKT for some areas of the region, and an urban fabric and modal preferences incompatible with mode shifting in some areas.

Constraints to medium and heavy-duty vehicle emissions are the high costs associated with zero emission fuel vehicles and market demand for such vehicles in the second hand (second owner) market as well as the capacity to meet ambitious renewable fuel targets.

Of these focus areas, transforming the fleet to zero emissions vehicles and decarbonizing fossil fuels have the greatest potential to reduce emissions in the region. Policies used for modeling are discussed in detail below:

*Transit system expansion (Policy #6)*

This policy looks at the impact of improvements to bus frequency and increased rapid transit service areas to displace personal vehicle travel with transit, reducing emissions. Under this scenario, the region doubles transit service per capita by 2050, that is to say expected increases in transit service hours will increase by roughly 2% per year from 2020-2050 resulting in minimum of five-minute headways for most convention transit service.

*Car Sharing Incentives (Policy #10)*

This policy looks at the impact of displacing personal car ownership with car sharing through a suite of tools such as preferential parking policies for shared vehicles and bundling shared vehicles with new multifamily developments. Under the CNS, car share vehicles account for 2.5% of registered vehicles in Urban Centres / Frequent Transit Development Areas by 2030 and 10% by 2050, which reduces, in turn, LDV ownership rates 10% over 2007 rates by 2030 and 25% by 2050. All care share vehicles will be obligated to be zero emissions by 2030.

*Active mobility shift (Policy #8)*

This policy displaces personal car ownership, trips, and VKT with walking and cycling. This is achieved through improvements to active transportation infrastructure (e.g., expanding all ages, all abilities cycle networks) and better integration of active transportation with other travel modes (e.g., increased bike lockers at SkyTrain stations), integrated regional travel demand management program, and regional e-bike subsidies. Investments in active mobility reciprocally support the compact, complete development modelled as part of the land use scenario. This policy assumes a 20% share of trips by active modes by 2030 and 30% by 2050, from 15.5% in 2017.

#### *Mobility pricing (Policy #9)*

Mobility pricing can reduce emissions through VKT reductions or accelerating ZEV use, depending on how it is designed. The policy modelled for this project looks at the impact of mobility pricing on VKT. Modelled assumptions align with recommendations in the Mobility Pricing Commission (MPIC) Report which proposes the implementation of a regional mobility pricing regime in the Metro Vancouver region that prioritizes congestion-based mobility pricing. The marginal social cost associated with congestion is used as a basis for the efficient pricing of transport services and infrastructure. The MPIC report estimates that the average household would pay between \$5 and \$8 per day or \$1,800 to \$2,700 per year if they do not change their behaviour in response. The VKT reductions resulting from changing travel patterns in response to the price were incorporated into the model.

#### *Passenger vehicle fuel efficiency standards (Policy #4)*

This policy assesses emissions reductions from increasing federal fuel efficiency standards for light duty vehicles. Based on an assessment of current federal regulations and technical feasibility limitations, it was assumed that fuel efficiency in internal combustion engines (ICE) would increase 4.2% per annum and 3.1% per annum for new light trucks and cars respectively from 2020 to 2035. This would increase fleet ICE fuel economy by a total of 27% from 2020 to 2035 (compared to a 23.6% improvement under the BAP).

#### *Strengthen passengers zero-emission vehicle mandate (Policy #3)*

This policy significantly reduces transportation emissions for light duty vehicles by accelerating the transition to zero-emissions vehicles. This would be achieved by moving the 100% new ZEV sales target to 2030 from the current 2040 milestone under B.C.'s ZEV mandate. Additionally, this policy assumes that low emission vehicles (plug-in hybrids with a significant electric range) would only be permitted for a limited time for light trucks sales; all remaining light trucks and all car sales would be met with electric vehicles (battery electric). While hydrogen vehicles can be considered ZEVs, market trends indicate that electric vehicles sales are growing much faster for passenger vehicles. For simplicity this modelling assumes that hydrogen technologies are unlikely to make up a significant proportion of passenger ZEV sales. Modelled sales targets are outlined below:

Light Trucks				
Fuel/Vehicle Type	2020	2030	2040	2050
Low Emission Vehicle	2.00%	25.00%	0.00%	0.00%
Electric Vehicle	1.00%	75.00%	100.00%	100.00%
Diesel	4.90%	0.00%	0.00%	0.00%
Gasoline	92.20%	0.00%	0.00%	0.00%
Cars				
Fuel/Vehicle Type	2020	2030	2040	2050
Low Emission Vehicle	2.00%	0.00%	0.00%	0.00%
Electric Vehicle	1.00%	100.00%	100.00%	100.00%
Diesel	2.90%	0.00%	0.00%	0.00%
Gasoline	94.10%	0.00%	0.00%	0.00%

*Table G. Sales targets for light duty vehicle sales.*

#### *Medium and Heavy Duty Zero Emission Vehicle Mandate (Policy 11)*

This policy reduces on-road transportation emissions for medium and heavy-duty vehicles by legislating a rising share of zero emission vehicles sales. Under this policy, medium duty vehicles are expected to completely electrify by 2050 and heavy-duty vehicles increase ZEV sales, but at a slower rate. While ZEVs could be powered by electricity or hydrogen, for simplicity this modelling assumes that hydrogen technologies are likely to make up a relatively small percentage of long haul HDV sales. Remaining HDV and all MDV sales are assumed to be met with electric technologies. Sales targets by year for each vehicle class are presented below:

Medium Duty Vehicles				
Fuel Type	2020	2030	2040	2050
Electric	0.0%	30.0%	75.0%	100.0%
Hydrogen	0.0%	0.0%	0.0%	0.0%
CNG/RNG	0.0%	5.0%	10.0%	0.0%
Diesel	66.0%	42.9%	9.9%	0.0%
Gasoline	34.0%	22.1%	5.1%	0.0%
Heavy Duty Vehicles				
Fuel Type	2020	2030	2040	2050
Electric	0.0%	9.5%	22.5%	63.8%
Hydrogen	0.0%	0.5%	2.5%	11.3%
CNG/RNG	0.0%	5%	7.50%	5.0%
Diesel	95.0%	80.8%	64.1%	19.0%
Gasoline	5.0%	4.3%	3.4%	1.0%

Table H. Sales targets for medium/heavy duty vehicle sales.

#### *Renewable Natural Gas-Powered Vehicles (Policy #11a)*

While the greatest potential emissions reductions in HDVs lies in transitioning the fleet to ZEVs, some vehicles may be good candidates for renewable natural gas use. Additionally, there are already a number of compressed natural gas (CNG) transit vehicles on the road that could transition to RNG use in order to support TransLink's transition to renewable fuels. The CNS assumes that a small proportion of specialized medium and heavy-duty vehicles may transition to compressed natural gas trucks that utilize renewable natural gas in the medium term (2020 – 2040) as ZEV technologies develop.

#### *Medium and heavy-duty vehicle fuel efficiency standards (Policy #11b)*

This policy assesses the impact of increases to medium and heavy-duty vehicle economy through federal fuel efficiency requirements. Fuel economy for internal combustion engine MDVs and HDVs increases by an average of 1.5% per annum from 2020 to 2035, increasing fuel economy by a total of 30% from 2020 to 2035 (compared to a 7.5% improvement under the BAP).

#### *Enhanced Low Carbon Fuel Standard (Policy #59)*

This policy strengthens GHG intensity targets for on-road transportation fuels. The stringency of the existing Provincial LCFS is increased from 2020 to 2030, and extended beyond 2030, increasing renewable fuel blending requirements for diesel and gasoline. This could be achieved through a combination of

increasing carbon intensity requirements and renewable content blending. For simplicity, this modelling assumes a rising percentage of renewable fuel content in line with the table below.

All On Road Vehicles				
Fuel Type	2020	2030	2040	2050
Diesel	6.7%	20.0%	45.0%	80.0%
Gasoline	8.0%	10.0%	10.0%	100.0%

*Table 1. Renewable fuel type targets for on road vehicles by decade.*

## Results

Emissions drop under the CNS for on-road transportation an additional 24% from 2010 by 2030 over the BAP (for a total of 36% reduction in emissions overall) and an additional 30% from 2010 by 2050 over the BAP (for a total of 97% reduction in emissions overall). Fossil fuel use is expected to decrease significantly with 26% and 32% additional reductions over the BAP by 2030 and 2050 respectively (or 31% and 98% total reductions from 2010 by 2030 and 2050 respectively). Overall energy demand is reduced from 70.4PJ in 2010 to 22.5 PJ in 2050. This is mainly due to the transition to highly efficient electric vehicles.

The largest share of reductions in 2030 (over 2010 levels) come from strengthening the passenger ZEV mandate at 13% reduction in GHGs followed by two VKT reductions measures: active mobility switch (2%) and mobility pricing (2%). By 2050, with deeper vehicle electrification penetration, the most effective policies for reducing emissions are ZEV sales requirements for medium and heavy-duty vehicles (10%), enhanced Low Carbon Fuel Standard (7%) and strengthening the passenger ZEV mandate (7%).

Relative to the BAP, CNS passenger VKT and vehicle ownership reducing policies have modest impact in reducing emissions by 2050. In total the four VKT reducing policies (transit system expansion, car sharing, active mobility shift and mobility pricing) cumulatively reduce emissions by an additional 3%. This is more significant in 2030 with a 6% drop, to contributing to progress towards 2030 targets. The modest contribution at 2050 is because the vast majority of vehicles will be decarbonized by 2050 under the BAP, and a shift out of a ZEV vehicle to another mode has limited emissions impact. However, there are significant co-benefits to VKT reduction which enhance the utility of these policies. These benefits include:

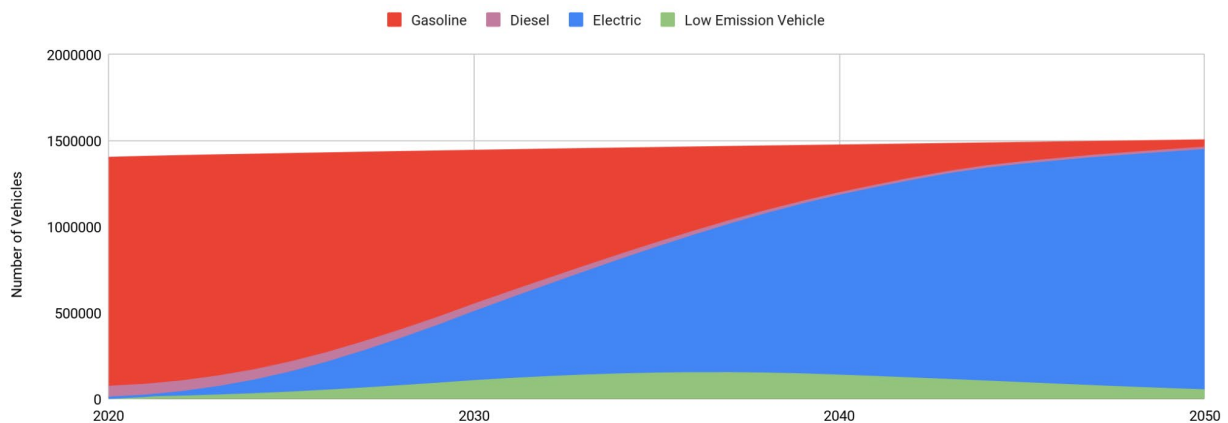
- Reduced congestion and travel times
- Improved physical activity and reduced obesity and associated health costs
- Reduced PM2.5 from braking and other non-combustion related vehicle operations
- Reduced infrastructure costs to accommodate a larger vehicle fleet
- Reduced auto-related fatalities

- Reduced transportation spending, the 2nd biggest household expenditure after housing

Strengthening fuel efficiency and the ZEV mandate, importantly, does not address many important costs of personal vehicular travel, some of which are amongst the region's top priorities (e.g. household costs). Additionally, while renewable fuels may have net neutral GHG emissions if their life cycle is regulated, they still produce some health-harming CACs.

Shifting to higher efficiency vehicles (internal combustion engine fuel economy) has a small impact on emissions in 2050, again due to fleets being dominated by zero emissions vehicles. Emissions impacts for the two engine efficiency policies result in 1% and 3% additional GHG reductions over the BAP scenario by 2030 and 2050, respectively.

Policies that accelerate zero emission vehicle penetration result in 14.7% and 16.1% additional emissions reductions over the BAP by 2030 and 2050 respectively, dramatically reducing fossil fuel consumption (95% of LDVs, 50% of HDVs; see graphs below).



**Figure 17.** Light Duty fleet vehicle composition by decade (2020-2050) under the CNS (# of vehicles).

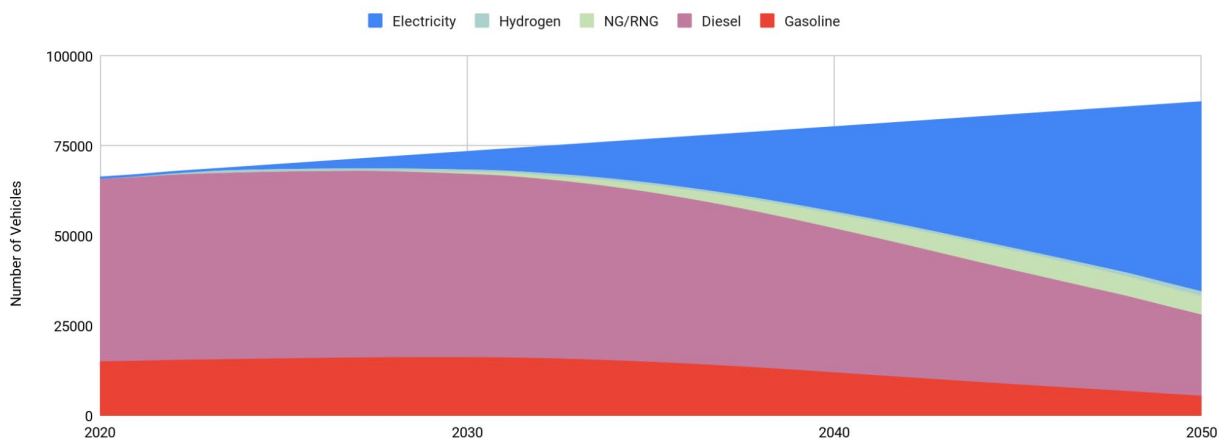


Figure 18. Medium and Heavy-Duty fleet vehicle composition by decade (2020-2050) under the CNS (# of vehicles).

Finally, an enhanced LCFS for on-road transportation results in significant GHG reductions. The remaining gasoline and diesel is decarbonised by 100% and 80% respectively by 2050, equating to 1.6% and 7.0% reductions in 2030 and 2050 respectively. However, renewable fuels still produce CACs. While emissions for some CACs may be lower as a result, the impact on emissions is not as significant as zero emission vehicles.

CNS policies will further decrease common air contaminants by 2030 (14% additional above and beyond CAC reductions in the BAP). As no additional CAC emission controls are modelled as part of the policies to the CNS most CAC reductions will be proportional to the reduction in gasoline, diesel and methane (fossil and renewable). As such, the drivers of CAC reductions are similar to those driving emissions reductions (that is to say, vehicle electrification, reduced driving distances, and more efficient engines). Renewable fuels such as renewable diesel and biodiesel have different emissions profiles than fossil diesel, but still emit CACs. Renewable natural gas produces the same amount of direct emissions as fossil natural gas.

The table below shows anticipated greenhouse gas emission reductions from modelled policies in this sector. The BAP results have been included as well to indicate the effect of general trends against the additional effort required for deep emissions reductions.



<b>Transportation On-Road</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
BAP GHG Emissions	5,086,059	5,506,007	4,457,406	2,962,824	1,632,115
Landuse	0	0	-46,899	-50,409	-22,404
Policy 11 Medium-Heavy Duty Zero Emission Fleet & Fuel Strategy	0	0	-92,193	-238,791	-492,525
Policy 11b Increased Fuel Efficiency	0	0	-7,805	-50,399	-70,152
Policy 6 Transit System Expansion	0	0	-22,683	-32,413	-11,923
Policy 10 Clean Car Sharing Capital	0	0	-63,740	-67,414	-32,448
Policy 8 Active Mobility Shift	0	0	-106,969	-105,885	-51,640
Policy 9 Mobility Pricing	0	0	-87,829	-86,938	-42,400
Policy 4 Passenger Vehicle Fuel Efficiency Standards	0	0	-42,603	-165,124	-90,927
Policy 3 Strengthen Passengers ZEV Mandate	0	0	-738,482	-1,022,523	-593,400
Policy 59 Renewable Transportation Fuels (Diesel + Gasoline)	0	0	-15,150	-14,409	-96,829
<i>Reductions</i>	<i>0</i>	<i>0</i>	<i>-1,224,353</i>	<i>-1,834,305</i>	<i>-1,504,648</i>
<i>Remaining Emissions</i>	<i>5,086,059</i>	<i>5,506,007</i>	<i>3,233,053</i>	<i>1,128,519</i>	<i>127,467</i>

Table J. Greenhouse gas emissions (tCO2e) from on-road transportation, and relative changes by policy.

