September 2013

2010 Lower Fraser Valley Air Emissions Inventory and Forecast and Backcast

Final Report and Summarized Results

metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION

The 2010 emissions inventory and forecast and backcast for the Canadian portion of the airshed were prepared by Metro Vancouver, with the exception of the 2010 ocean-going vessels emissions inventory and the volatile organic compounds emissions inventory, both of which were prepared by SNC-Lavalin under contract with Environment Canada and the railway and locomotive emissions inventory which was prepared by SNC-Lavalin under contract with Port Metro Vancouver. Emissions data for Whatcom County was obtained from US EPA's National Emissions Inventory Database, Northwest Clean Air Agency, Puget Sound Clean Air Agency and Washington Department of Ecology.

We would like to acknowledge the contributions of the following agencies in developing this emissions inventory and forecast / backcast:

- Agriculture Canada
- AirCare
- BC Lung Association
- BC Ministry of Agriculture
- BC Ministry of Environment
- BC Ministry of Forests and Lands and Natural Resource Operations
- BC Stats
- Environment Canada
- Fortis BC
- Fraser Valley Regional District
- Insurance Corporation of British Columbia
- Municipal Fire Departments
- Northwest Clean Air Agency
- Port Metro Vancouver
- Statistics Canada
- TransLink
- Vancouver Airport Authority
- Washington Department of Ecology

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Cover Photo Courtesy of Port Metro Vancouver

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List of Acronyms

BC	British Columbia
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
DPM	Diesel Particulate Matter
ECA	Emission Control Area
FVRD	Fraser Valley Regional District
GHG	Greenhouse Gas
LFV	Lower Fraser Valley
NH_3	Ammonia
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
N_2O	Nitrous Oxide
PM	Total Particulate Matter, also referred to as TSP, Total Suspended Particulate
PM_{10}	Inhalable Particulate Matter, particles smaller than 10 microns in diameter
$PM_{2.5}$	Fine Particulate Matter, particles smaller than 2.5 microns in diameter
SFP	Smog-Forming Pollutants
SO_2	Sulphur Dioxide
SO_x	Sulphur Oxides
VOC	Volatile Organic Compounds

Section A – Introduction

The 2010 emissions inventory provides information on the types of air emission sources in the Lower Fraser Valley, their location and the amount of air contaminants emitted, for the year 2010.

Like the emissions inventory, another essential tool in the air quality planning process is a forecast and backcast of emissions. Emission backcasting involves revisiting previous emissions inventories and updating them for consistency with the current year inventory in terms of methodology and study area. This allows for an equitable analysis of emission trends.

Emission forecasting is the process of estimating future emissions by projecting changes in activity (growth or decline) combined with changes in emission rates or controls. These changes could be influenced by technological advances, environmental regulations, process and control equipment deterioration, fuel formulations or other factors. The forecast allows for an assessment of future air emissions and impacts of emission reduction measures.

Together, the 2010 inventory and the forecast and backcast data can be used to identify where significant progress has been made in reducing emissions and where additional action is warranted. This information is also essential for the development of Air Quality Management plans for the Lower Fraser Valley (LFV) airshed.

This report provides the results of the 2010 Lower Fraser Valley airshed emissions inventory, as well as the forecast and backcast of the 2010 emissions inventory. The backcast includes emissions inventories for 1990, 1995, 2000 and 2005, while the forecast presents emissions to the year 2030, in five-year increments.

What is the Study Area?

The 2010 emissions inventory and forecast and backcast has been compiled for the Lower Fraser Valley area of British Columbia (BC), encompassing virtually the entire Metro Vancouver region, the

Figure 1: Lower Fraser Valley emissions inventory study area.

south-western portion of the Fraser Valley Regional District (FVRD) and Whatcom County in the State of Washington, which is representative of the United States portion of the Lower Fraser Valley airshed.

This inventory and the forecast and backcast include estimated emissions for the entire Lower Fraser Valley International airshed. In 2010, the international airshed had a combined population of about 2.86 million.

What Emissions are Inventoried?

Common Air Contaminants

The common air contaminants addressed in this inventory include:

- Carbon monoxide (CO)
- Nitrogen oxides (NO_x)
- Total particulate matter (PM)
- Inhalable Particulate Matter (PM_{10})
- Fine Particulate Matter ($PM_{2.5}$)
- Sulphur oxides (SO_x)
- Volatile organic compounds (VOC)
- Ammonia (NH_3)

Greenhouse Gases

Greenhouse gases contribute to global climate change, a shifting of the world's climate systems to wider extremes and variability. Greenhouse gases included in the emissions inventory are:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)

Sources of Emissions

The emissions inventory and forecast and backcast cover three main categories of emissions: industrial, area, and mobile sources. Table 1 defines these sources.

Table 1: Emissions source categories, definitions and sub-categories

Source Category	Sub-Categories
Industrial Sources Industrial sources are facilities or utilities operating under an air discharge permit, or in some cases a regulation issued by Metro Vancouver or the BC Ministry of Environment (BCMOE), or under a Solid Waste Management Plan authorized by BCMOE, or under the jurisdiction of the Washington State Department of Ecology or Northwest Clean Air Agency. In general, these sources are large, stationary sources that release pollutants into the atmosphere.	•Bulk Shipping Terminals •Chemical Manufacturing •Electric Power Generation •Heating / Cogeneration Utilities •Metal Foundries and Metal Fabrication •Non-metallic Mineral Processing Industries (e.g. cement plants) •Paper and Allied Products •Petroleum Products •Primary Metal Industries •Wood Products •Concrete Batch Plants •Miscellaneous Industrial Sources
Area Sources Area sources are smaller, broadly distributed light industrial, commercial, institutional, residential, agricultural and naturally occurring sources that normally do not require an air discharge permit but may be regulated by other mechanisms.	•Agricultural Sources •Vegetative Burning •Fuel Distribution •Natural Sources •Chemical Products Use (Industrial, Commercial, and Consumer)(e.g. paints, solvents) •Heating (e.g. homes and commercial space) •Fugitive Dust (e.g. road, coal and construction) •Waste (e.g. landfills, sewage and waste-to-energy) •Miscellaneous sources
Mobile Sources Mobile sources are intended to be moved around, and typically involved in transportation of people and goods. Some of these operate on roads and others off road.	•Light-Duty Vehicles •Heavy-Duty Vehicles •Aircraft •Rail Locomotives •Marine Vessels •Non-Road Engines and Equipment (e.g. construction, lawn and garden)

Forecast and Backcast

The forecast of 2010 emissions was performed under three growth rate scenarios: low, moderate and high growth.

The forecasts use projections from numerous sources on variables such as changes in population, economy, kilometres travelled, fuel consumed and future growth. The forecasts also incorporate all committed federal, provincial and regional activities and policy measures, as well as new emission sources. Table 2 lists the policy measures quantified in the forecast.