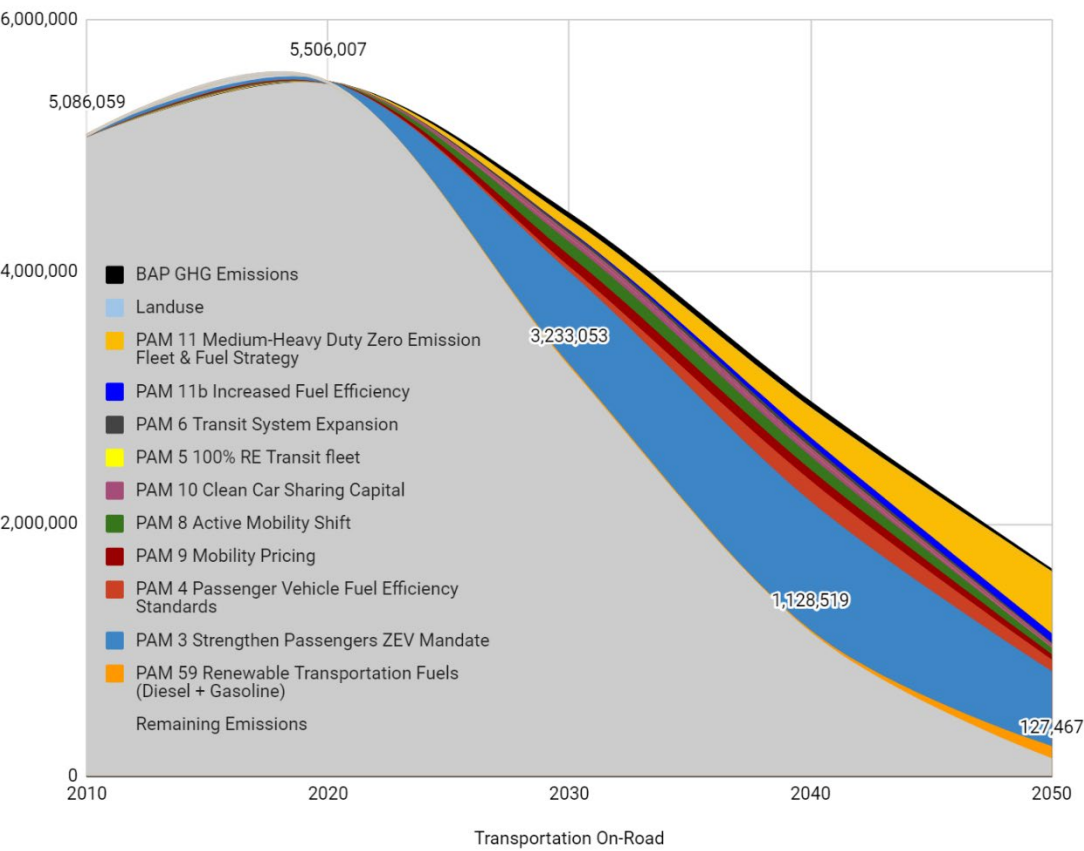


Figure 19. Emissions reductions in on-road transportation under the CNS.

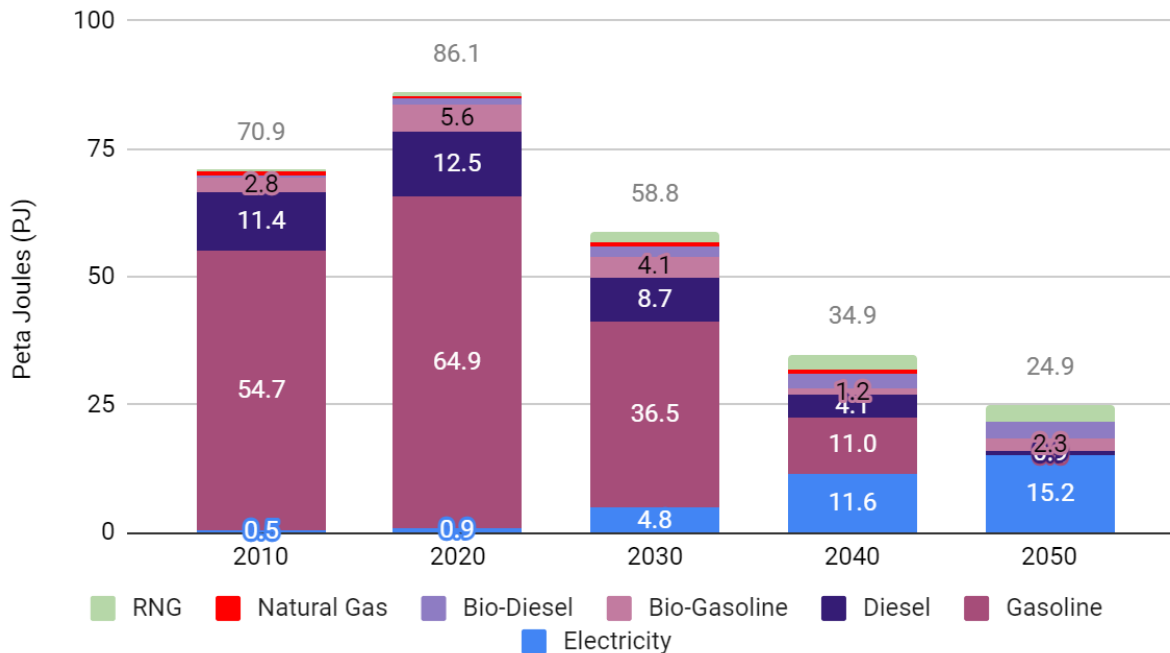


Figure 20. On-road transportation energy use under the CNS (PJ).

#### Remaining Emissions and Further Reduction Opportunities

Emissions in this sub-sector are nearly eliminated under CNS by 2050 with just 127,467 tCO<sub>2</sub>e remaining in 2050 (a 97.5% reduction over 2010). These reductions represent a significant shift as on-road transportation goes from the largest emissions sector in the region to almost completely eliminating tailpipe emissions in 2050. However, in order for Metro Vancouver to meet its 2030 emissions reductions target, additional policies are likely needed – particularly for LDVs as the largest transportation sub sector. The project team has identified the following areas for further exploration:

- Mobility pricing assumptions in this study have been aligned with recommendations from the MPIC report, which examines the impact of a pricing mechanism designed to reduce congestion. However, pricing policies have potential to more drastically reduce emissions if designed to prioritize emissions reductions. Future work that analyzes the potential of mobility pricing to reduce emissions – whether from VKT reductions or accelerated ZEV use – would provide better insight on the potential of this policy tool to meet GHG reductions targets. Additional policy tools such as low or zero emission zones also have the potential to accelerate local ZEV use beyond Provincial sales targets, but were not modelled in this analysis. Additional analysis is needed to better understand the potential impact of these policies on regional ZEV use.
- This modelling takes an outcome-based approach to uptake of car sharing and active transportation. Additional work that more closely examines the actions and policy drivers that

would lead to these levels of use would improve understanding of the link between policy and mode switching.

- More work is required to explore fleet transformation and understand the potential for MDV/HDV decarbonization through hydrogen for long haul activities.
- Further work is necessary to better understand the opportunities associated with emerging transportation trends such as ride hailing, telecommuting and the emergence of autonomous automobiles.
- This analysis treats renewable fuels as carbon neutral, assuming that all direct GHG emissions are balanced out by CO<sub>2</sub> uptake by feedstock plants. However, the production and supply of renewable fuels can create GHG emissions at numerous points. Additionally, the use of agricultural or forested land for feedstock growth may lead to significant GHG emissions release and has consequences for agriculture and conservation. Future work that assesses the feasibility of producing and supplying renewable fuels while maintaining a net neutral emissions and limiting other environmental impacts is needed to understand the lifecycle impact of renewable fuels.

### *Sector Context*

Industrial point source emissions and nonroad sources comprised 23% of the region's GHG emissions in 2010, with point source emissions consisting of 14% and nonroad sources consisting of 8%. While there are roughly 150 individual facilities that contribute to the industry point source sector, the top 10% of permitted facilities constitute over 90% of their GHG total. These facilities include cement and mineral processing, petroleum products, district energy/heating utilities, and wood products. Emissions from industrial sources are highly varied and require specialized policy approaches often in the form of facility-specific permits. Through permitting, Metro Vancouver regulates existing facilities with mandatory emission limits and control works. Emission increases in this sector are the result of new or expanded industry and permitted sources.

Nonroad sector emissions stem from the numerous pieces of equipment used to support industrial, commercial and residential activities, from small equipment including lawn mowers and other yard equipment to large cranes, loaders and bulldozers. Federal CAC emissions standards exist for nonroad equipment, resulting in dramatically lower emission rates of key CACs such as NO<sub>x</sub> and PM<sub>2.5</sub> for newer engines when compared to older. Metro Vancouver also has a related regulation called the Nonroad Diesel Engine Emission Bylaw 1161 (2012) that affects CAC emissions by incentivizing newer, lower emitting equipment. Federal nonroad fuel regulations also exist, which have effectively improved the nonroad fuel specifications to on-road levels. These regulations do not affect fuel economy however and significant growth in total fuel consumption (and related GHG) is included in the BAP over time.

CACs from the industry point source group, including PM<sub>2.5</sub>, VOCs, NO<sub>x</sub>, and SO<sub>x</sub>, comprised 21% of the regional total in 2020. While the top 10% emitters still constitute the vast majority of emissions in the region at about 80%, these larger emitters typically have advanced control works to manage and mitigate these emissions. Emission sources from these facilities are highly varied and include both process operations as well as fuel combustion. Unlike other sectors, industrial fuels include coal, petcoke and refinery gas, all of which are used for specialized activities. Displacing these fuels with low-carbon alternatives will be challenging, expensive and require significant technical innovation.

### *Business As Planned Future*

#### *Policies and Assumptions*

In the near-term, industry growth rates between 2010 and 2020 were determined by analyzing the Metro Vancouver emissions inventories for 2010 and 2015 developed based on operating data (i.e. fuel usage, material throughput, production, stack testing, and emissions monitoring programs), collected from

annual reporting as required by issued air quality management permits. These values were compared against National Pollutant Release Inventory (NPRI) reporting to ensure accuracy. Facilities were then grouped into sectors based on the North American Industry Classification System (NAICS) and growth rates were aggregated. Annual growth rates were then applied to facilities on a sector-by-sector basis. In the longer-term, growth rates between 2020 and 2050 revert to sector projections based on long-term economic growth rates. As the commissioning of new emitters is impossible to predict, these growth rates assume the inclusion of both expansion of existing industry and new industrial sources. As such, the projections assume that there are no new, significant emitters in the region (i.e. a source that usurps one of the top 10% emitters). For reference the top 10% emitters released between 20 and 800 kt of CO<sub>2</sub>e per facility in the baseline year.

Regulation and enforcement of issued permits/emitters are not expected to be changed. This includes no changes to fees and taxes levied on emitters including the provincial carbon tax, permitting fees, and air contaminant emission fees. For existing emitters, emission reduction initiatives—either for corporate sustainability or enhanced regulatory compliance—are not expected to be undertaken, resulting in emission growth rates corresponding with industrial activity growth rates.

Nonroad fuel consumption and emissions for future years were taken from the existing Metro Vancouver forecasts, which stem from estimates completed by ECCC for the region, using the US EPA 'NONROAD' model. Increases in emissions are driven primarily from the construction and commercial sub-sector of nonroad. However, the implied nonroad growth, determined by extending the expected growth between 2025 - 2035 out to 2050, seemed high when taking in to account anticipated growth in related sectors. It was therefore assumed that growth after 2035 would be 75% of this implied rate, assuming there will be some mitigation to the key drivers in this sector.

## Results

Industrial point source emissions are projected to rise from 14% to 22% of the region's GHG emissions under the BAP scenario by 2050. Within its sector, industry emissions are expected to rise 42% from 2010 to 2050 (from 2.1 mtCO<sub>2</sub>e to 3.0 mtCO<sub>2</sub>e). Reflecting an overall increase in fossil fuel consumed in industrial processes, CACs are expected to increase from 20% of the regional total to 26% by 2030. Under the BAP scenario, energy consumption rises 53% from 2010 to 2050. Natural gas is expected to continue to be the dominant fuel type; petcoke and coal will persist as a fuel source due to the cement and mineral processing industry, and refinery gas will continue to be used as a fuel source in the petroleum products industry.

Nonroad emissions comprised 8% of the region's GHG total in 2010 and are projected to rise to 14% in the BAP scenario by 2050. This is a greater rate of increase compared to the industry sector and greater than any other sector included in the BAP, even after growth rates were adjusted downwards to reflect

uncertainty in high growth projections. Diesel use dominates the sector, with gasoline and propane used primarily for the smaller engines.

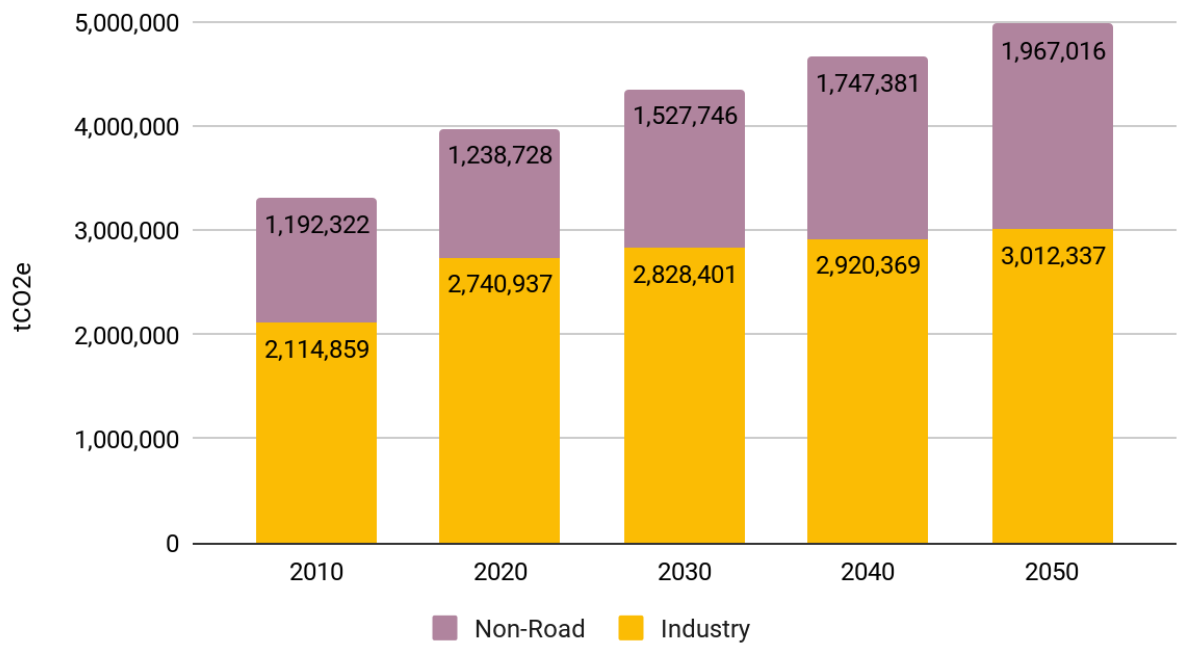


Figure 21. Business As Planned modelling of Greenhouse Gas Emissions (tCO2e) by the industry sector from 2010 to 2050.

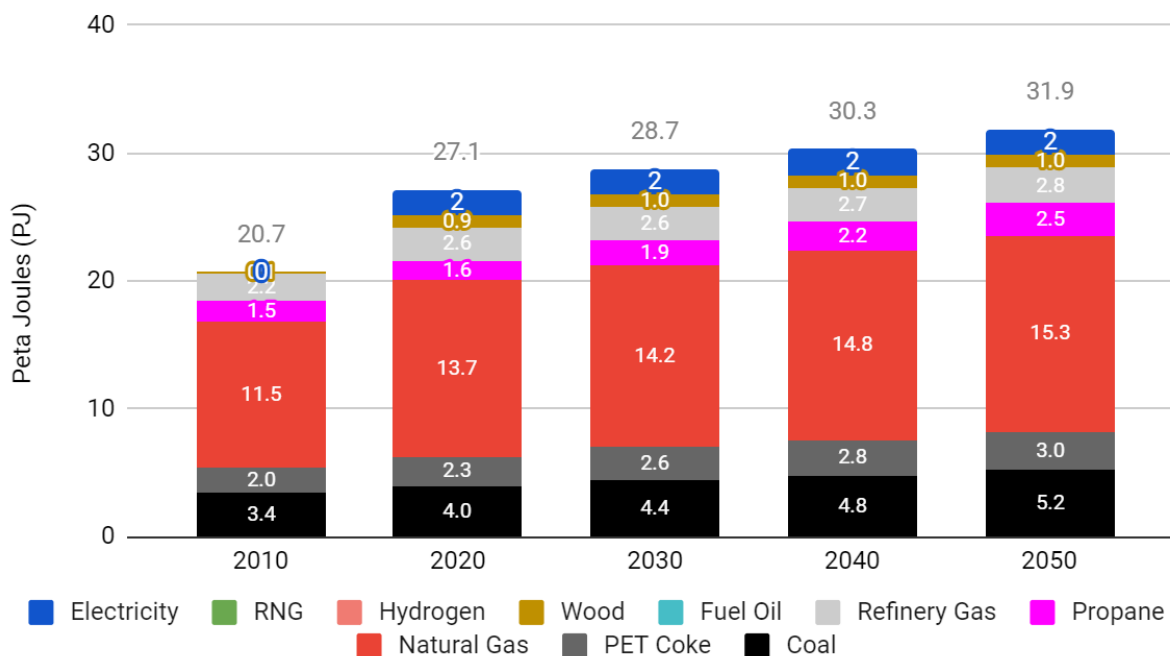


Figure 22. Business As Planned modelling of primary energy usage by industry fuel type from 2010 to 2050 (PJ).

### Carbon Neutral Scenario

#### Policies and Assumptions

A main focus of the Industry policies and assumptions was on the top 10% emitters, which, as noted above, are responsible for more than 90% of GHG emissions. Decarbonization of the industry sector is a particular challenge as operations are highly varied. As such, policies such as the carbon tax are important to ensure incentives are aligned and to stimulate investment into low-carbon technologies. Revenues generated from carbon pricing may also be reinvested back into low-carbon technologies to aid in the decarbonization of the sector. Programs such as the CleanBC Industrial Incentive Program (CIIP) that provide incentives for emissions reduction based on industry benchmarks are also valuable in ensuring transparency and reinvestment.

Stemming from the low carbon intensity of BC's electrical grid, a push towards electrification is an attractive decarbonization policy that can be impactful for both the industry and nonroad source groups. However, there are limitations to electrification within industry, especially for feedstocks (i.e. raw materials converted into another product) and high heat applications. An alternative to electrification for these types of industry sources is to switch to a low carbon energy source. Despite these efforts, it is still highly unlikely that some industrial emitters will be able to achieve deep emissions reductions, necessitating the deployment of carbon capture initiatives. Nonroad on the other hand is highly amenable



to electrification. Reductions for this sector are primarily associated with conversion of fuel engines to battery-powered motors.

#### *Industrial energy switching (Policy #27)*

This policy looks at the impact of regional regulations that require increased use of renewable energy in boilers, heaters, and other industrial applications. Fossil fuel boilers and heaters are required to transition to renewable energy sources, reaching 50% in 2030 and 100% in 2050. The modelled energy mix consists of 10% electrification in 2030, and 30% in 2050, with the remaining energy demand met with RNG.

This modelling also looks at the potential for coal combustion to fuel cement kilns to be partially replaced with the use of biosolids. Based on estimates of regional biosolids availability, this policy assumes that 50,000 tonnes of biosolids will be used in clinker production by 2030; and 150,000 tonnes will displace coal combustion in 2050.

Finally, this policy looks at the potential emissions impact of displacing remaining coal and petcoke use with fossil natural gas. While all three of these fuel types are fossil fuels, natural gas produces less greenhouse gas emissions and generally less CACs than coal or petcoke. Additionally, transitioning to natural gas use would facilitate the use of more RNG if regional availability of RNG exceeds expected supply.

#### *Large emitter carbon capture (Policy #23)*

This policy models the use of Carbon Capture Utilization and Storage (CCUS) for major emitters, particularly for the cement and mineral processing sector. The unique processes that are involved in the operation of major emitters result in challenges to reducing their reliance on fossil fuels. For these industrial subsectors, CCUS is a critical pathway to decarbonization. CCUS technologies are not yet widely used, and uncertainty remains about the scale they may be implemented in. This policy assumes a relatively modest amount of CCUS at 50,000 tonnes of net CO<sub>2</sub> captured in 2030 and 200,000 tonnes of net CO<sub>2</sub> captured in 2050.

#### *Low carbon cement (Policy #25)*

This policy looks at the impact of regional and/or Provincial regulations, contracting policies, and incentives that support increased production of low-carbon cement (such as Portland Limestone), and limited growth in cement production. This policy assumes that 20% of cement produced in the region is Portland limestone by 2030 and 75% is Portland limestone by 2050, with the carbon intensity of Portland limestone cement being 10% less than conventional Portland cement; and that the cement production growth rate declines from 18% by 2050 (as in the BAP) to 10% by 2050, which is generally consistent with the International Energy Agency's (IEA) low-carbon transition projections for the cement industry.

#### *Industry efficiency improvements incentives (Policy #29)*

This policy looks at the impact of industrial energy efficiency improvements incentivized through utility rebate programs based on efficiency targets compared to industry benchmarks. This policy assumes a 5% improvement in system-wide efficiency by 2030 and a 20% improvement by 2050.

#### *Electrification requirements for non-road engines (Policy #22)*

This policy models an increased use of battery-operated equipment to displace fossil fuel use. This policy follows two guidance paths: the Vancouver Fraser Port Authority (Port) for its Cargo Handling Equipment (CHE) plans and the California Air Resources Board (CARB) for its electrification plans (some of which are fully developed and some in the mid-point of promulgation). The order the actions are identified shows the order they are implemented in the inventory.

Within this policy, the Port's 'electric CHE' program is acknowledged by simulating the gradual conversion of all port CHE to electric (20% by 2030, 100% by 2050). The port CHE emissions are estimated to be 11% of the 'Construction, Mining and Industrial' sub-sector of the full nonroad inventory. Phase 1 and Phase 2 of the CARB program are also implemented, which target forklifts of horsepower (hp) less than 65 hp as well as all aircraft support equipment (Phase 1) and all larger engines (Phase 2) within the Construction & Mining, and Industry sub-sectors of nonroad. Key assumptions for Phase 1 are that forklifts less than 65 hp constitute 40% of the total forklift fuel consumption in the inventory. For Phase 2, assumptions are that the entire sub-sectors that consume diesel noted above are affected. Phase 1 becomes effective shortly after 2030 and is 100% realized by 2050 whereas Phase 2 assumes forced retirement of the large equipment wouldn't happen until 2060 (80% penetration is assumed by 2050). This represents a slight delay behind the implementation timeline that California is pursuing to reflect the need for some additional lead time to implement such a program in BC.

An additional action is simulated in this policy referred to as 'electric generators'. There is already evidence that electric generators are being voluntarily used in the MV region. This action assumes 15% of generators are electric by 2030 (displacing diesel use) and 100% by 2050. These generators make up 68% of the fuel consumption in the 'Commercial' nonroad sub-sector.

For all of these actions, conversion to electric motors are considered to completely remove the associated CAC emissions.

#### *Fuel economy standards for non-road equipment (Policy #19)*

This policy has enhanced non-road emission regulations applied to fuel economy. The key performance assumption for this policy is that all non-road equipment and all fuels (not including electricity) are

targeted, with fuel economy standards identified below. It is noted that CARB foresees Tier 5 engine standards being introduced in the mid-2020s that would logically include hybrid technology as an option for compliance. We assume a related manufacturers regulation in Canada could be harmonized with the CARB one and that an efficiency requirement would be included, lagging CARB by 5 years. This makes the first effective year of the program 2030 (and therefore there is no effect in this year). By 2050 it is assumed that the regulation would have fully penetrated the operating fleets. All nonroad sectors and all fuels would be affected equally. The impact of the policy is simulated to be 0 (no effect) in 2030 and a 25% reduction in fuel use for the remaining fossil fuel driven fleet by 2050. CAC reductions are assumed in the same proportions.

*Enhanced Low Carbon Fuel Standard (Policy #59)*

While the Low Carbon Fuel Standard (LCFS) does not currently apply to nonroad sources, this policy assumes it is practically implemented (as described in the on-road transportation section on page 48) for the non-road sector, for all diesel and gasoline use, following the application of Policy 19 and 22.

## Results

Presented in the table below are the anticipated reductions in emissions by modelled policy actions and measures for this sector. For simplicity, the BAP has been included as well to indicate the effect of general trends against the additional effort required for deep emissions reductions.

<b>Industry - Point Source</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
BAP GHG Emissions	2,114,859	2,740,937	2,828,401	2,920,369	3,012,337
Policy 23 Large Emitter Carbon Capture	0	0	-50,000	-125,000	-200,000
Policy 24 Cement Fuel Switching	0	0	-45,752	-87,778	-129,804
Policy 25 Low Carbon Cement	0	0	-124,005	-338,658	-553,310
Policy 27 Industrial Energy Switching	0	0	-319,804	-633,741	-947,677
Policy 29 Industry efficiency improvements incentives	0	0	-35,384	-93,861	-152,337
<i>Reductions</i>	<i>0</i>	<i>0</i>	<i>-574,945</i>	<i>-1,279,037</i>	<i>-1,983,128</i>
<i>Remaining Emissions</i>	<i>2,114,859</i>	<i>2,740,937</i>	<i>2,253,456</i>	<i>1,641,333</i>	<i>1,029,209</i>

<b>Non-Road</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
BAP GHG Emissions	1,192,322	1,238,728	1,527,746	1,747,381	1,967,016
Policy 22 Electrification requirements for non-road engines	0	0	-37,876	-684,176	-1,330,475
Policy 19 Fuel economy standards for non-road equipment	0	0	0	-76,369	-152,738
Policy 59 Renewable Transportation Fuels (Diesel + Gasoline)	0	0	-213,298	-282,031	-350,764
<i>Reductions</i>	<i>0</i>	<i>0</i>	<i>-251,174</i>	<i>-1,042,576</i>	<i>-1,833,977</i>
<i>Remaining Emissions</i>	<i>1,192,322</i>	<i>1,238,728</i>	<i>1,276,572</i>	<i>704,806</i>	<i>133,039</i>

*Table K. Greenhouse gas emissions from industry and non-road, and relative changes by policy (tCO<sub>2</sub>e).*

The policies modelled in this scenario result in a greenhouse gas emissions increase of 6.7% by 2030 over 2010 and a reduction of 65% by 2050. Fuel switching from non-renewable fuels—with significant reductions in coal, PET coke, and natural gas—to renewable fuels—with significant increases in electricity,

RNG and biosolids—drives this GHG reduction. Non-renewable fuel consumption is expected to decrease 87% from 2010 to 2050; the policies responsible for this reduction include cement fuel switching and industrial energy switching. Large emitter carbon capture and industrial efficiency improvements are other important policies that have a direct impact on reducing GHGs, and the low emissions concrete indirectly impacts GHGs by shifting cement demand to less intensive alternatives.

The same trend of decreasing emissions is not shared by CACs. CAC emissions are largely stable in relation to the various policies, with any reductions being extremely limited. Industry is the major emitter of SOX, and NOX, and Non-Road is the third highest sector for NOX emissions. Non-Road and Industry are the second and third highest emitters of VOC, respectively, with on-road being the highest emitting sector. Industry and Non-Road have the highest emissions of PM2.5, in that order. Emitters are highly regulated through the Metro Vancouver air permitting process for stationary sources. Prior to granting authorization to discharge air contaminants from a facility, Metro Vancouver will assess a multitude of factors including the size and siting of the facility (including how close it is to residences, schools, care facilities and other sensitive receptors), its impact on the environment, public complaints, and current industry standard control technologies, with an emphasis on best available control technology (BACT). Through this regulatory process, Metro Vancouver ensures that CAC emissions are not a significant detriment to the environment. Thus, policy actions that were effective at reducing GHGs, such as switching from natural gas to RNG and cement fuel switching, are not effective at reducing CACs. Electrification strategies, fuel efficiency, and shifting cement demand to alternatives were the most influential policies that resulted in CAC reductions in 2030.

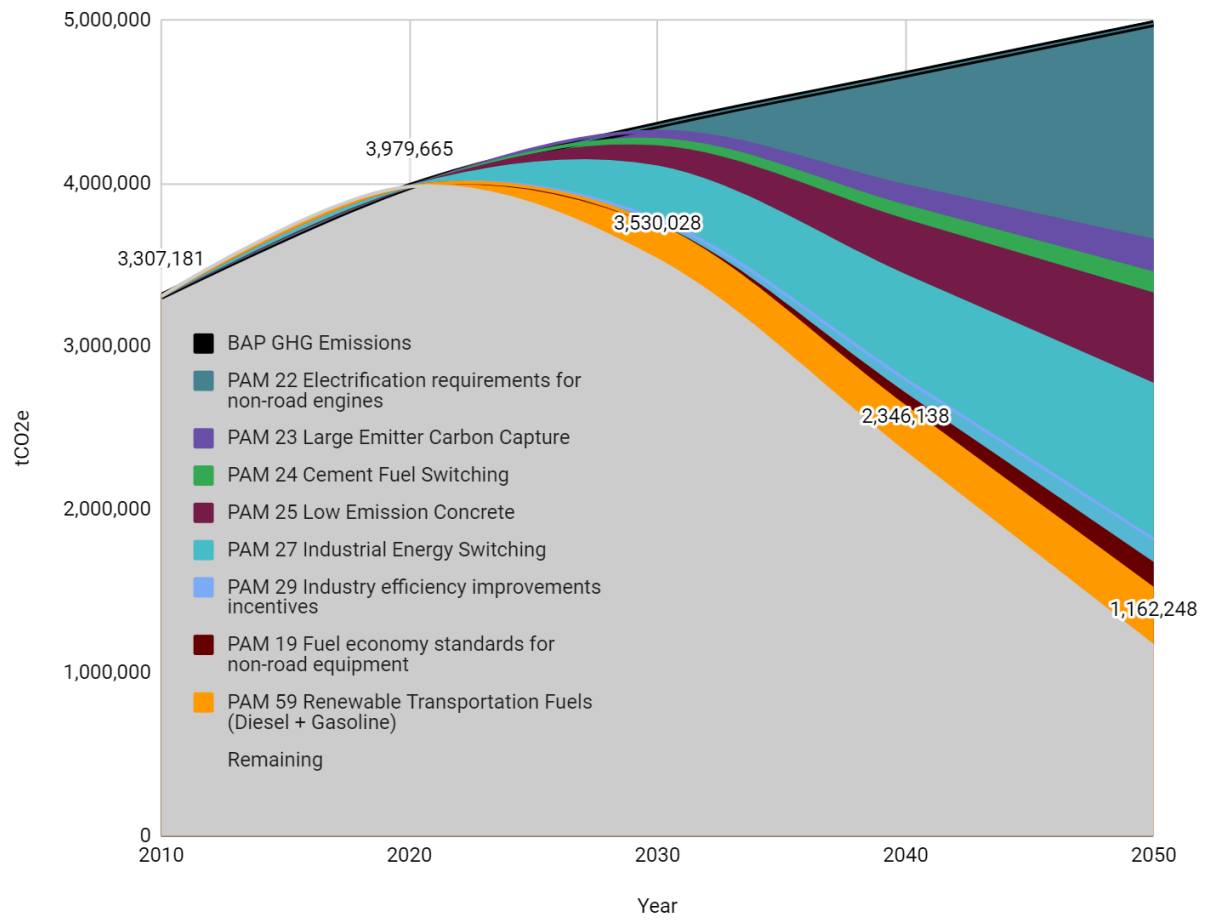


Table L. Industry and non road emissions reductions resulting from CNS Policies (tCO<sub>2</sub>e).

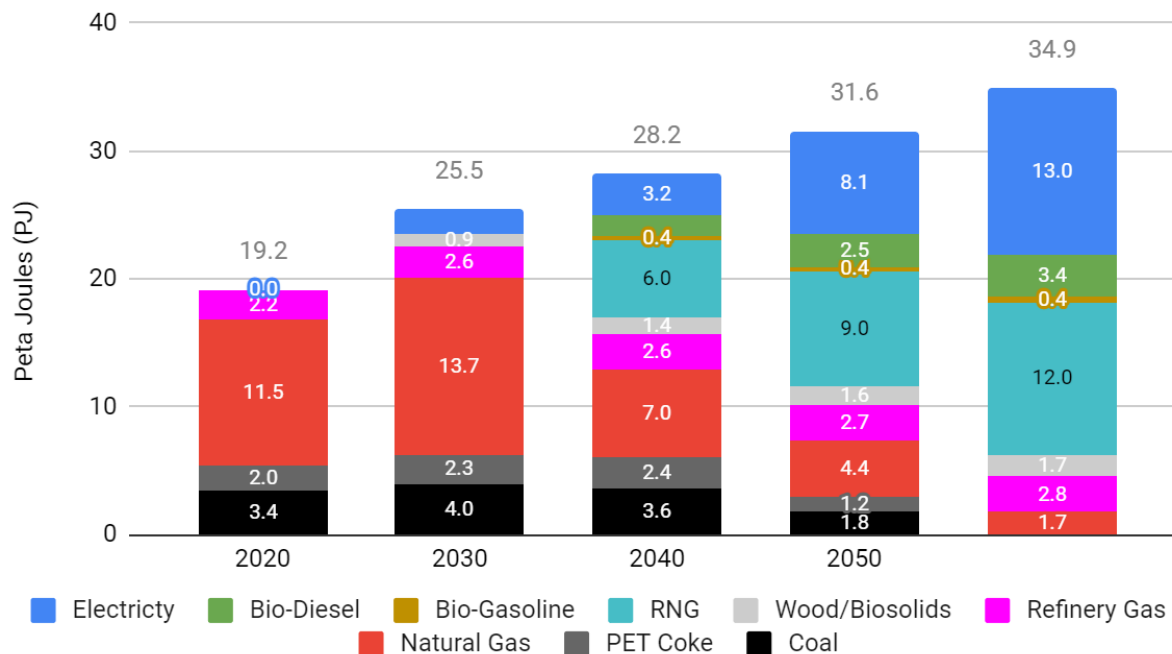


Figure 23. Industry and non-road energy use (GJ) in the CNS (2010-2050).