A number of additional policy measures and new sources were noted but not quantified for reasons such as uncertain implementation status, lack of data with which to estimate, and low impact. These policies and sources may have impacts on emissions levels in the future, and include:

- BC Building Code Energy Requirements
- BC Open Burning Smoke Control Regulation
- New district energy systems
- Federal Base Level Industrial Emission Requirements (BLIERs)
- Heavy Duty Vehicles Retrofit Requirement (Provincial)

In addition to the forecast, emissions were also backcast to 1990, in five-year increments. This is to get a sense of trends in emissions over time in a way that allows for comparison of emissions in previous years to the current year.

Table 2: Forecasted policy measures and new sources

Source Category	Sub-Categories
Industrial Sources	•Metro Vancouver (MV) permit changes •New waste-to-energy facility (MV) •Boiler and Heater Regulation (MV)
Area Sources	•BC Carbon Tax (Provincial) •Wastewater Systems Effluent Regulations (Federal) •Boilers and Heaters Regulation (MV) •Agricultural Boilers Regulation (MV) •Dry Cleaning Regulations (Federal) •Architectural Coatings Regulations (Federal) •Automotive Refinishing Regulations (Federal) •Woodstove Exchange Program (MV, FVRD) •BC Landfill Gas Regulation
Mobile Sources	•BC Carbon Tax (Provincial) •Light Duty Vehicles Greenhouse Gas Regulation (Federal) •Heavy Duty Vehicles Greenhouse Gas Regulation (Federal) •Low Carbon / Renewable Fuel Standards (Federal / Provincial) •Cold Ironing for Cruise Ships (Federal) •New Aircraft NOx Standards (Federal) •Tier 3/4 Locomotive Engine Emission Standards (Federal) •Sulphur in Non-Road Diesel Fuel (Federal) •Sulphur in Gasoline (Federal) •Emission Control Area (ECA) (Federal) •Tier 4 Non-Road Standards (Federal) •Non-Road Diesel Engine Bylaw (MV) •New and Expanded Coal Terminals •Marine vessel activity related to projected growth in shipping •AirCare Program (until 2014, after which emissions testing ends for light-duty vehicles)

For more information on policy measures and sources included in the forecast, contact AQInfo@metrovancouver.org.

Section B – Results by Pollutant

This section contains summary information by pollutants inventoried for 2010 and backcast and forecast years.

Nitrogen Oxides (NO_x)

Nitrogen oxides (NO_x) are formed when fuel is burned at high temperatures, like in an engine or boiler. Under certain weather conditions, NO_x can react with other chemicals to form ground-level ozone, secondary particulate matter and acid rain. NO_x can irritate the lungs and lower resistance to respiratory infections. NO_x includes NO and NO_2, and the convention is to report NO_x on the basis of the molecular weight of NO_2.

In 2010, NO_x emissions were dominated by mobile sources, namely cars and trucks (onroad), non-road equipment and marine vessels. Natural gas use in homes, offices and industry also play a role in NO_x emissions.

NO_x emissions decline from 1990 through to 2020 and then are projected to level off. The role of light-duty vehicles has declined over time largely due to improved vehicle emission standards and the AirCare vehicle inspection and maintenance program. The relative role of marine vessels is increasing and by 2015, marine vessels are projected to become one of the dominant sources of NO_x. The anticipated increase in marine emissions is due to projected growth in shipping. This growth will be mitigated over time with the implementation of the North American Emission Control Area (ECA), which will result in steady improvements in NO_x emissions from marine vessels by 2030.

For more on nitrogen oxides, see www.metrovancouver.org/services/air/Documents/NOxFactsheet.pdf.

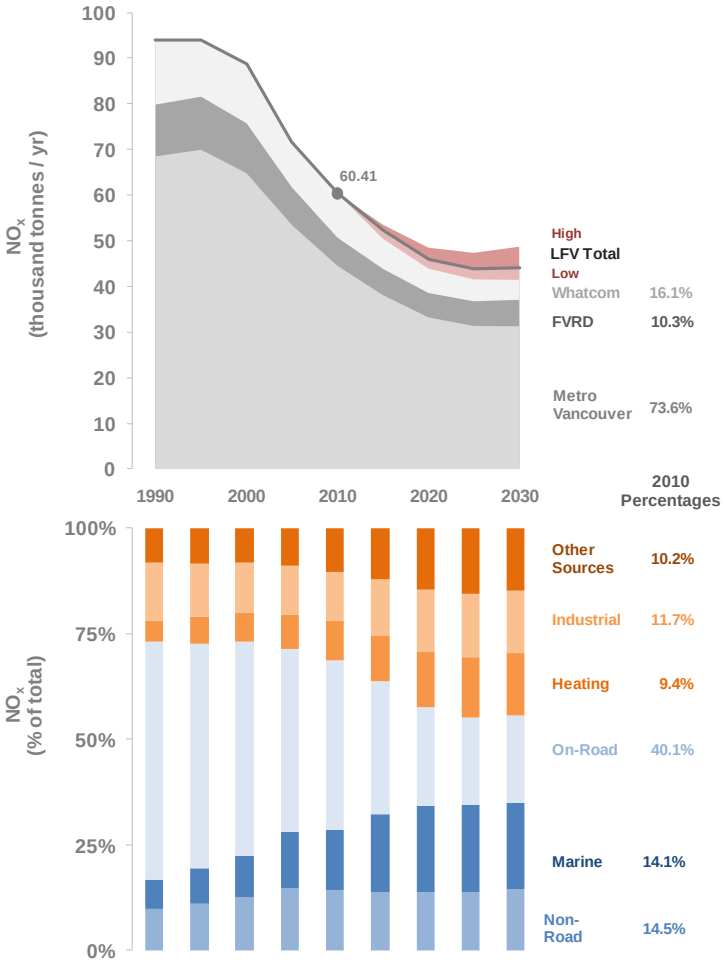

Figure 2: NO_x Emissions Trends and Percentage Distribution across Sectors

Particulate Matter (PM)

Particulate matter includes dust, dirt, soot, smoke, and liquid droplets, which are emitted from sources like windblown dust, the burning of fuel, industries such as coal and grain handling, and travel on roads. Particulate matter is characterized by its size, as different size fractions have different impacts and sources. The most common size fractions are total particulate matter (all sizes), PM_{10} and $PM_{2.5}$.

Total Particulate Matter

Total particulate matter (PM) is made up of particles of all sizes. Important sources of total PM include construction and demolition dust, tilling and wind erosion of agricultural land, industrial activities and residential wood burning.