#### Remaining Emissions and Further Reduction Opportunities

As discussed above, the CNS results in a 6.7% increase in GHGs by 2030 and 65% reduction by 2050 (relative to 2010), with 1.1 million tonnes remaining. Deeper reductions will be necessary in industry to meet Metro Vancouver’s 2030 and 2050 targets. Heavy industry that transforms raw materials into new products and high heat applications will be particularly challenging to decarbonize. While a range of emissions reduction strategies have been modelled—from fuel switching to energy efficiency improvements to carbon capture—the investment and adoption of low-carbon technologies is challenging to predict and quantify. This has been modelled in the cement industry as best as possible, but has not been analyzed for all facilities due to the varied nature of their operations. Ultimately, achieving zero emissions may not be possible for this sector from a production standpoint and further explorations of carbon removal technologies may be necessary. However, the project consulting team has identified a number of areas to explore for potential further emissions reductions:

- Hydrogen has shown promise as a low-carbon fuel, and the federal government has indicated support for the development of hydrogen fuels and infrastructure, namely through National Resources Canada’s “Hydrogen Strategy for Canada” document. While it has great potential to decarbonize processes that cannot be electrified, hydrogen was ultimately not included as a

pathway for these sectors due to its current relative immaturity. Additional analysis could focus on the potential use of hydrogen to further reduce emissions, primarily for industry.

- While carbon capture for large industrial sources is a promising technology, it is a last measure for achieving carbon neutrality with the primary focus being on emission reductions. Further analysis is needed to better understand the potential contribution of CCUS in balancing out remaining emissions. There are a number of challenges requiring further exploration. While the capture of CO<sub>2</sub> from point sources is technologically feasible, facilities need an end-use or storage for the captured CO<sub>2</sub>. Facilities will often not have a use for the captured CO<sub>2</sub> on-site and will need to compress and transport it by pipeline, ship, or rail to be used in different applications or injected into deep geological formations for permanent storage. For this to be realized, a local market needs to be fostered and infrastructure needs to be developed for captured CO<sub>2</sub> for facilities to be willing to adopt this technology. Regional measures that employ carbon capture should also be supported including direct air capture and bioenergy with carbon capture storage for power generating stations.
- Industry Investment in low-carbon technologies has an opportunity to provide an important impact on emissions reduction. Due to the varied nature of operations, investment and analysis must be done at the facility level.
- Understanding the potential for impact reductions in industry if consumers adopt low emissions alternatives – such as Portland Limestone cement – in large quantities that displace conventional, higher emissions products.
- Nonroad policies will require improved understanding of the energy consumption and emissions in this sector. Fuel economy is currently unregulated, and would be complex to establish and regulate. Data and modelling are also limited, and additional work could benefit and inform policy development. Corporate Average Fuel Economy (CAFE) standards such as those applied in the on-road vehicles sector could be considered. Technology developments are important to consider for off-road electrification. The current developments of on-road heavy duty electric trucks (example, drayage trucks in California) show that large engine electrification is possible. There has not been the same level of attention applied to large engine off-road equipment and further emphasis could be placed here. This is a program that was modelled, but not expected to be impactful until 2040 or later. Accelerating this program may be possible.



### *Sector Context*

As a port region, the flow of goods through marine and rail transportation comprises a substantial amount of activity, and emissions in Metro Vancouver. Pleasure craft and rail-based passenger travel make up a very small proportion of emissions within this context. Aviation is another important activity to consider, with a regionally important airport and a current growth rate in both freight and travel that is likely to continue.

Marine, rail, and aviation emissions make up an increasing portion of the regional inventory with potential CO<sub>2</sub>e increases of 34% and 69% from 2010 to 2030 and 2050 respectively (from 870,348 tCO<sub>2</sub>e in 2010 to 1,164,738 in 2030 and 1,474,736 in 2050). Marine is the largest sub-sector within this grouping, approximately equalling in magnitude to GHG from medium and heavy-duty vehicles.

Drivers for these emissions increases include substantial growth in trade over the last decade, and this is projected to continue. With port growth comes growth in cargo ship movements and the marine industry that supports them. North American ports have invested heavily in GHG reduction plans that are largely incentive based, reflecting that the largest emission sources, cargo ships, are not under domestic control. Still, Canada and the U.S. have successfully established Emission Control Areas (ECAs) for the east and west coasts, which establishes control over the ship emissions of SO<sub>x</sub>, NO<sub>x</sub> and PM while in domestic waters. These ECAs are effective for common air contaminants (CACs) but have limited impact in curtailing GHG emission growth. However, the International Maritime Organization (IMO) has committed to a target of reducing total annual greenhouse gas emissions from international shipping by at least 50% by 2050 (compared to 2008). The Federal Government is responsible for adopting, implementing, and enforcing IMO requirements within Canada.

Canadian rail serves the port and rail movements have been growing in step with marine emissions. Rail falls under federal jurisdiction and most of the rail activity in the region is subject to Locomotive Emissions Regulations (2017), requiring the rail lines to meet emission standards for new locomotives that target CACs. Use of alternative fuels and electric or electric hybrid systems is under study, but challenged with economics, technology readiness (hydrogen) and infrastructure. At this time, little to no decarbonization of rail is anticipated for the BAP.

Aircraft, also under federal jurisdiction, are currently omitted from the pending federal Clean Fuel Standard as the industry is currently developing capacity for technological changes. Appropriate no or low carbon fuels are being studied and becoming available and used at a few leading international airports. However, no alternative fuel use is assumed for the BAP. The International Civil Aviation Organization (ICAO) has adopted the aspirational goals of carbon neutral growth for the international aviation sector

from 2020 onwards, as well as 2% annual fuel efficiency improvement from 2021 to 2050. Member nations are responsible for developing their own regulatory approaches to reaching these goals.

BC's Low Carbon Fuel Standard has no effect on these emissions sources in the BAP, since marine, rail, and aircraft fuels are not included in this regulation. While the Federal government is in the process of developing a Clean Fuel Standard to apply to diesel and marine fuels, this was not well developed enough at the time of the BAP model run to reflect.

### *Business As Planned Future*

#### Key Assumptions / Policies

Growth rates under the BAP are consistent with the growth rates in the Metro Vancouver inventories, with some exceptions. The marine inventory was updated from the Environment and Climate Change Canada (ECCC) national marine model, extracted by ECCC for the Metro Vancouver region specifically for this project. The ECCC inventory forecasts are based on national economic projections and for key cargoes. The Port of Vancouver's forecast rates were considered more representative and were used for cruise, container and bulk commodities growth. All domestic activity (BC Ferries, fishing, harbour vessel) forecasts assume the ECCC rates. The rail forecasts follow the port growth rates for line haul and switching activities and retain the Metro Vancouver growth rates for passenger rail (which relate to expected growth in diesel fuel demand to 2035). Aviation forecasts in the MV inventory were unchanged. Existing forecasts in these inventory models do not extend to 2050 and the rates of change from 2025 - 2035 were extended to 2050.

It is important to note that the growth rates for all of these subsectors inherently assume that the 2015 energy consumption rates scale linearly, acknowledging improvements in fuel consumption where expected. This method does not account for changes in how the activities may be carried out - for example train movements occur with similar capacity trains, flights with similar capacity planes. While this is reasonable to assume in general, some ship types such as container vessels are becoming larger and therefore this assumption may be considered less reasonable for the marine sector.

As noted above, there are no domestic government policies that influence GHG emissions for marine, rail, and air sources and only a moderate limiting effect on the growth of the emissions in the BAP is assumed, due to technological improvement (small improvements in fuel economy for similar amounts of work performed, in the rail and marine sectors). Diesel engines have had a long history of development and further efficiency gains from current levels are very challenging to achieve. There are international regulations in the marine sector with new vessel efficiency standards such as the Energy Efficiency Design Index (EEDI) and these affect cargo efficiency by using larger ships for example. However, these regulations do not have a clear impact on vessel anchoring and berthing emissions in the region, which dominate the totals for this sector. There have been improvements in rail cargo efficiency for the class 1

rail lines (Canadian National (CN) Rail & Canadian Pacific (CP) Rail) that serve the region, measured as litres fuel per tonne-km of goods movement, which is tracked annually by the Rail Association of Canada (RAC). CN has a target of further improvement in cargo efficiency by 2030 but since this isn't a policy or regulation it is not assumed for the BAP.

## Results

Fuel and energy dynamics for this sector under the BAP are largely responsive to the trends identified above. By 2050 total energy demand is expected to increase by 71%. Total GHG emissions are expected to increase by 69%. Marine growth is significant and much of this growth stems from an expected increase in container and bulk commodities traded, which also drives much of the growth in rail. An almost 100% growth in containerized trade is expected in 2050 compared to 2010, a direct result of increased globalization. Lesser, but nearly as sizeable increases are expected in bulk goods trade. Mitigations are being planned to reduce the GHG impact of these growth levels, but their impact has yet to be experienced.

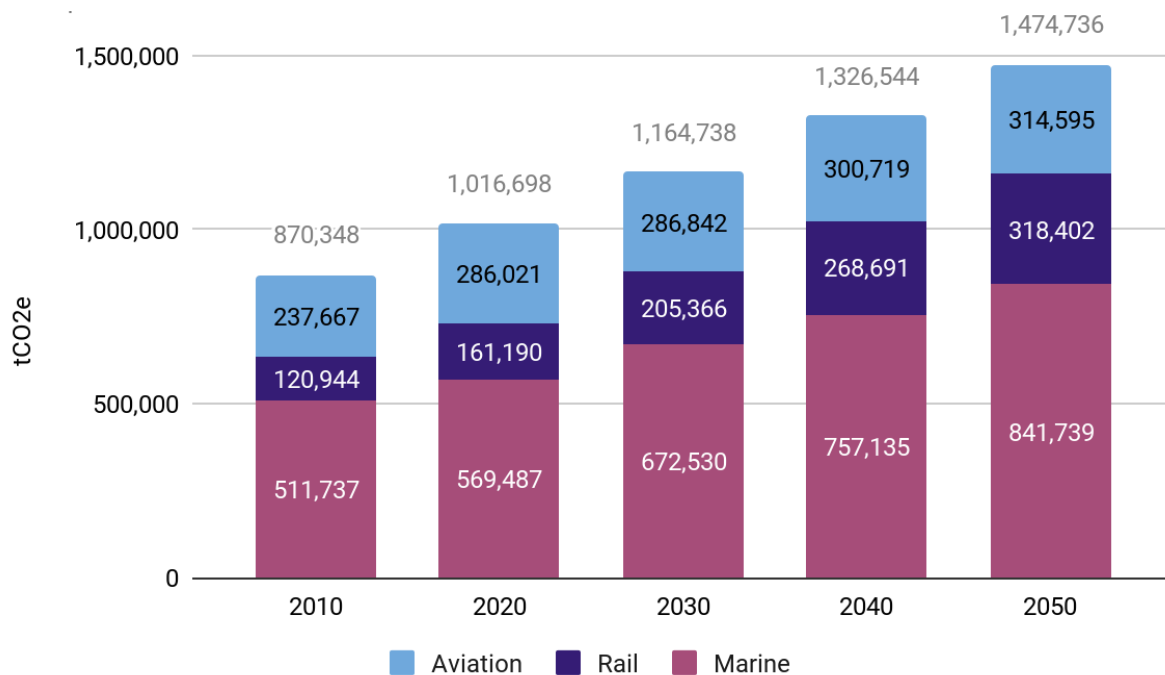


Figure 24. Business As Planned modelling of primary energy usage by marine, rail, and aviation (transportation) from 2010 to 2050 (tCO<sub>2</sub>e).

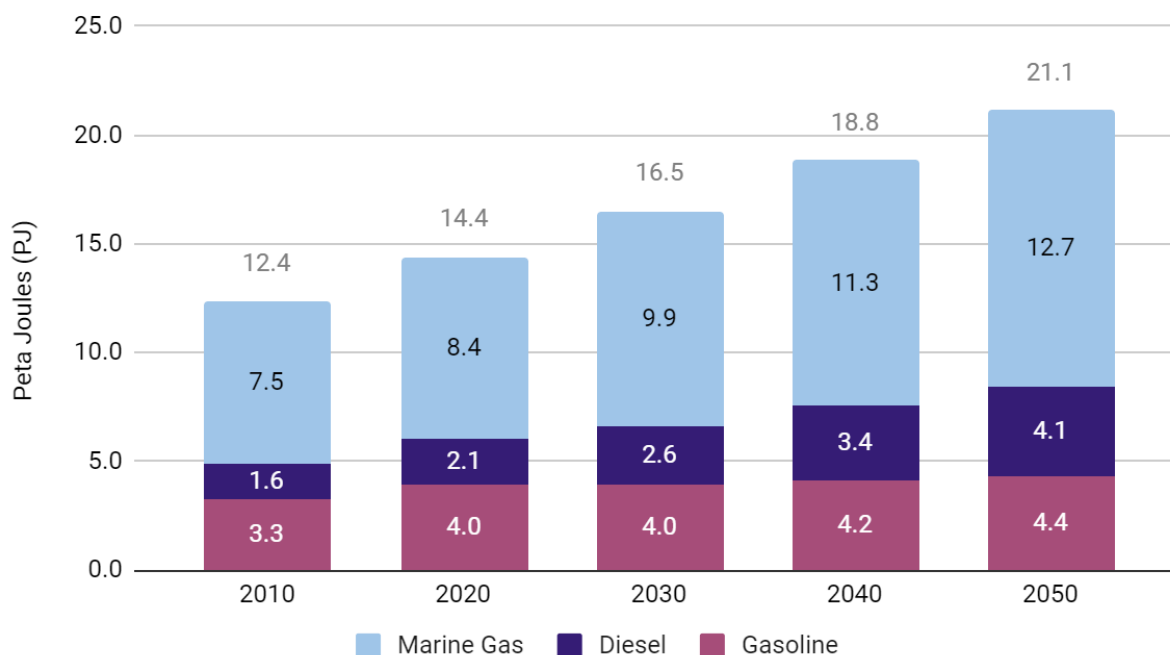


Figure 25. Business As Planned modelling of primary energy usage by marine, rail, and aviation (transportation) fuel type from 2010 to 2050 (PJ).

Cost, scale and reliability of new technologies to reduce emissions are all factors for this sector. Additionally, policy is difficult to implement due to a high degree of coordination required with other jurisdictions, including international bodies. Given the high degree of uncertainty both forecasting this sector as well as the scale of required change, it is anticipated that even under an aggressive reduction scenario that reductions in this sector will not be as large as those identified in other areas.

### Carbon Neutral Scenario Reductions

#### Key Assumptions / Policies

Emissions strategies exist in each of these sectors, with the marine and aviation sectors the most difficult to affect due to their international aspect. The policies employed here are a mix of regulation and incentive programs that have been identified in the literature as well as in key provincial programs such as CleanBC. Studies, implemented regulations and expected regulations that affect GHG emissions in California also play a role in the simulated actions. While it may be difficult to implement and enforce policies on the same time frames to those envisioned in that state, it is reasonable to expect similar actions here may be as impactful several years following.

Electrification also plays a key role here, acknowledging that larger engines are more difficult to electrify currently, due to greater power demands. Additionally, long range transportation is currently considered to be more amenable to alternative emission reducing strategies such as biofuel use.

#### *Aviation biofuels (Policy #14)*

Policy #14 evaluates the implementation of a group of measures including aircraft operational and technological improvements, renewable aviation fuels, and electrification that would meet the ICAO target of a 50% drop in CO<sub>2</sub> intensity by 2050. This would be achieved in part with a 2% improvement in fuel efficiency per year until 2050, in line with the ICAO's fuel efficiency aspirational goals. Additionally, 2% of Pacific Northwest flights (BC, AL, WA, OR, and CA) are electric by 2030 and 15% by 2050. The use of renewable fuels supplements these strategies to meet the ICAO 50% target. Aside from reductions associated with reduced total fuel use, No CAC reductions are associated with this policy due to lack of reliable information to distinguish CAC emission rate differences between conventional aviation fuel and biofuel.