Inhalable Particulate Matter, PM_{10}

PM_{10} refers to particles smaller than 10 microns. In comparison, a human hair is about 50 to 100 microns in diameter. PM_{10} is a mixture of constituents including nitrates, sulphates, and diesel particulate matter exhaust. PM_{10} may be solid particles or liquid droplets.

Significant sources of PM_{10} include construction and demolition dust, residential wood heating, industrial activities and wind erosion of agricultural land.

Fine Particulate Matter, $PM_{2.5}$

$PM_{2.5}$ refers to particles smaller than 2.5 microns. They can be breathed deep into the lungs and contain substances that are particularly harmful to human health. Scientific studies have linked these small particles to premature death, aggravated asthma, acute respiratory symptoms, and chronic bronchitis. As well, $PM_{2.5}$ scatters light in the atmosphere and reduces visual air quality.

At this size fraction, residential wood heating is the dominant source, with industry and mobile sources as the second largest sources.

Since 1990, $PM_{2.5}$ emissions have decreased steadily. Reductions from the petroleum refining and wood products sectors coupled with reductions from light and heavy-duty vehicles have driven the declining trend. However, the forecast of $PM_{2.5}$ emissions shows a steadily increasing trend from 2015 to 2030.

Heating (primarily residential wood burning), the industrial sector and the other mobile source sector (e.g. non-road engines) continue to be the main sources of $PM_{2.5}$ in the future.

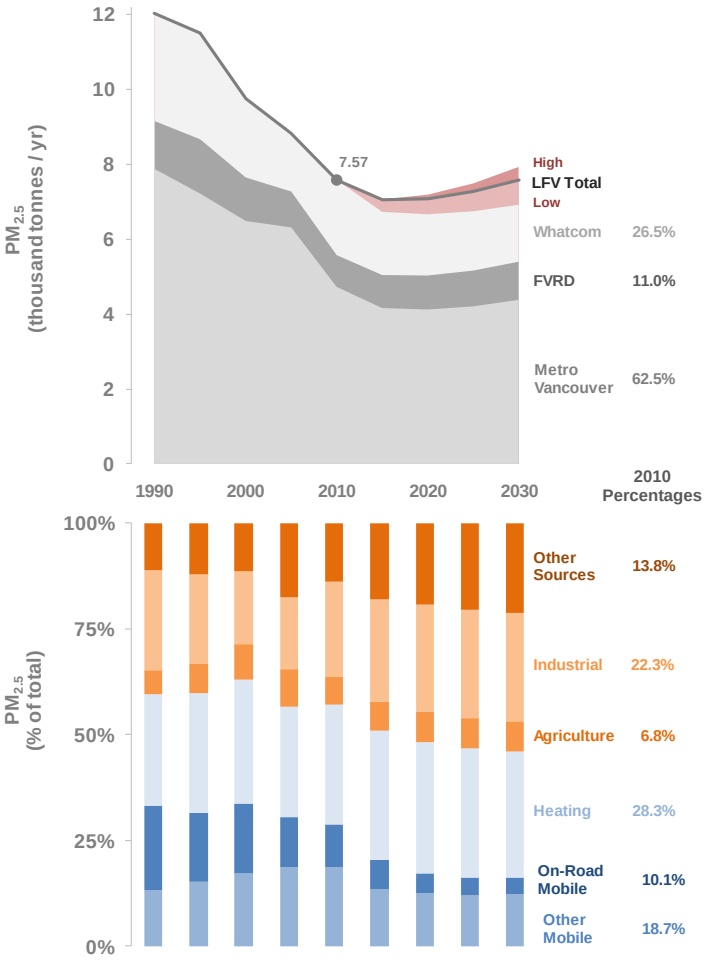

Figure 3: $PM_{2.5}$ Emissions Trends and Percentage Distribution across Sectors

Road Dust

Road dust is a type of particulate matter made up of material that has been previously deposited on the travel surface such as mud and dirt track-out, litter, garbage, refuse, leaves, plants, vehicle exhaust, tire debris, brake linings, pavement wear, and fallout from industrial emissions. Traffic or wind resuspends the road dust into the air, followed by the redeposition of some of it back

onto the streets. Road dust is the single most significant source of PM. It is also a primary contributor of PM_{10} emissions, but less so for $PM_{2.5}$ emissions, since road dust emissions tend to become less significant in the smaller size fractions than in the larger size fractions. However, road dust emissions are not included in the PM estimates in this emissions inventory, given that a portion of road dust emissions are considered to be non-transportable, and are redeposited rather than being suspended in the air.

Diesel Particulate Matter (DPM)

Diesel engines emit a mixture of air pollutants, mainly composed of gaseous and solid matter. The visible emissions in diesel exhaust are known as particulate matter, made up of carbon particles, as well as other gases that become visible as they cool. Diesel particulate matter is a toxic air contaminant, with a potential to cause cancer and other adverse health effects. In addition to particulate matter, emissions from diesel fueled engines include over 40 other cancer-causing substances.

DPM emissions show a declining trend from 1990 to 2030. The decrease in emissions is a result of cleaner marine diesel fuels, more stringent engine emission standards for light and heavy-duty vehicles and non-road engines, and reductions due to Metro Vancouver's bylaw for non-road diesel engines. DPM emissions from marine and rail are projected to increase after 2015 due to increased activity in these sectors.

For more on particulate matter and DPM, see www.metrovancouver.org/services/air/Documents/PMFactsheet.pdf.

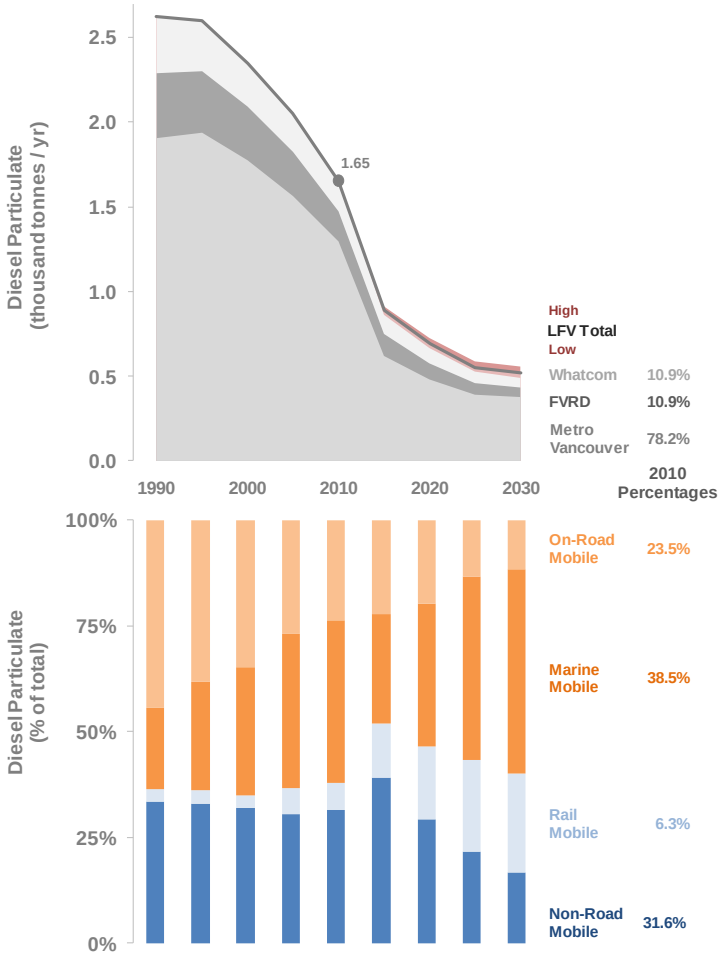

Figure 4: DPM Emissions Trends and Percentage Distribution across Sectors

Sulphur Oxides (SO_x)