#### *Incentive programs to reduce marine emissions (Policy #15)*

Policy #15 models incentive programs that expand on the Vancouver Fraser Port Authority's existing program. Regulations are difficult to implement on international vessels and tend to be set by the IMO before ratification by member countries. There is more potential to regulate domestic marine craft, but international cargo ships dominate emissions for this group. Additionally, there is considerable willingness for much of the domestic fleet to voluntarily reduce emissions, in part for competitive reasons (lower carbon ships help secure new contracts). This context supports the efficacy of incentive or voluntary programs. For cargo vessels, the port has had a successful incentive program historically (primarily for CAC reductions) and this policy would expand on that approach. Shore Power (SP) utilizes electrical connections for ships while at berth, which requires the vessel to have the onboard capability. This capability exists in most cruise ships and many newer container ships but will take time to develop in other vessel classes. Key performance assumptions are:

- All cruise and 30% of container ships will use SP in 2030 and 10% of roll-on roll-off (ro-ro) and tanker ships use SP as well. In 2050 container SP use rises to 100% and ro-ro and tanker to 30%. The BC Ferries Clean Future Plan is interpreted to have 20% of ferry activity electric by 2030 (modelled as a 20% reduction in fuel use due to electric and hybrid ferries) and 50% of ferry fleet is electric by 2050. CAC reductions are assumed with this Policy by 2030, with reductions in step with the electrification rates.
- Port incentive programs support reduction of GHG emissions from ocean going vessels (that include underway, anchor, and berth) matching the broad IMO 2050 commitment of 50% reduction by 2050, assuming 15% reduction in GHG locally by 2030 and 50% reduction by 2050. Federal regulations may be needed to adopt, implement, and enforce the IMO's proposed

target. CAC reductions are assumed to be half of these levels (e.g., ½ of the GHG reductions would be associated with efficiency gains or zero emission technologies). The port's differentiated harbour dues program is one method of incentivizing this initiative; and

- Port procurement program or federal regulation has new escort and assist tugs from 2030 to be electric capable (such as diesel electric), with minimum efficiency requirements of 25% or equivalent, aligning with CARB's proposed requirements for harbour vessels 'enhanced efficiency diesel-electric' technology that would be phased in from 2025. The effect of the tugs program is assumed to lag CARB by 5 years and is fully implemented by 2050. It is assumed that this rule would affect 50% of the total tug activity in the region. CAC reductions by 2030 are assumed in step with the electrification rates.

#### *Low carbon rail performance standard (Policy #16)*

Policy #16 models a low carbon rail performance standard that acknowledges the draft federal Clean Fuel Standard (CFS) regulation and the considerable support for green hydrogen development from the Canadian federal government. Electrification of switch locomotives (e.g., rail car shunting) is an initiative that has gained momentum in California through continuing pilot projects and is assumed to progress in Canada. Key performance assumptions include (1) a 15% overall improvement in cargo efficiency (measured as GHG per revenue tonne-kilometre) by 2030 from 2015, following CN's stated performance goal of 29% reduction in this metric by 2030. CN's goal, which is assumed to include the effect of the CFS (which provides an additional 10% GHG reduction in Policy 59) shows that there is willingness and potential for efficiency improvement in the sector. CAC reductions are assumed in line with the efficiency improvements; (2) a 40% improvement in cargo efficiency by 2050 (assuming use of green hydrogen displaces diesel by this time); and (3) switch locomotive operations are 15% electrified by 2030 and 100% electrified by 2050, with CAC reductions in line with the electrification rates.

It is noted that switch locomotive electrification, which largely constitutes activity in railyards, sidings and marine terminals, has had interest from government and industry for over 15 years. While early models of electric switch locomotives were not very successful, there has been considerable development of the technology since that time and pilot studies continue in states areas such as California. Feasibility studies for port electrification completed for the Port of Vancouver identify terminal-owned electric switch locomotives may be ready for full deployment as early as 2030 - 2035, with pre-commercial use between 2025 - 2030<sup>3</sup>. This shows that the timeline assumed here for rail electrification is aggressive and will require support.

#### *Enhanced Low Carbon Fuel Standard (Policy #59)*

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<sup>3</sup> Port of Prince Rupert Electrification Roadmap, Pinna Sustainability Inc., March 26, 2020

The Low Carbon Fuel Standard (LCFS) doesn't apply to marine and rail, and this policy assumes it is practically implemented for these sectors, or is superseded by a more stringent federal Clean Fuel Standard. However, there is evidence that bio-content required for on-road fuels is already included in fuels sold for these sectors: domestic marine diesel in the region already includes some biodiesel, based on communications with one fuel supplier in the area and the impending federal CFS may result in bio-content used in rail fuels sold in neighbouring provinces such as Alberta (line haul rail is known to obtain at least some of its fuel expended in western Canada from that province). Therefore, some of the effect of this policy may be expected without any direct action taken (because this is not certain and is not supported by identifiable regulation or policy, it is not assumed in the BAP).

Specific assumptions applied for this policy are:

- 10% renewable content is included in all diesel consumed by rail, matching the impending federal CFS. This is applied after the effect of Policy 16. The CFS is based on a reduction in life cycle carbon intensity and although this may be met by direct emission reductions in the upstream activities (fuels extraction, processing and transportation) it is assumed to be entirely met with renewable content here;
- The full effect of the BC LCFS, as described in the transportation section, is assumed for all domestic marine diesel use, following the application of Policy 15. Specifically, this applies to all BC Ferries, fishing, tugboats/workboats and other commercial ferries;
- The use of liquid natural gas (LNG) produced from renewable natural gas (RNG) is also simulated, with a 50% displacement of domestic marine diesel by 2030 and 100% displacement by 2050;

This policy has no associated CAC reductions with the exception of LNG use. CAC reductions are estimated following LNG emission rates identified by the IMO. A resultant effect of this policy is that no diesel of any type (bio or conventional) is used by domestic marine by 2050.

## Results

Presented in the table below are the anticipated reductions in emissions by modelled policy actions and measures for this sector. For simplicity, the BAP has also been to indicate the effect of general trends against the additional effort required for deep emissions reductions.

<b>Marine, Rail and Aviation</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
BAP GHG Emissions	870,348	1,016,698	1,164,738	1,326,544	1,474,736
Marine : Policy 15 Incentive programs to reduce marine emissions	0	0	-167,997	-308,879	-449,761
Rail : Policy 16 Low carbon rail performance standard	0	0	-28,800	-100,030	-157,645
Aviation : Policy 14 Aviation Biofuels	0	0	-3,008	-86,370	-169,731
Rail and Marine : Policy 59 Renewable Transportation Fuels (Diesel + Gasoline)	0	0	-241,548	-470,927	-686,691
<i>Reductions</i>	<i>0</i>	<i>0</i>	<i>-199,805</i>	<i>-495,278</i>	<i>-777,137</i>
<i>Remaining Emissions</i>	<i>870,348</i>	<i>1,016,698</i>	<i>920,182</i>	<i>769,248</i>	<i>618,314</i>

*Table M. Policy effectiveness for the transpo-non-road sector across emissions, energy, and CACs (tCO<sub>2</sub>e).*

Presented in the graphs below are potential emissions and energy reductions anticipated through the application of the CNS policies for this sector. Fundamentally, we can expect to see emissions increase by 6% by 2030 over 2010 and drop 29% by 2050. Energy use in this sector is expected to increase by 25% from 12.4PJ from 2010 to 16.6PJ by 2050. However, fossil fuel energy in this sector is expected to decrease by 16% by 2050 from 2010. These decreases will be driven primarily by switches to cleaner fuels (including electrification).



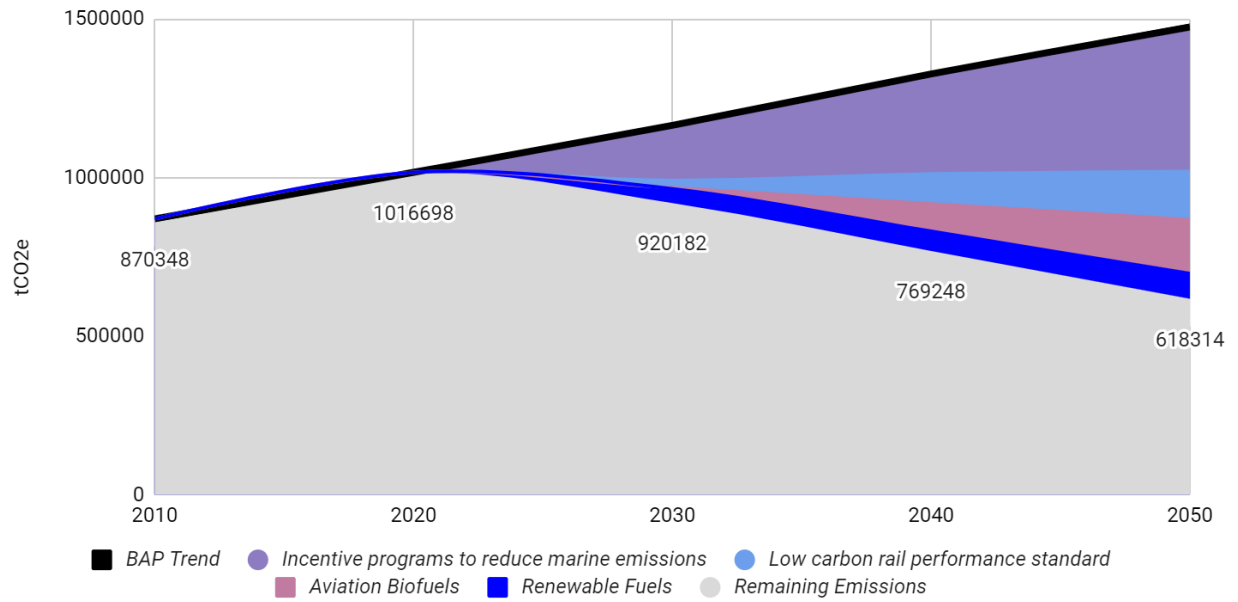


Figure 26. 2050 marine, rail, and aviation (transportation) emissions reductions resulting from CNS Policies (tCO2e).

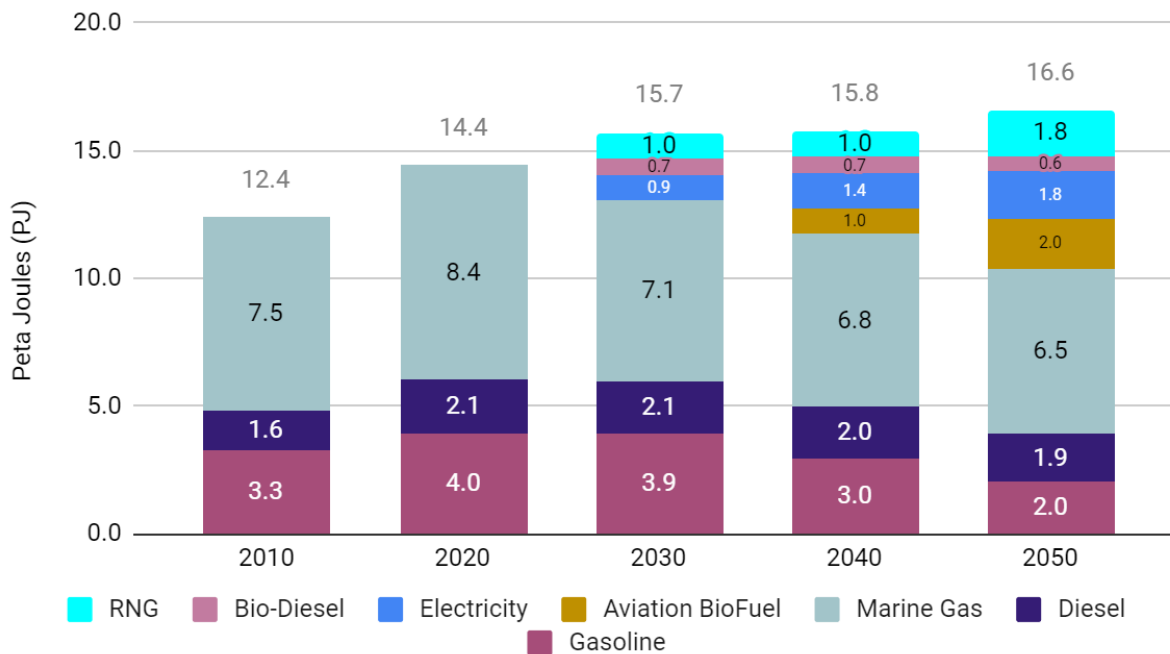


Figure 27. Marine, rail, and aviation (transportation) energy use (PJ) in the CNS from 2010-2050

#### Remaining Emissions and further emission reduction opportunities

With approximately 600,000 tCO<sub>2</sub>e remaining by 2050 there exists a good opportunity in this sector to accelerate emissions reductions. Deeper reductions are required to meet Metro Vancouver's 2030 and 2050 targets.

As a proportion of BAP, marine, rail and aviation achieve approximately 50% decarbonization, in line with the outcomes-based approach to modelling these sectors. This reflects the difficulty in implementing policies on international and inter-provincial sources. The bulk of the remaining emissions are associated with international cargo ships, international jets and domestic line haul rail. The project consulting team has identified further reduction opportunities each sub-sector:

#### Marine:

- Additional analysis is needed to understand how low carbon fuels such as renewable natural gas may be produced and made available in sufficient volumes for cargo ships and incentivized (price) such that carriers choose to purchase them. While there is interest in alternative fuels for some of the domestic carriers that must procure fuel locally, international carriers can purchase fuel from many different markets and therefore pricing is a key sensitivity.

- There is significant interest in greatly increasing low- or no-carbon methanol in Western Canada, to serve markets such as international marine. Alberta's Petrochemicals Incentive Program encourages private sector investment into new or expanded petrochemical manufacturing facilities and as production of green fuels increases support will be needed to promote their use by international carriers.
- A potential activity that was not fully considered is OGV anchoring. It may be possible to reduce anchoring periods and emissions by incentivizing short stays at port. Further analysis is needed to understand this potential opportunity.
- International marine regulation is difficult to affect and can only be impacted from the federal level (involvement with the IMO). Further understanding is needed to promote or incentivize the key technologies that will have an impact on this sector (and will be supported by the international carriers).

#### Aviation:

- While a shift to 100% replacement of traditional fuels with sustainable aviation fuels by 2050 is possible from a technical perspective, it would necessitate a complete shift in petroleum refining and an expansion of the agricultural sector that would be economically and practically challenging. Thus, supply constraints will prove to be a key challenge to overcome. Availability of acceptable low carbon biofuels for blending and agreements between biofuel producers and large international airports are key challenges to address. Aviation is currently omitted from the federal Clean Fuel Standard (intentions paper), due to lack of suitable biofuels to blend.
- A BC LCFS white paper exists that identifies the California regulation of the same name, which has an opt-in credit-based system that aims to decrease jet fuel CO<sub>2</sub> intensity from 89.37 to 80.36 kg CO<sub>2</sub>/MJ by 2030. Additionally, the International Energy Agency (IEA) Sustainable Development Scenario anticipates aviation biofuels reaching 10% of demand by 2030 and 20% by 2040. These developments may facilitate the uptake of aviation biofuels locally as soon as feasible.

#### Rail:

- Low carbon hydrogen is viewed to be a future fuel with considerable potential, both from the rail companies and the Canadian federal government. These are early days for hydrogen production and fueling infrastructure, but continued financial support and feasibility studies will help support advancement in this technology. A 40% reduction in line haul rail emissions was modelled, assuming hydrogen would be used. Line haul rail constitutes 90% of rail emissions and the great distances and power requirements associated largely rule out electrification. While cross Canada fueling infrastructure for rail is a considerable barrier when thinking of newer fuels such as hydrogen, it may be possible to accelerate the adoption of hydrogen fuel cells in line haul locomotives such that greater reductions are achieved by 2050.
- CN rail and ports have shown interest in using lower carbon fossil fuels such as CNG as an interim strategy to reduce emissions from diesel use in locomotives. This approach was not considered in

this study due to its low adoption rate currently. Additional analysis that considers the direct emissions benefit, upstream emissions from methane extraction and production, and the possibility of technology lock-in before net-zero options are developed must be analyzed in more detail to understand the potential role for CNG in rail.

## Agriculture

### *Sector Context*

The agricultural sector comprises two primary emission sources: methane produced from livestock (predominantly in the digestive system of cattle) and carbon dioxide produced from the combustion of natural gas in greenhouses for heating and plant fertilization. Together these two sources account for most of the 400,000 tonnes of carbon dioxide equivalents (tCO<sub>2</sub>e) in 2010. Greenhouses produce most of these emissions, accounting for about 78% of total GHGs from the agriculture sector. CACs in the agricultural sector are produced from two sources: (1) the burning of natural gas and wood in greenhouse boilers, and (2) VOCs resulting from the digestive systems of livestock. Both of these sources result in significant volumes of PM<sub>2.5</sub> and VOCs (2.7% and 4.4% of regional total respectively.)

Agricultural land in British Columbia is protected through the Agricultural Land Reserve (ALR). This designation means that agricultural land in the region is unlikely to decrease significantly over time. This has implications for modelling emissions for the agriculture sector, and impacts regional carbon sequestration.

In addition to opportunities for emissions reductions, the agricultural sector presents opportunities for renewable energy generation. Aerobic digestion of agricultural waste – predominantly dairy manure – can generate RNG, a valuable fuel for displacing fossil natural gas in a variety of sectors and applications. Aerobic digestion plants also have the potential to generate industrial food grade CO<sub>2</sub> that can help reduce natural gas demand for plant fertilization. While renewable energy generation is not the focus of this work, some rough estimates of potential RNG production on regional agricultural land were generated to inform assumptions regarding overall RNG availability (see page Overarching Energy and Fuel Assumptions on page 19).