Sulphur oxides (SO_x) are a group of sulphur and oxygen compounds which, like NO_x, are formed when fuel is burned. The major health effects of concern associated with exposure to high levels of SO_x include effects on breathing, aggravation of existing respiratory and cardiovascular disease, and mortality. SO_x can also interact with other compounds in the air to form secondary particulate matter and can lead to acid rain formation. SO_x emissions include SO_2 and SO_4 (sulphate) but are reported on the basis of the molecular weight of SO_2.

Marine vessels, mainly ocean-going vessels in Metro Vancouver waters, are the largest contributor of SO_x emissions in the airshed in 2010. The next largest contributor was the primary metal industry operating in Whatcom County. The petroleum products industry is also a major contributor of SO_x due to refineries operating on both sides of the Canada-US border.

SO_x emissions declined from 1990 to 2015, largely as a result of desulphurization of fuels, the shutdown of several Metro Vancouver refineries and reduced emissions from the cement plants.

The projected decrease in SO_x emissions is due to the implementation of the North American Emission Control Area (ECA), which takes effect in August 2012 and January 2015, in two stages. To some extent, electric shorepower facilities at Canada Place will also have some emissions reductions in the future.

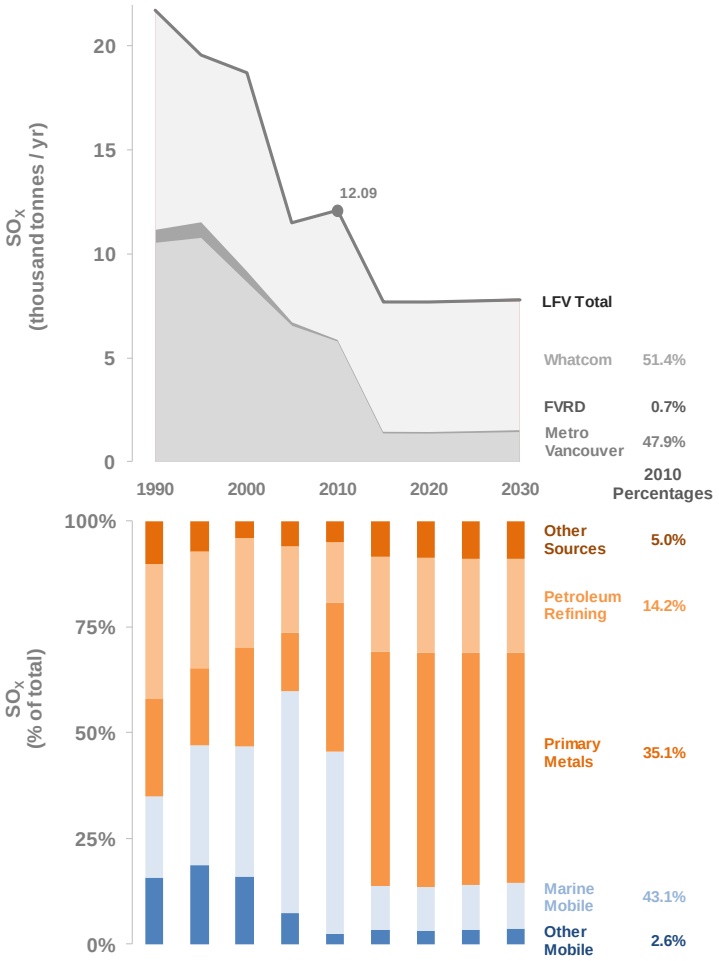

Figure 5: SO_x Emissions Trends and Percentage Distribution across Sectors

The main contributors of SO_x emissions in the future include primary metals industries in Whatcom County and industrial sources such as the petroleum refining and marine vessels. The forecast of these emissions takes into account a number of permit changes, activity levels and regulation implementation.

For more on SOx, see www.metrovancouver.org/services/air/Documents/SO2Factsheet.pdf.

Volatile Organic Compounds (VOC)

Volatile organic compounds (VOC) can react with NO_x in the atmosphere to form ground-level ozone, a key constituent of smog. Some VOC can also have a potential carcinogenic or toxic effect.

There are three major sources of VOC in the region: chemical products use, natural sources / vegetation and light-duty cars and trucks. Historically, light-duty vehicles were the primary source of VOC, but this role is steadily declining due to improved vehicle emission regulations and implementation of the AirCare program in Metro Vancouver and the FVRD.

In 2010, the chemical products sector (e.g. industrial, commercial, and consumer products such as paints, stains, varnishes, solvents, and thinners) became the main anthropogenic source of VOC, overtaking cars and light trucks. In the future, chemical products use is projected to still be a significant source of VOC emissions, even with the federal government's proposed regulations for volatile organic compounds in consumer and commercial products in place.

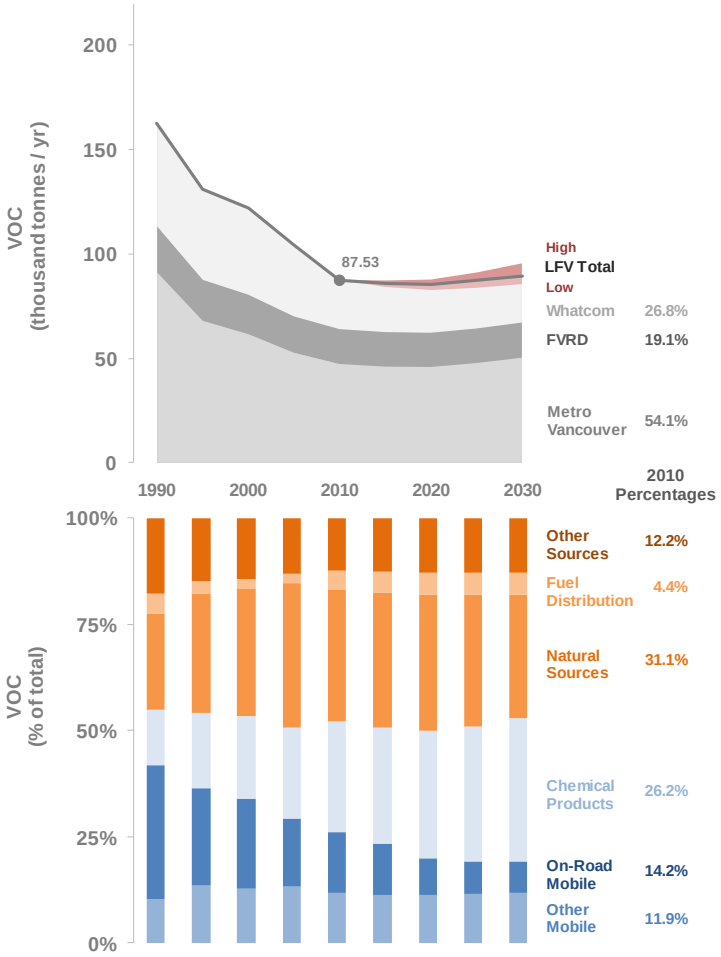

Figure 6: VOC Emissions Trends and Percentage Distribution across Sectors

Ammonia (NH3)

Ammonia is a colourless gas with a very sharp odour. It is produced by animals, wastes, and fertilizer application. NH_3, along with SO_x, NO_x and some VOC, can react in the atmosphere to form secondary $PM_{2.5}$, thus contributing to visual air quality impairment and the health effects associated with $PM_{2.5}$.

Almost all of the ammonia in the region comes from the agriculture sector (e.g. fertilizer application, poultry and cattle). Other sources such as cars and light trucks and miscellaneous sources play smaller roles.

NH_3 emissions are projected to steadily increase from 2010 to 2030 due to an increase in agricultural activity, light-duty vehicle use, and increased loading on our wastewater treatment facilities.

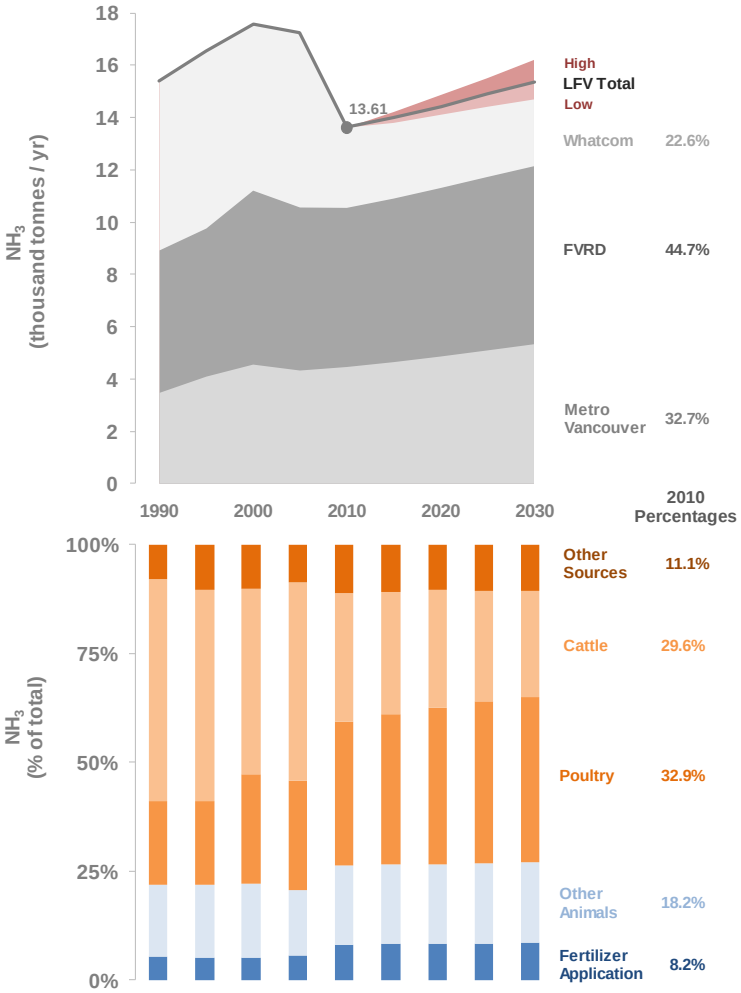

Figure 7: NH_3 Emissions Trends and Percentage Distribution across Sectors

Smog-Forming Pollutants (SFP)

The key components of smog are small particles (including secondary particulate matter that can form in the atmosphere in the presence of NO_x, SO_x and NH_3) and ground-level ozone. Ozone is a colourless and highly irritating gas that forms in the air when sunlight "cooks" the precursor pollutants (i.e. NO_x and VOC) over urban areas especially on hot summer days.

For more on ground-level ozone, see www.metrovancouver.org/services/air/Documents/GLOFactsheet.pdf.

In order to provide a simplified, aggregate indicator of where "emissions" may be heading, we have summed the emissions of the principal "smog-forming pollutants", namely NO_x, VOC, $PM_{2.5}$, SO_x and NH_3. These are the major contributors to the formation of ground-level ozone and fine particulate matter, and to the degradation of visual air quality. In 2010 and previously, aside from natural sources, the main contributors to smog-forming pollutants were cars and light trucks, followed by non-road engines, chemical products use and agriculture.

The trend in smog-forming pollutant emissions decreases until 2020, after which emissions begin to rise. By 2030, chemical products, industry and agriculture (shown under "other sources" in Figure 8) overtake cars and light trucks and non-road engines as the largest anthropogenic sources. The predominance of these sources is due to an expected growth in activity in these sectors, as well as emission reductions resulting from regulations on motor vehicles and non-road engines.