### *BAP Assumptions*

As the greenhouse sector is not assumed to grow significantly between 2020 and 2050, energy consumption in this sector remains static with approximately 8 PJ of energy required to heat greenhouses. Under the BAP it is assumed that the split between wood-fired boilers and natural gas-fired boilers (12.5% wood, 87.5% natural gas) would remain constant to 2050.

In terms of additional modeling assumptions, growth in all agricultural activities was held flat under the BAP operating under an assumption that there would be no net loss or gain of agriculture land in the region, and additionally, agricultural land uses and practices would be equally diverse today as they will be in the future. Generally, the growth in greenhouse space and emissions were kept flat, however the introduction of cannabis cultivation will increase the energy use intensity but not the floor area of greenhouses under the BAP. Modest increases to livestock activities were envisioned under the BAP scenario based on current trends with regards to growth in the poultry (2% per annum) and dairy sectors (1% growth per annum). Emissions management practices especially as they pertain to CACs should remain unchanged to 2050.

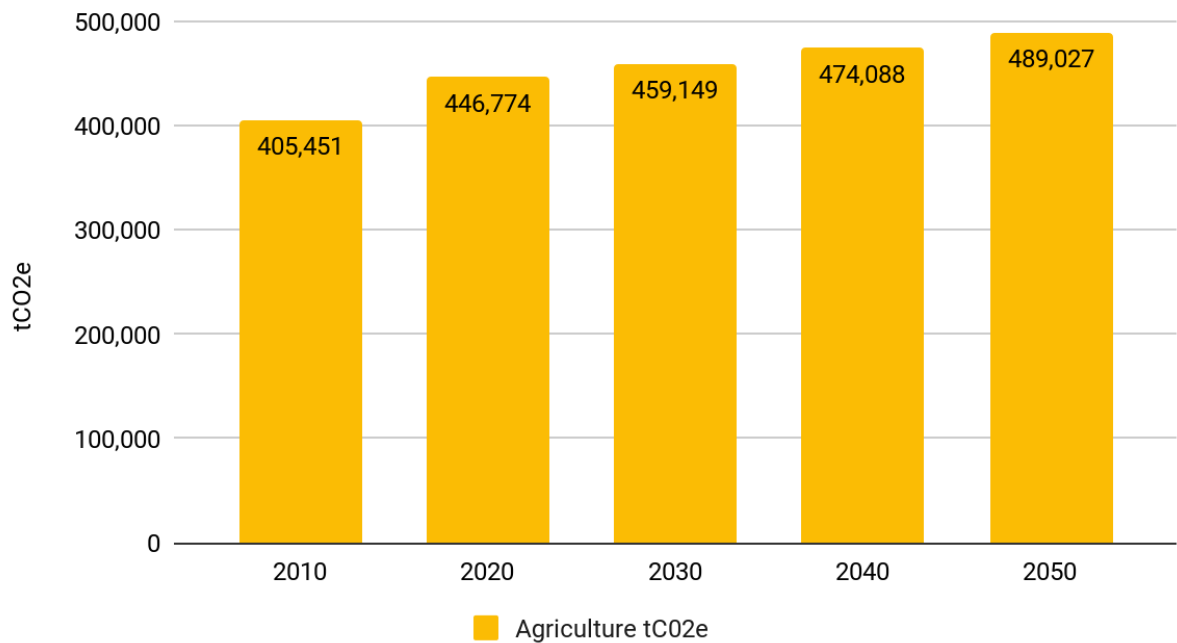


Figure 28. Business As Planned modelling of emissions (tCO2e) by agriculture from 2010 to 2050

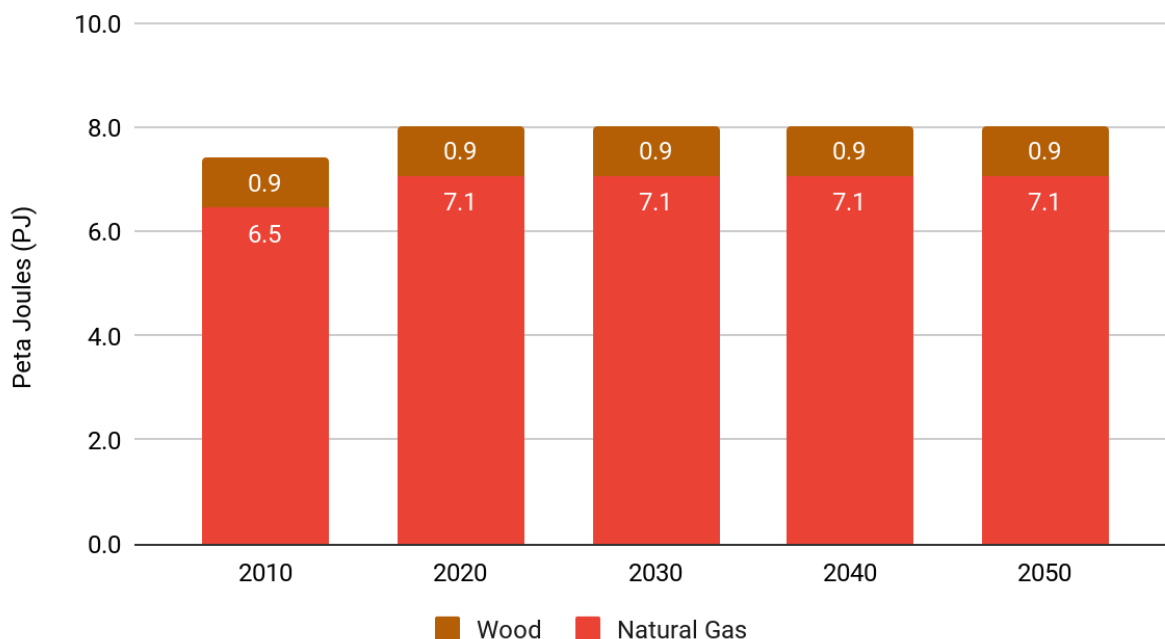


Figure 29. Business As Planned modelling of primary energy usage by agriculture fuel type (PJ) from 2010 to 2050

### Discussion

Under the BAP, the 9% increase, from 2020 to 2050, in greenhouse gas emissions in this sector is the result of a steady increase in anticipated livestock over this period. Conversely, emissions do not increase from greenhouses as there is little increase in activity expected for this sector. As such, fuel use is constant in the 2020-2050, though feed requirements for livestock will increase over the modeling period. CACs, particularly VOCs and PM2.5 which result from increased livestock activity will increase marginally (2.8% to 597.4 tonnes and 1.6% to 51.7 tonnes respectively).

### Carbon Neutral Scenario Reductions

#### Context/Description

The primary objective of the CNS for agriculture was to reduce fossil gas consumption in greenhouses. While modest efficiency improvements that reduce overall energy consumption may be possible, they may be somewhat limited due to the design and technical demands of greenhouses. Switching greenhouses to renewable fuel sources will therefore be an important strategy to reduce emissions from this sector. Given that the majority of emissions from agriculture are generated from greenhouses, the policies modelled for this sector focus on opportunities for emissions reductions in greenhouses.

#### Policies and Assumptions

##### Greenhouse Energy Efficiency and Fuel Switching (Policy #49)

This policy looks at the impact of regional emissions incentives and regulations that require improvements to energy efficiency and use of renewable gas to meet emissions targets. This policy assumes that energy efficiency improvements of 25% by 2050 are met through upgrades to heating, cooling, lighting, humidity control, etc. Natural gas use is transitioned to RNG, based on regional availability. This policy assumes RNG use is 5% in 2030 and 40% in 2050 of the total Natural Gas use.

## Results

Emissions from CNS agricultural policies result in a 50% reduction in greenhouse-related emissions by 2050 over the 2010 baseline through the decarbonization of horticultural greenhouses. Total natural gas energy use (ie RNG + NG) under the CNS declines by 25% with fossil natural gas usage declining by 56.6% in the 2010-2050 period. Reductions in greenhouses are offset by continued increases in livestock emissions which are not affected by any CNS policies. Overall, greenhouse gas emissions from the agricultural sector are reduced by 27% by 2050 relative to 2010. CACs in this sector are expected to decrease in proportion to the decrease in natural gas usage which results in an 2.6% reduction between the 2020 and 2030 periods.

A summary of reductions by policy for emissions are presented in the table below.

<b>Agriculture</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
BAP GHG Emissions (tCO <sub>2</sub> e)	405,451	446,774	459,149	474,088	489,027
Policy 49 Greenhouse Energy Efficiency and Fuel Switching	0	0	-45,624	-119,946	-194,268
<i>Reductions</i>	<i>0</i>	<i>0</i>	<i>-45,624</i>	<i>-119,946</i>	<i>-194,268</i>
<i>Remaining Emissions</i>	<i>405,451</i>	<i>446,774</i>	<i>413,525</i>	<i>354,142</i>	<i>294,759</i>

*Table N. Policy effectiveness for the agriculture sector across emissions, energy, and CAC reductions (tCO<sub>2</sub>e)*

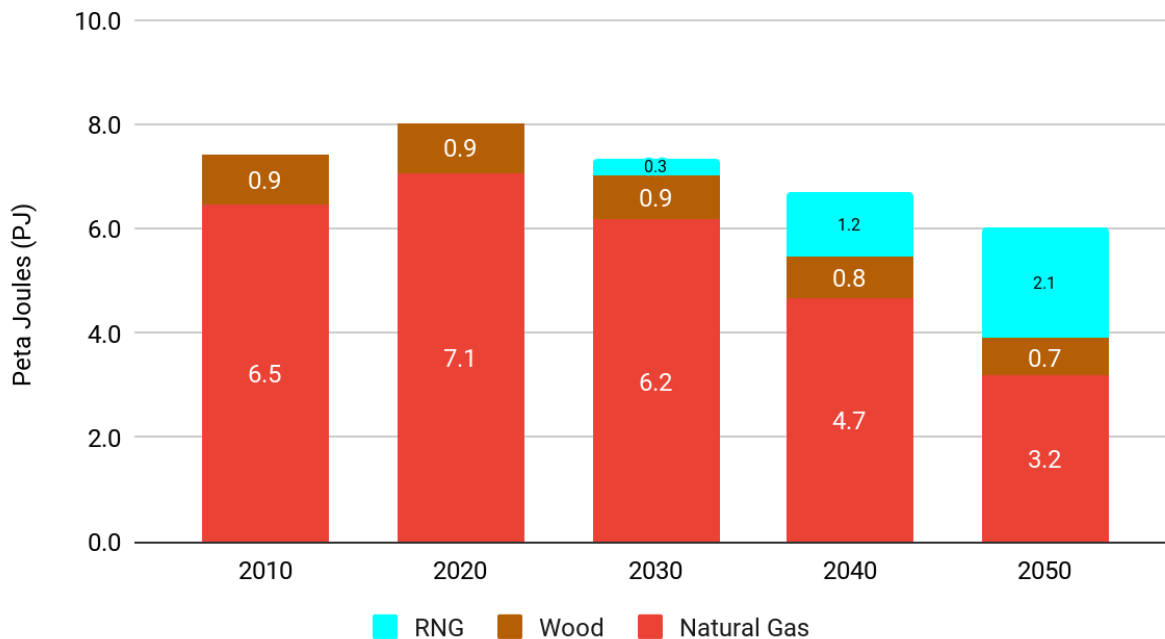


Figure 30. Industry fuel use resulting from CNS Policies from 2010-2050 (PJ).

#### Remaining Emissions and further emission reduction opportunities

300,000 tCO<sub>2</sub>e remain in the agricultural sector in 2050, of which half is resulting from greenhouse energy use and the remaining half resulting from livestock. Emissions reductions by 2030 amount to 27% from 2010. The project consulting team has identified the following opportunities to consider for additional policy and modelling, and to accelerate and deepen GHG reductions:

- More analysis is needed to better understand the potential GHG emissions impact of livestock methane management. There is important overlap between agricultural land protection and soil carbon sequestration. While this is not a strategy for direct emissions reductions, further exploration of the potential for soil carbon sequestration on agricultural land may enhance understanding of total regional carbon sequestration.



### *Sector Context*

Emissions from liquid and solid waste occur from collection, treatment and disposal activities, and comprised about 3% of the Region's total GHG emissions in 2010. Emissions that were modeled in the Waste category only included the treatment and disposal stages, since collection is already counted under Heavy Duty Vehicles. Therefore, the facilities considered in this study included landfills (Vancouver Landfill, Ecowaste and closed landfills), the Metro Vancouver Waste to Energy Facility and Metro Vancouver's five Wastewater Treatment Plants.

Solid waste is generally collected and transported using trucks and taken either to a sorting facility for separation and recycling or taken to a disposal facility. Solid waste in Metro Vancouver has many origins and many destinations, including a large portion of waste that is handled outside the region. Further, the existing solid waste facilities in the region have limited lifespans, and Metro Vancouver is in the process of updating its Integrated Solid Waste and Resource Management Plan. Three disposal facilities exist within the Metro Vancouver region including Vancouver Landfill receiving approximately 700,000 t per year mixed solid waste plus another 45,000 t per year of construction and demolition waste; Metro Vancouver Waste to Energy Facility (WTEF), receiving approximately 255,000 t per year; and Ecowaste Landfill, a private construction and demolition waste facility, receiving about 230,000 t per year.

Recycling is handled through private sector operations and any in-region end treatment GHG emissions are included under Industry. Organics recycling facilities include composting at the EnviroSmart facility in Delta, Vancouver Landfill and the Surrey Biofuel Facility, along with several smaller green waste recyclers. Organics recycling is assumed to have a negligible carbon and CAC footprint in this study as well.

A large portion of solid waste leaves the region including mixed solid waste, separated organics and other recyclables. This study included GHG emissions from out-of-region landfilling, assuming the Roosevelt Regional Landfill in Washington State receives all surplus disposal waste.

GHG emissions from solid waste primarily come from organic waste decomposition to methane gas (CH<sub>4</sub>) and combustion of fossil carbon in the WTEF. CAC emissions result from landfilling operations (PM from dust), and VOC, NO<sub>x</sub> and SO<sub>x</sub> from landfill gas combustion.

Liquid waste mostly flows through the regional sewer collection system to Metro Vancouver's five wastewater treatment plants, with a very small amount of trucked liquid waste arriving at the treatment plants. The treatment plants use primarily electrical power to run treatment processes, and anaerobic digesters at four of the five existing plants provide biogas for process heating. A small amount of natural gas is consumed by the wastewater treatment plants to supplement heating needs. Natural gas is the principal source of GHG emissions, while biogas combustion in co-generation is the primary source of CACs from liquid waste.

#### *Business as Planned Future*

Waste receipt under the BAP were assumed to be consistent with today's rates at the existing waste management facilities in the region. Waste production will occur at the same per capita rate and composition. The region's wastewater treatment plants have a very small emissions footprint, which will not change significantly. A new Biosolids Drying Facility is planned to be constructed at the Northwest Langley Wastewater Treatment Plant, which will add approximately 10,000 t CO<sub>2</sub>e/year to the BAP.

#### Policies and Assumptions

##### **Solid Waste**

In the modeling context for this study, several assumptions are included that aim to simplify some of the uncertainty in modeling future waste management options:

- Overall solid waste production was forecast to continue at a constant per capita rate of 1,360 kg/cap/a, and a constant ratio of 18% organics, 64% recyclables and 18% non-recoverable waste.
- In-region disposal quantities are assumed to continue at a constant rate to 2050
- Total organics diversion remains flat at 443,000 t/a. As the region grows, the proportion of diverted organics and wood waste will decrease from 65% in 2020 down to 48% by 2050.
- Emissions from out-of-region disposal were included in the forecast.

The WTEF is point source of GHG emissions from combustion of fossil carbon, primarily plastics. A small amount of N<sub>2</sub>O emissions also contribute to the total GHGs from the WTEF, roughly 130,000 t CO<sub>2</sub>e/year, and processing about 255,000 t of solid waste per year.

While this study is focused on emissions reductions opportunities and not energy supply, an estimate of renewable energy production was conducted to inform assumptions on regional RNG availability (see page 19). Energy is currently produced at the WTEF (electricity), Surrey Biofuel Facility (pipeline RNG) and VLF (electricity/cogeneration). The VLF is transitioning to pipeline RNG, which will divert nearly all landfill gas to RNG production. The VLF could produce almost 1.8 million GJ of RNG by 2040. The Surrey Biofuel Facility is described as having an annual RNG output of 320,000 GJ. The WTEF produces approximately 600,000 GJ of electricity, but there could be up to 700,000 GJ of excess heat available for thermal use such as district heating. Diverted wood waste is used as a thermal fuel for several district energy projects and industrial processes.