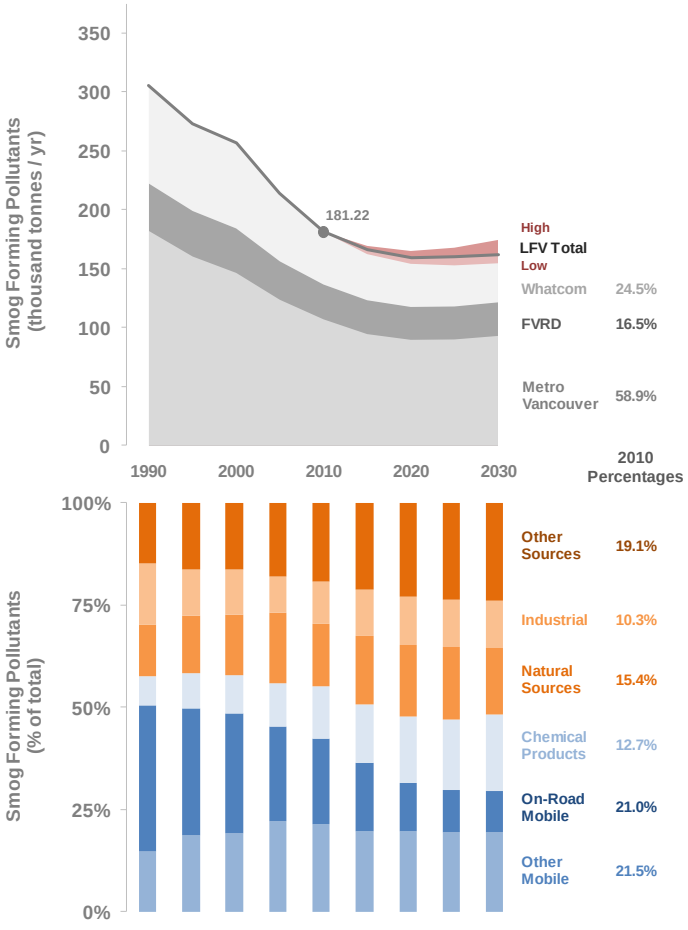

Figure 8: SFP Emissions Trends and Percentage Distribution across Sectors

Carbon Monoxide (CO)

Carbon monoxide (CO), a colourless and odourless gas, is formed when carbon material does not burn completely. The main source is transportation, particularly motor vehicles and non-road engines and equipment. CO is a health concern because elevated exposure can reduce the ability of the blood to carry oxygen to the heart, brain, and other tissues, resulting in impaired performance, respiratory failure, and death.

Total CO emissions declined steadily from 1990 to 2010. This decline has resulted largely from the AirCare program and improved vehicle emission standards.

A slight increase is expected between 2010 and 2015, due to the end of emissions testing for light-duty vehicles in the AirCare program. Post-2020, CO increases steadily, almost entirely due to non-road equipment (e.g. construction, agricultural, lawn and garden) use.

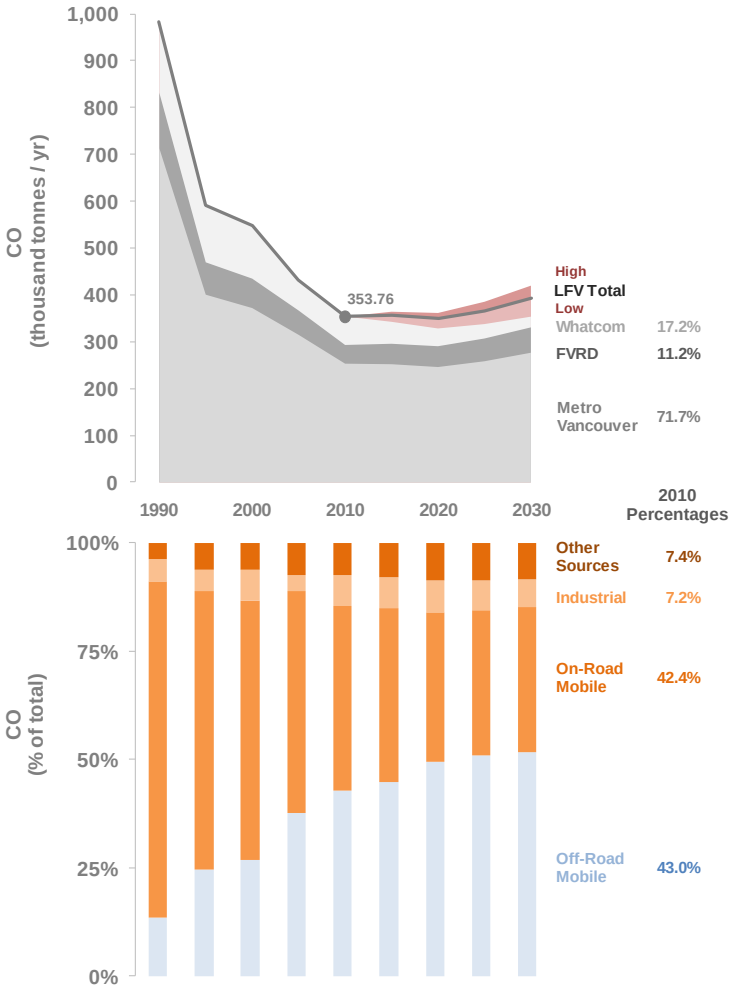

Figure 9: CO Emissions Trends and Percentage Distribution across Sectors

Greenhouse Gases (GHGs)

Some greenhouse gases occur naturally in the atmosphere, while others result from human activities. GHG emissions from human activity are believed to be shifting the world's climate systems to wider extremes and have already warmed the earth's average temperature by 1°C.

The principal greenhouse gases for which emissions have been estimated in this inventory are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Other GHGs, namely hydrofluorocarbons, perfluorocarbons, and sulphur hexafluorides, have not been included in this report, as they are believed to be insignificant in the region, compared to CO_2, CH_4, and N_2O. GHGs are expressed as CO_2-equivalent (CO_2e), which aggregates all GHGs based on the relative heat-trapping power (or global warming potential, GWP) of each pollutant compared against CO_2. For example, methane is 21 times as potent as CO_2 and therefore would be expressed as 21 CO_2e, while the GWP for N_2O is 310 CO_2e.

The main contributors to total GHG emissions in the LFV are heating (e.g. buildings), cars and light trucks, the petroleum products sector (mainly refineries), the non-metallic mineral sector (mainly cement plants), heavy trucks and buses, and non-road engines.

In 2010, light-duty vehicles, industry and heating were the major sources of GHG emissions in the LFV. Emissions from heating are projected to continue to climb to 2030, while GHG emissions from light-duty vehicles are projected to start declining due to new federal tailpipe standards. GHG emissions from the industrial sector continue to be a dominant source in the future.

GHG emissions were highest in 2000, due in part to increased emissions from an electric power generation plant in Metro Vancouver. GHG emissions from this facility were significantly lower in 2010 and projected to remain low in the future due to reduced operations.