## **Liquid Waste**

Metro Vancouver operates five wastewater treatment plants (WWTPs):

- Annacis Island (AIWWTP), the largest, with secondary treatment, anaerobic digesters and co-generation from biogas;
- Iona Island (IIWWTP), a large plant serving Vancouver, UBC, YVR and parts of Burnaby with primary treatment, anaerobic digesters and co-generation from biogas;
- Lions Gate / North Shore (NSWWTP), the existing Lions Gate WWTP will be decommissioned by 2021 and replaced with a new NSWWTP, with secondary treatment, anaerobic digesters and co-generation from biogas;
- Lulu Island (LIWWTP), located in Richmond which has secondary treatment, anaerobic digesters and biogas boilers (excess is flared). Metro Vancouver is currently implementing a biogas upgrading project and LIWWTP will produce RNG from excess biogas by 2022; and
- Northwest Langley (NLWWTP), which currently serves a small portion of the Township of Langley, but will be replaced and expanded to serve a portion of the catchment currently served by AIWWTP. The new plant will feature tertiary treatment with anaerobic digestion and biogas upgrading, with process heat from effluent heat pumps. This site will also host the regional Biosolids Drying Facility, slated to be completed by 2023.

Metro Vancouver is in the indicative design phase for the replacement of the IIWWTP, which will include upgrading to tertiary treatment. The BAP scenario currently only includes use of the existing anaerobic digesters in the initial 2030 build, but assumes these will be expanded to handle all plant sludge by 2040. From 2030 to 2040 the secondary sludge would be trucked to the Biosolids Drying Facility.

The Biosolids Drying Facility will initially be heated with natural gas as a biogas supply from NLWWTP will not be available for several years. This will increase the Liquid Waste carbon footprint by several orders of magnitude, though this is intended to be offset by displacing coal used in cement kiln heating processes.

## Results

GHGs in this sector will increase proportionally to population with no changes in waste management capacity, as the solid waste disposal quantities in excess of the in-region capacity is assumed to be landfilled. Under the BAP emissions are expected to increase from 2010 by 15% and 30% by 2030 and 2050 respectively.

Methane releases from landfills are the largest source of GHG emissions in the solid waste sector, which will continue to rise to roughly 310,000 t CO<sub>2</sub>e/year by 2050, plus out-of-region emissions of 93,000 t CO<sub>2</sub>/year. The emissions from out-of-region landfilling are projected to have the greatest increase of any single source in the Waste sector over the next 30 years as the projected out-of-region waste disposal quantity doubles between 2020 and 2050.

CACs are forecast to remain relatively flat but much lower than 2010 since the landfill gas at VLF will be processed to biogas instead of combusted, as will biogas at the Lulu Island Wastewater Treatment Plant. This has the largest impact on SO<sub>x</sub> and NO<sub>x</sub>. Other CAC category emissions are less than 1.5% of the regional emissions totals.

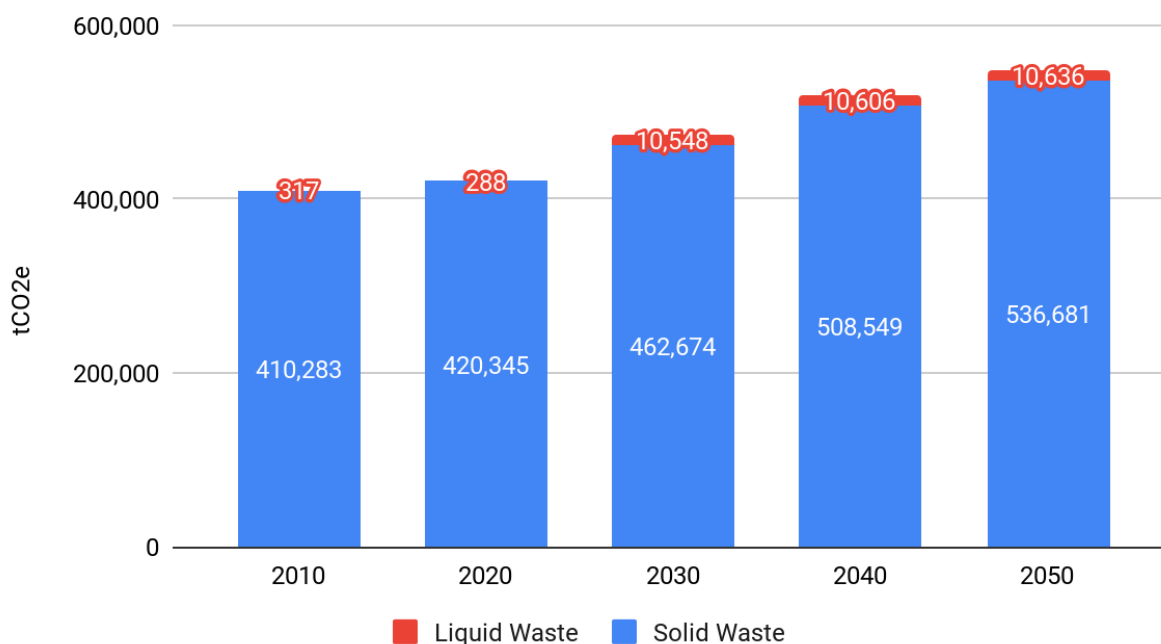


Figure 31. Business As Planned modelling of GHG emissions by liquid and solid waste from 2010 to 2050 (tCO<sub>2</sub>e).

## *Carbon Neutral Scenario Reductions*

### *Policies and Assumptions*

Policy #38 and Policy #40 reduce GHGs by capturing fugitive GHG emissions and reducing the organics disposal fraction. The Policies and Assumptions were not intended to address the relatively small amounts of CAC emissions originating from the Waste sector.

The Policies and Assumptions used to generate estimates for renewable energy from liquid and solid waste streams do not have a direct impact on Waste-derived emissions.

#### *Landfill biocovers and improved gas capture and use (Policy #38)*

Policy #38 evaluates the impact of major landfill facilities reducing methane emissions through increased use of biocovers and gas capture. This policy assumes a 25% reduction in uncaptured methane emissions after 2030 at the Vancouver Landfill and Ecowaste facilities. This assumption was determined based on the assumptions that approximately 30% of landfill area remains to be covered, and that a higher performance biocover could capture 80-90% of methane emissions. Key performance assumptions for this Policy are (1) that it only applies to Vancouver Landfill and Ecowaste; and (2) there is a 25% reduction in uncaptured methane emissions after 2030.

#### *Divert additional waste from waste stream (Policy #40)*

Policy #40 models further separation of organics, wood waste, and recyclables. This policy focuses on wood waste and organics, assuming that end treatments exist and emissions are accounted for under the appropriate sector. It assumes that diversion of 65% of organic waste is maintained from 2020 to 2050, and that no clean wood waste is landfilled.

### *Results*

Presented below are potential emissions and energy reductions anticipated through the application of the CNS Policies for this sector. Emissions will rise less quickly than under the BAP scenario with Policies limiting increases in GHGs to 13% and 17% over 2010 by 2030 and 2050. If further efforts to reduce fugitive emissions from landfills (Policy 38) are successful, and additional organics diversion to biogas is realized the projected increases under BAP can be nearly offset.

CACs are not projected to change significantly due to Policies prior to 2030. This is because most of the Waste CACs are due to landfill/biogas combustion.

Presented in the table below are the anticipated reductions in emissions by modelled policies actions and measures for this sector. For simplicity, the BAP has been included as well to indicate the effect of general trends against the additional effort required for deep emissions reductions.

Waste	2010	2020	2030	2040	2050
BAP GHG Emissions (tCO <sub>2</sub> e)	410,600	420,633	473,222	519,155	547,317
Policy 40 Divert additional waste from waste stream	0	0	-23,779	-46,884	-62,828
Policy 38 Landfill biocovers and improved gas capture / use	0	0	14,285	-14,938	-3,763
<i>Reductions</i>	<i>0</i>	<i>0</i>	<i>-9,474</i>	<i>-61,822</i>	<i>-66,591</i>
<i>Remaining Emissions</i>	<i>410,600</i>	<i>420,633</i>	<i>463,748</i>	<i>457,333</i>	<i>480,726</i>

*Table O. Anticipated sectoral emissions reductions by Policy (tCO<sub>2</sub>e).*

### *Remaining Emissions and Further Reductions Opportunities*

The project consulting team has identified a number of opportunities for further emissions reductions. The VLF remains as the largest single facility source of emissions in the Waste sector. Further diversion of organic and wood waste and solutions for capturing fugitive CH<sub>4</sub> emissions are needed to achieve further reductions. Organics and wood waste then can be up-cycled into bioenergy products, which have double impact since the diverted waste avoids both CH<sub>4</sub> emissions in the landfill and causes downstream reductions in fossil fuel use. Existing organics infrastructure does not have sufficient capacity to maximize the potential production of bioenergy.

The WTEF is the next-largest source of emissions, which are mostly due to plastic waste. There is potential to better utilize the WTEF heat for displacing fossil fuel use with district heating for communities such as Burnaby, Vancouver and New Westminster. As carbon capture technologies advance, there may be options for capturing CO<sub>2</sub> emissions from the WTEF. However, RNG produced at this facility helps reduce emissions in other sectors. The long-term lifespan of the existing WTEF has not been reviewed in this study.

Implementing solutions for the Ecowaste landfill to produce more recoverable biofuel or otherwise reduce fugitive CH<sub>4</sub> emissions will be challenging given it is privately owned and is assumed to meet regulatory requirements. Additional incentives or regulation may be needed to further drive any emissions reductions from this facility.

For liquid waste the largest emissions source will be the planned Biosolids Drying Facility. The downstream intent is for the biosolids to be consumed by cement kilns or other thermal processes, which would more than offset the natural gas-derived emissions from drying. However, it cannot be guaranteed that the biosolids will be used for fuel, therefore some emissions risk may be retained. Beyond 2040, Metro Vancouver may have alternative waste processing and recovery pathways that avoid production of biosolids altogether.

To turn to future opportunities, WWTPs may be optimized for biofuel production. Co-generation of heat and power using biogas as a fuel is carbon-neutral, but there is likely to be increasing demand for RNG in other sectors in a carbon neutral future. Converting this resource to RNG and relying more on BC Hydro electricity would support deeper emissions reductions. Additionally, processing biogas or landfill gas into RNG involves stripping CO<sub>2</sub> from the gas stream, which can potentially be captured, used or sequestered.

### *Sector Context*

Metro Vancouver is characterized by large areas of natural and urban forests, as well as a diverse set of sensitive estuarine, intertidal, wetland, and riparian ecosystems. These ecosystems provide essential services to society, including the filtration of water, protection against flooding and erosion, and the regulation of climate through the sequestration and storage of carbon. The nature and ecosystems sector uniquely sequesters carbon (that is to say the annual rate by which carbon is removed from the atmosphere through the process of photosynthesis), as opposed to producing GHG emissions.

Within this sector, three components of carbon sequestration are considered: forests, soil, and non-forest sensitive ecosystems (NFSE). Though historically the size of these areas has changed considerably, we consider 2010 as a baseline metric for the components in this study. Soil is considered stable in terms of sequestration, but will contribute to GHG emissions if it is disturbed. 97% of carbon sequestration occurred in forests (deciduous and coniferous species) in the TAZ study area in 2010, whereas 3% of carbon sequestration occurred in NFSE (estuarine, intertidal, and wetland ecosystems). The capacity of carbon sequestration in forests and of forests and NFSE in both land use futures will be determined by increasing population and employment in the Region that may increase demand for undeveloped land.

Key data sources used in estimating impact of future land use scenarios include the regional carbon storage dataset, sensitive ecosystem inventory (SEI), and Landsat satellite time series imagery. The regional carbon storage dataset was used alongside age-over-height lookup tables per tree species type (coniferous or deciduous)<sup>4</sup> to determine the carbon sequestration capacity after aging and future land use impacts considered. The SEI was used to identify NFSE areas in the Region. Carbon sequestration potential for NFSE areas was estimated with sequestration rates ( $\text{tC ha}^{-1} \text{ yr}^{-1}$ ) that were identified in literature review<sup>5, 6, 7</sup>. Landsat satellite time series data was used to estimate the extent of logging in the Region during 2000 to 2019<sup>8</sup>.

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<sup>4</sup> Kimmins, J.P., Maily, D., and Seely, B. (1999). Modelling forest ecosystem net primary production: the hybrid approach used in FORECAST. *Ecol. Model.* 122: 195-224. doi: 10.1016/S0304-3800(99)00138-6.

<sup>5</sup> Chastain, S. & Kohfeld, K. E. (2016). Blue Carbon in the tidal wetlands of the Pacific Coast of Canada. Commission for Environmental Cooperation.

<sup>6</sup> McLeod, E., Chmura, G., Bouillon, S., Salm, R., Björk, M., Duarte, C., Lovelock, C., Schlesinger, W., Silliman, B. (2011). A blueprint for blue Carbon: Toward an improved understanding of the role of vegetated coastal habitats in sequestering CO<sub>2</sub>. *Frontiers in Ecology and the Environment*. 9. 10.1890/110004.

<sup>7</sup> Wilkinson, G. M., Besterman, A., Buelo, C., Gephart, J., Pace, M. L. (2018). A synthesis of modern organic Carbon accumulation rates in coastal and aquatic inland ecosystems. *Scientific Reports* (8). DOI: <https://doi.org/10.1038/s41598-018-34126-y>

<sup>8</sup> Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. (2013). High-Resolution Global Maps of 21st-



## Sector Assumptions

BAP and CNS land use scenarios affect forest carbon sequestration and soil GHG emissions relative to the respective patterns of projected development. In addition to the varying impact of both land use futures, parcel-level assumptions also include:

- The percent forest area per parcel as identified from the regional carbon storage dataset, is assumed to remain consistent from 2017 to 2050.
- The disturbed area from development is multiplied by 1.5 to account for areas not in the parcel fabric, such as roads, sidewalks, and alleyways.
- Development areas retrain 10% of the total development area for tree replanting, and replanting trees are 14-year old, deciduous trees.
- Development areas disturb 66% of soil carbon at the development site<sup>9</sup>.
- Regional logging remains consistent with the trend interpolated between the years 2000-2019, which is calculated as a loss of around 3,500 tC yr<sup>-1</sup>.

NFSE carbon sequestrations are not affected by land use scenarios as they remain protected in all futures. NFSE carbon sequestration is affected by additional policies that target increasing NFSE sequestration capacity.

### *Business As Planned Future*

## Policies and Assumptions

The BAP scenario for nature and ecosystem calculated total and yearly carbon sequestration in the Region as affected by the BAP buildout. The ALR is not affected by the BAP land use scenario and thus this model assumes no net loss of carbon storage in the ALR. As for all futures in the Nature and Ecosystems sector, carbon sequestration capacity is affected by new developments in greenfield areas and redevelopments of existing buildings across the Region. The model assumes that each redevelopment will disturb existing forest at the site, as well as retain a fraction of existing trees and add young trees. It is assumed that developments will disturb 66% of the soil at the site. Regional logging is assumed to continue at the same rate as calculated from 2000 - 2019.

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Century Forest Cover Change. Science 342 (15 November): 850–53. Data available on-line from: <http://earthenginepartners.appspot.com/science-2013-global-forest>.

<sup>9</sup> Seto, K. C., Gruneralp, B., and Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1211658109

## Results

Based on current trends in land use change and regional logging activities, sequestration rates are expected to decrease in projected years in the BAP scenario. Sequestration rates will decrease from 1.13 mtCO<sub>2</sub>e yr<sup>-1</sup> in 2010 forests to 0.95 mtCO<sub>2</sub>e yr<sup>-1</sup> in 2050 forests, as shown in figure 36. Yearly GHG emissions from soil are stable at 12,574 tCO<sub>2</sub>e yr<sup>-1</sup> from 2010 to 2050. Factors affecting future sequestration rates in the BAP include development and removal of forests in forested greenfield areas and sustained regional logging trends.

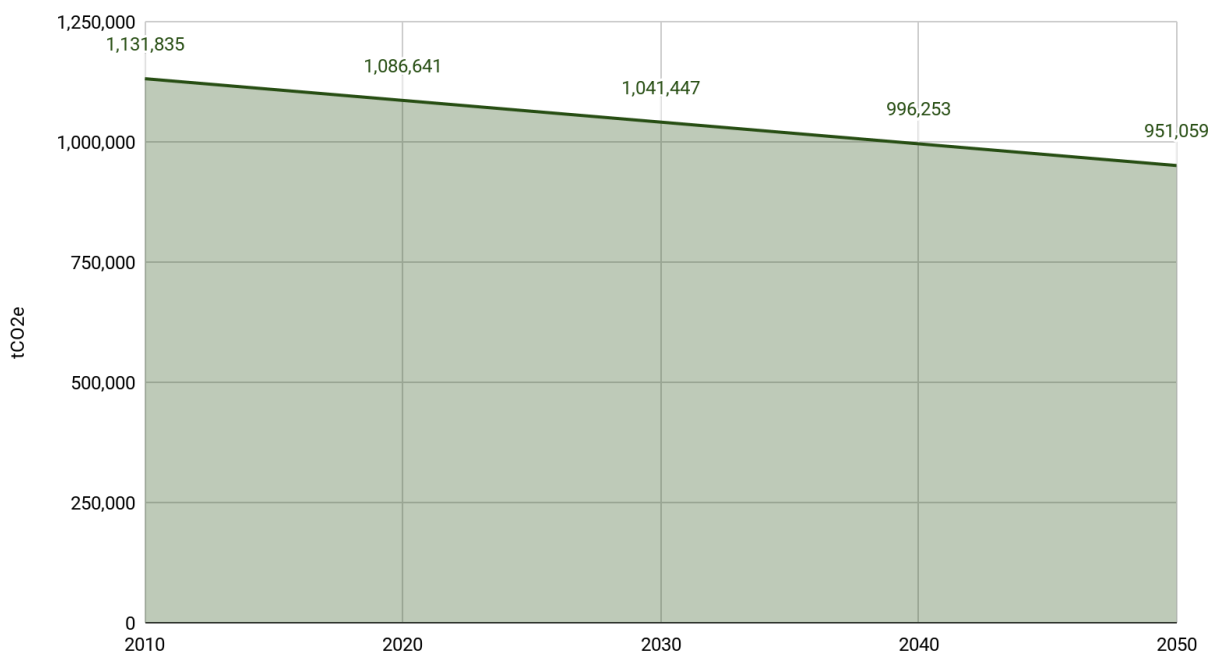


Figure 32. Business As Planned modelling of yearly forest carbon sequestration (tCO<sub>2</sub>e) from 2010 to 2050.

### Carbon Neutral Scenario Sequestration

#### Policies and Assumptions

The CNS for nature and ecosystem focuses on (1) mitigating development impacts on the carbon sequestration rates of the Region's forests and soils, and (2) implementing specific policies that increase the carbon sequestration capacity of the Region's forests, soils, and NFSE.

#### Ecosystem enhancement (Policy #54)

Policy #54 models an increase in regional forest canopy through coordinated municipal and regional efforts and Provincial support. This policy assumes that canopy cover is increased by 6% in the region

(from 54% to 60%) by 2030, and a further 5% by 2050 (to 65%). This includes an 8% increase in tree canopy within the urban containment boundary, which in total covers 40% of the region.

#### *Urban containment (Policy #56)*

Policy #56 models regional land use guidance, with support from municipal land use and zoning, that does not permit greenfield development for urban expansion, agriculture, or other land uses. Key assumptions are (1) no new greenfield development starting 2030; (2) assumed existing developed areas will be the extent of a new potential UCB; (3) half of all farmland not within the ALR will not undergo development by 2030; and (4) beyond 2030, no additional farmland not within the ALR will be developed through to 2050. This Policy aims to reach sensitive ecosystem protection goals of (1) 5% increase in protected areas by 2030, and (2) 10% increase in protected areas by 2050.

## Results

Presented in the table below are the anticipated yearly sequestration rates by modelled policies, actions, and measures for this sector. For simplicity, the BAP GHG sequestration has been included as well to indicate the effect of general trends against the additional effort required for deep emissions reductions.

<b>Nature &amp; Ecosystems</b>	<b>2010</b>	<b>2020</b>	<b>2030</b>	<b>2040</b>	<b>2050</b>
BAP GHG Sequestration (tCO <sub>2</sub> e)	-1,156,373	-1,107,806	-1,062,612	-1,017,418	-972,224
Policy 0 Landuse	0	0	-8,111	-7,835	-7,559
Policy 56 Urban Containment	0	0	-2,366	-2,276	-2,186
Policy 54 Ecosystem Enhancement	0	0	-34,609	-42,579	-44,228
<i>Additional Sequestration</i>	0	0	-36,653	-38,576	-40,499
<i>CNS Sequestration</i>	-1,156,373	-1,107,806	-1,099,265	-1,055,993	-1,012,722

*Table P. Policy effectiveness for the sequestration of CO<sub>2</sub>e from applicable Policies.*

The table above shows soil carbon emission rates from development disturbance across BAP, land use, and urban containment build out scenarios and relative to the 2010 baseline. In the BAP scenario, there is no reduction in carbon emissions from soil as it remains constant. The CNS land use scenario shows a 14% reduction in GHG emissions emitted from soil disturbance and the urban containment scenario shows a small additional reduction in soil emissions. Soil emission reductions result from changes in land use development patterns between the various build-out scenarios that disturb less soil and is modelled independently from forests sequestration rates.

The table below shows the total amount of tonnes of carbon stored<sup>10</sup> per build-out scenario. In the BAP scenario, forest carbon increases from 35.13 mtCO<sub>2</sub>e to 63.98 mtCO<sub>2</sub>e in 2010 to 2050, an increase of over 80%. The Land use scenario increases from the same 35.13 mtCO<sub>2</sub>e in 2010 to 64.1 mtCO<sub>2</sub>e in 2050. The Urban Containment policy stores the most carbon scenario, increasing from 35.13 mtCO<sub>2</sub>e in 2010 to 64.15 mtCO<sub>2</sub>e in 2050. The increase in carbon sequestration across all scenarios in this model can be explained by the relationship of tree age and tonnes of carbon it is able to sequester. Though tree mortality and disturbance is considered in this model, forest stands with projected years will sequester considerably more carbon than is estimated currently.

	2010	2020	2030	2040	2050
<i>BAP (tCO<sub>2</sub>e)</i>	35,131,567	35,131,567	44,750,109	54,368,651	63,987,192
<i>Land use</i>	35,131,567	35,141,683	44,793,946	54,446,209	64,098,472
<i>Urban Containment</i>	35,131,567	35,145,955	44,812,459	54,478,962	64,145,465

*Table Q. Total carbon (tCO<sub>2</sub>e) in forests from 2010 to 2050.*

The table below shows the tonnes of carbon stored per build-out scenario in the urban containment boundary only. In the BAP scenario, forest carbon increases from 3.37 mtCO<sub>2</sub>e to 7.43 mtCO<sub>2</sub>e in 2010 to 2050. The Land use scenario increases from the same 3.37 mtCO<sub>2</sub>e in 2010 to 7.62 mtCO<sub>2</sub>e in 2050. The Urban Containment scenario stores the most carbon scenario, increasing from 3.37 mtCO<sub>2</sub>e in 2010 to 7.65 mtCO<sub>2</sub>e in 2050.

	2010	2020	2030	2040	2050
<i>BAP (tCO<sub>2</sub>)</i>	3,371,480	4,386,849	5,402,218	6,417,586	7,432,955
<i>Land use</i>	3,360,988	4,425,880	5,490,772	6,555,664	7,620,556
<i>Urban Containment</i>	3,346,522	4,421,495	5,496,468	6,571,441	7,646,414

*Table R. Total carbon (tCO<sub>2</sub>) in forests in the urban containment boundary in 2010 and 2050.*

Presented below are the expected changes to sequestration by 2050. The BAP demonstrates the loss in carbon sequestration expected as land is developed to accommodate population growth. Policies 54 to 57 aim to offset loss of sequestration capacity from this growth. However, the magnitude of recovery does not make up for the loss expected from population and employment growth from 2010 to 2050.

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<sup>10</sup> As mentioned, carbon sequestration is the removal of carbon from the atmosphere. Carbon storage refers to the amount of sequestered carbon bound up in plant-based materials above and below ground.

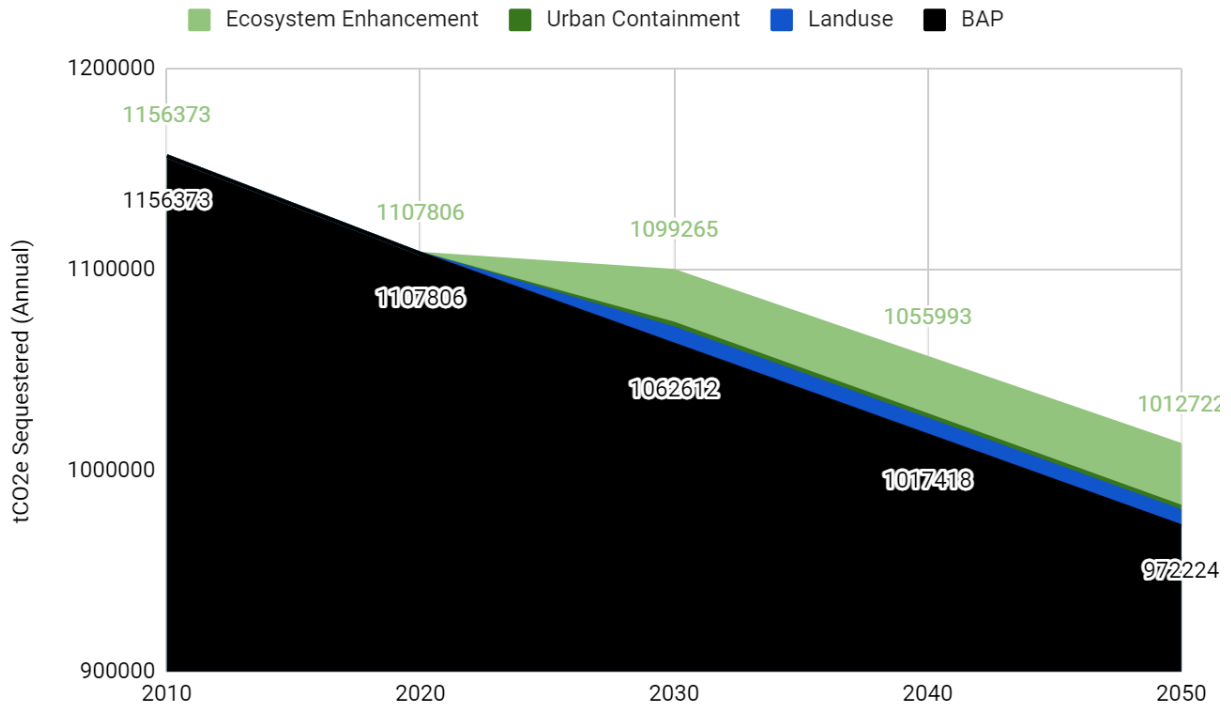


Figure 33. Nature and ecosystems yearly carbon sequestration capacity reductions and recoveries resulting from CNS Policies (tCO<sub>2</sub>e).

The model calculates projected carbon storage by indexing the net tonnes of carbon per hectare stored by trees relative to their age and type (coniferous or deciduous). The net tonnes of carbon per hectare stored considers ecosystem disturbance and tree mortality. For example, a coniferous tree aged 14 years in 2017 will store roughly 61 tCO<sub>2</sub>e. In 2050, the now 47 year old coniferous tree will store roughly 198 tCO<sub>2</sub>e<sup>11</sup>. The projected values are multiplied by the forested area as identified by the Region's LiDAR land classification. The impact of developments in each land use scenario will affect the rate of carbon storage per hectare and consequently the amount of carbon sequestered per year. We note that the increase of carbon storage as years are projected forward is considerable. This increase of carbon storage and sequestration from 2010 to 2050 may allude to a component of carbon storage that is not being represented in the model.

<sup>11</sup> Kimmins, J.P., Maily, D., and Seely, B. (1999). Modelling forest ecosystem net primary production: the hybrid approach used in FORECAST. *Ecol. Model.* 122: 195-224. doi: 10.1016/S0304-3800(99)00138-6.

### *Further Opportunities for Terrestrial Carbon Protection & Sequestration*

Opportunities to increase yearly sequestration can be linked to the re-naturalization of highly productive forests and natural areas. In practice this means restoring tree canopy in urbanized areas, reducing logging, and mitigating against the effects of urban development for the remaining forested areas in the Region. Constraining these opportunities is the steady requirement for new urban land to develop under the BAP scenario. Indeed, by 2050 and under the BAP scenario, development is expected to decrease carbon sequestration capacity of the Region by 15.75%. Cumulatively, land use and urban containment scenarios reduce the size of this impact, recovering 0.41% of the impact on carbon sequestration brought upon by the BAP scenario. The combined recovery effect of land use, urban containment, and other Policies in this sector is 3.25% by 2050. The remaining, unrecovered loss of sequestration capacity in the BAP scenario is a result of the form of growth in the region.

Results for emissions reductions across all sectors suggest that a substantial amount of carbon (63.6, 63.8, and 63.9 million tonnes of carbon in the BAP, CNS, and Land Use scenarios respectively) will remain, even if the aggressive policies modelled in the CNS are implemented. However, it may not be possible to deepen sequestration potential. Indeed, there are a number of factors not considered in this analysis that may result in lower regional carbon sequestration than the estimates produced with this modelling:

- The forested land base within the MV region is very large relative to the area disturbed area in all scenarios. The study area boundaries are too broad to truly reflect the carbon impact of anthropogenic emissions and land use change associated with the built-out areas and their environs. Additional analysis could exclude the actual forest areas surrounding the region in order to focus on the direct impacts of development and land use change on carbon emissions and storage.
- Projected regional climate impacts, including hotter drier summers, droughts, and windstorms are likely to impact regional forest carbon sequestration. These impacts are not considered in this analysis. A more detailed study on the climate impacts on regional forest carbon is needed to better understand likely carbon sequestration in the mid to long term. This work could also consider the impact of strengthened forest and ecosystem management Policies that reduce risks to carbon loss due to forest fire and insect infestation.
- Uncertainties of total carbon storage exist in the current structure of the model. Aging trees and indexing new tonnes of carbon values results in a large increase of stored carbon over a relatively short period of time. An academic review to validate the age-to-carbon index methodology would be valuable in addressing the uncertainties surrounding the projected total carbon stored in the Region by 2050.

In addition to possibilities for future work that refines estimates of carbon sequestration, analysis of diverse costs and co-benefits to optimize nature and ecosystems Policies may be considered, e.g.

- While providing modest carbon storage/sequestration potential, protecting natural greenspaces in frequent transit corridors is increasingly important in mitigating flood and heat risk as well providing high value recreational space for people living in medium to high density areas.
- The region's ecosystems provide numerous benefits including human health, flood protection and extreme heat risk mitigation, which will be important as we adapt to the impacts of climate change. Nature and ecosystems are therefore of immense value to residents and communities, regardless of the carbon implications.

## Conclusion & Priority Opportunities

The report focuses on understanding the essential technical and policy potential for achieving Metro Vancouver's targets of 45% emission reductions by 2030 and carbon neutrality across the region by 2050, aligning with IPCC 1.5°C stabilization recommendations. This work has identified policies with significant GHG reduction potential and those with modest impact. The single most important insight is the imperative for immediate action.

While this analysis demonstrates deep emissions reductions are possible with the implementation of aggressive and achievable policies that go far beyond a business as planned future, the 2030 target remains elusive due to the ever-narrowing timeline, relatively slow climate action progress by all orders of government to-date, and the abrupt course correction now required. While close, the results also fall short of reaching regional carbon neutrality by 2050.

### Priority Opportunities

This analysis provides a solid foundation for taking action in a manner that focuses on immediate big opportunities. It can be linked to broader planning agendas and policy priorities, and establishes a meaningful framework to guide implementation and monitoring to meet 2030 and 2050 targets. While outside the scope of this analysis and the project in general, the project consulting team has identified the following recommendation for consideration:

- ***Undertake multi-criteria analysis:*** This report focuses on GHG reductions. The most successful climate change mitigation agendas around the world are driven by co-benefits that address key local priorities, e.g.: economic and industrial development, affordability, congestion management, etc. Understanding the cost of action and financing synergies is also informative. Undertaking effective multi-criteria analysis can help prioritize and optimize policies.
- ***Map authority and influence:*** Effective sectoral and sub-sectoral climate change mitigation typically involves action by multiple orders of government. Coarsely evaluating the authority and influence of each order of government over each policy can inform collaborative policy making, partnership imperatives, and action prioritization. Those policies over which local government has the greatest authority and influence are likely amongst the easiest to take action on.

- ***Scope institutional and organizational change imperatives:*** Most technologies and practices under the Carbon Neutral Scenario exist and have been deployed in some form in leading jurisdictions. The biggest challenges are not technical. The biggest challenges are institutional. Much can be learned from the governance and institutional changes in leading jurisdictions. Institutional transformation is necessary to adjust course, expeditiously drive adoption at scale, accelerate further innovation and further reduce costs. Many other institutional adaptations and new institutions are needed.
- ***Develop a carbon risk management lens:*** All projects and activities have carbon risk profiles. A lens should be crafted for major projects undertaken by or in Metro Vancouver and member municipalities to understand the short-, medium- and long-term carbon risks and develop mitigation strategies.
- ***Build on the policy and modelling foundation:*** Further and more nuanced policy development and modeling work can be undertaken to strengthen the pathway to meeting 2030 and 2050 targets. Major planning agendas such as the Regional Growth Strategy, Regional Transportation Plan and should consider GHG implications and management strategies that advance the region's climate action objectives.
- ***Advance sectoral target and indicator framework:*** A suite of way points can help the region get on and stay on a path to meet 2030 and 2050 targets. As the province has set sectoral targets, it would be useful for Metro Vancouver to advance the key indicators and targets it has developed to support continuous improvement and cultivate collective action across the region, with municipalities as well as other private, public and social sector players, on implementation, monitoring and course corrections. The extensive data and modelling work brought together to support this project provides a solid foundation to establish a target and indicator framework.



## Closure

Information in this report has been presented to meet the overall objectives of the project. The authors of this report, and all of the members of the project team are excited to have produced modeling and recommendations that can serve Metro Vancouver's planning purposes. We greatly look forward to future iterations of this work.



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