GHG emissions in the airshed are projected to decline from 2010 to 2015, and then increase

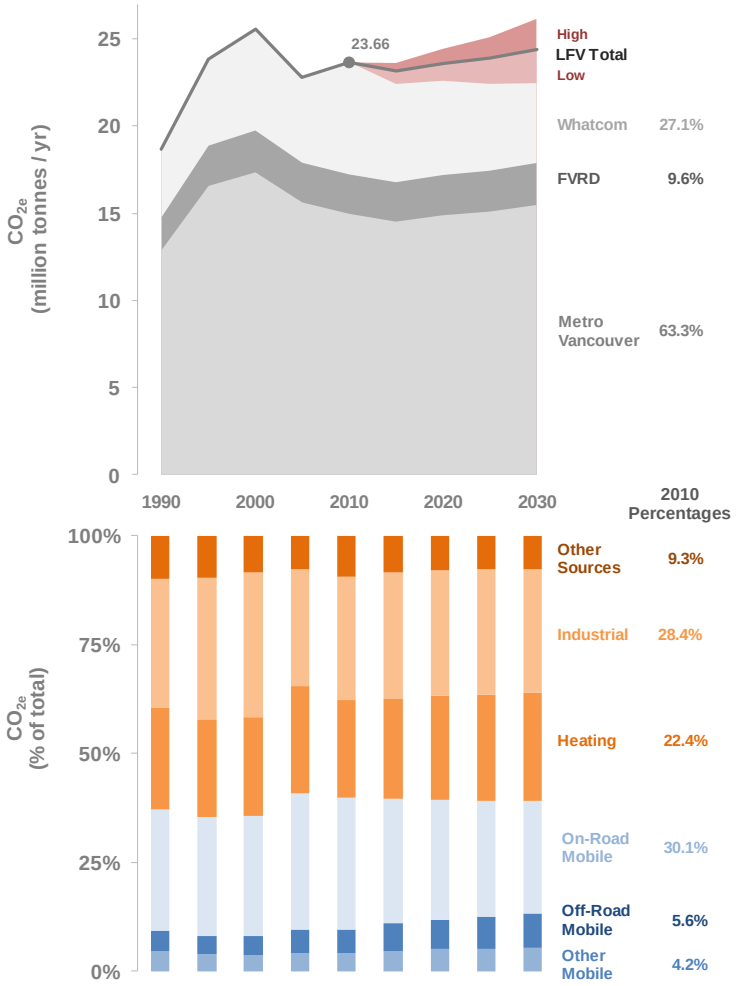

Figure 10: Greenhouse Gas Emissions Trends and Percentage Distribution across Sectors

between 2015-2030, primarily due to increasing population and greater economic activity.

Although GHG emissions are steadily increasing, it is interesting to note that per capita GHG emissions are projected to decrease: from about 6 tonnes per year in 2010 to about 5 tonnes in 2030 for Metro Vancouver; from about 8 tonnes per year in 2010 to about 6 tonnes in 2030 for FVRD; and from about 32 tonnes per year in 2010 to about 25 tonnes in 2030 for Whatcom County. The difference in Whatcom County and Metro Vancouver-FVRD per capita GHG emissions is largely due to the greater presence of heavy industry in Whatcom County. Emissions from the Whatcom County electric power generation, aluminum smelting and petroleum refining industries drive the per capita emissions upward.

For more on GHGs, see
www.metrovancouver.org/services/air/Documents/GHGFactsheet.pdf

Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is released to the atmosphere when fuels (oil, natural gas, coal, wood and plastics) are burned. In Metro Vancouver and FVRD, the main contributors of CO_2 are heating (e.g. buildings) and cars and light trucks. CO_2 is also released from certain industrial processes through chemical reactions that do not involve combustion, for example, the production of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. Metro Vancouver also has significant emissions from cement plants and petroleum refining. In Whatcom County, the main contributors are petroleum refining, electric power generation and aluminum smelting.

In 2010, light-duty vehicles, industry and heating were the major sources of CO_2 emissions in the LFV. CO_2 emissions in the airshed are projected to decline to 2015, and then increase between 2015-2030, primarily due to a growing population and increased economic activity (e.g. more driving, building heating / cooling requirements). By 2030, industry will be the dominant emission source, followed by light-duty vehicles. The reduced share of light cars and trucks is a result of new tailpipe standards that improve fuel economy in new vehicles.

Historically, emissions of CO_2 were highest in 1995 and 2000, due in part to significant emissions from an electric power generation plant in Metro Vancouver. CO_2 emissions from this facility were significantly lower in 2010 and projected to remain low in the future due to decreased operations.

Methane (CH_4)

Methane (CH_4) is emitted during the production and transport of natural gas and from the decomposition of organic wastes in municipal solid waste landfills and the raising of livestock. Mobile and industrial sources make minor contributions.

In 2010, the two dominant sources of methane in the region were cattle and landfills. Historically, these two sources made roughly equal contributions to CH_4 emissions. As landfill emissions decrease in the future, largely due to improved landfill gas collection at the City of Vancouver's landfill in Delta and decreased anaerobic activity at decommissioned landfills, agricultural sources play a more dominant role. Whatcom County emissions are projected to remain unchanged in the future, reflecting more or less the same agricultural activity.

Nitrous Oxide (N_2O)

Nitrous oxide (N_2O) is mostly emitted from agricultural activities and the combustion of fossil fuels in motor vehicles and non-road equipment.

N_2O emissions declined from 2005 to 2010, and are projected to remain fairly steady with slight growth through 2030. The impact of emissions from light-duty cars and trucks is expected to decrease between 2010 and 2030, due to more stringent emission standards, while the emissions share of non-road equipment is expected to increase over this time.

Section C – Results by Geographic Region

Where emissions occur is often as important as the amount of emissions that are released. Examining emissions spatially allows us to draw different conclusions about the state of air quality in the region.

The figure below represents emissions on a per land area basis within municipalities; darker shading represents a higher emissions "intensity" for the respective municipality. These simple images highlight the differences in emissions by location.

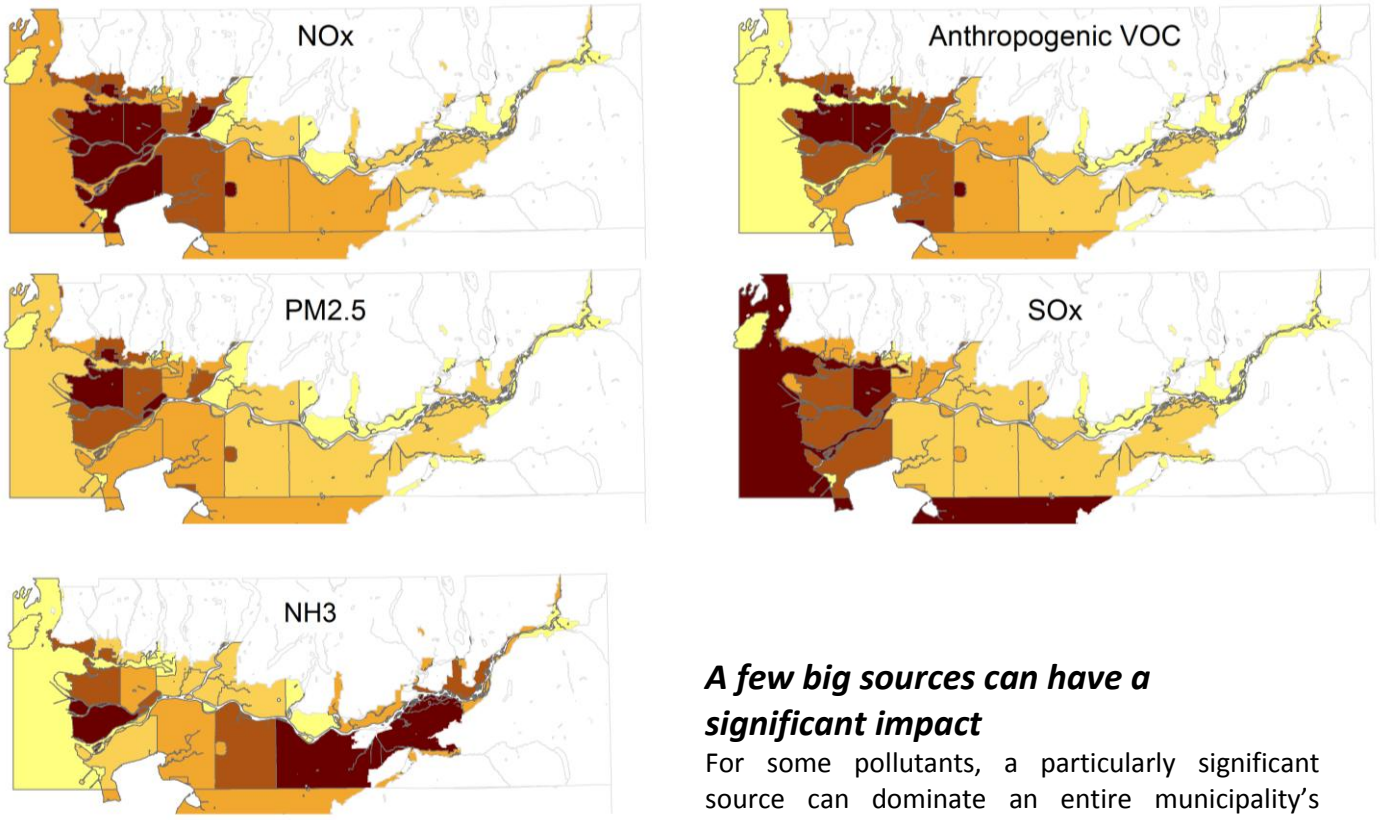

Figure 11: Municipal emissions intensity (total municipal emissions divided by populated land area).

Pollution is related to population

Since emissions for many air pollutants are combustion based, and level of combustion activity is linked to population and economic activity, it is not surprising that there is an increase in emissions with density. This is evident with pollutants such as NO_x, VOC, PM and CO_2.

A few big sources can have a significant impact

For some pollutants, a particularly significant source can dominate an entire municipality's emissions. This effect is apparent with SO_x, which is dominated by marine shipping using high sulphur bunker fuels and industrial activities. This is especially the case in Burnaby and Whatcom County, as well as in areas adjacent to intense shipping activities, such as Delta and the Burrard Inlet.

A different emissions profile in the FVRD

With a lower population density and dominance of agriculture instead of industry, the emissions profile of the Fraser Valley Regional District is

somewhat different than that of Metro Vancouver. In general, emissions are lower in the FVRD, which is less populated and industrialized; however, ammonia emissions from agricultural activities are significantly higher than those in Metro Vancouver.

For greenhouse gases, it is meaningful to examine emissions by land area and by population. Figure 12 illustrates these comparisons.

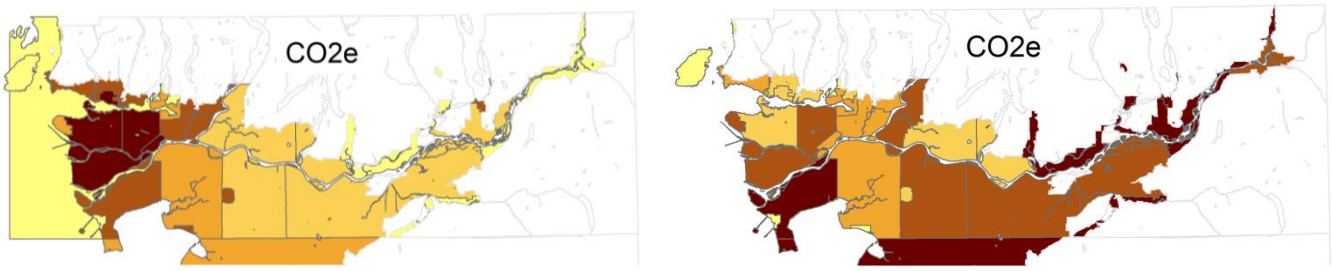

Figure 12: Municipal emissions intensity (total municipal emissions divided by populated land area) (left) and municipal per capita emissions (total municipal emissions divided by number of residents) (right).

Greenhouse gas emissions vary with density and per capita

Comparing the two maps in Figure 12 leads us to several conclusions. First, like many pollutants, more greenhouse gas emissions result from more population and more economic activity. Not surprisingly, therefore, the map on the left shows that the highest density of emissions occurs in the most densely populated areas of the region.

When CO_2e is adjusted on a per capita basis (map on the right), we see a different picture. Whereas municipalities with high population densities had high overall emissions of CO_2e, the per capita emissions drop. There appears to be a trend where areas with low density have some of the highest per capita emissions of CO_2e, likely influenced by longer commute distances and differences in building stock.

Section D – Conclusions

An analysis of the past and current emissions inventory data and forecast data indicates a few key findings:

Smog-Forming Pollutants

- In 2010, light-duty vehicles were the largest source of smog-forming pollutants, followed by non-road equipment, chemical products usage and agriculture. Overall, smog-forming pollutants show a declining trend until 2020, after which emissions begin to rise. By 2030, chemical products usage is projected to be the largest source of smog-forming pollutants.
- NOx emissions are projected to decline from 2010 to 2020 and then level off. The decline in emissions is primarily due to strict vehicle emission standards.
- There was a substantial decrease in $PM_{2.5}$ emissions between 1990 and 2010, due to reduced emissions from mobile and industrial sources. However, $PM_{2.5}$ emissions are projected to increase between 2020 and 2030 due to expected increases in emissions from industrial sources, residential wood burning and area sources (e.g. heating, construction) driven by growth in population and increased economic activity.
- SO_x emissions declined substantially between 1990 and 2005. This was due to desulphurization of fuels for motor vehicles, improved emissions control at refineries in Metro Vancouver and Whatcom County, and reduced production at the smelter in Whatcom County (which subsequently increased production in 2010). Marine vessels were the most significant source of SO_x emissions in 2005-2010; however, due to the implementation of the North American Emission Control Area on August 1, 2012 and further regulated improvements in fuel quality on January 1, 2015, emissions from this sector are projected to decrease significantly from 2010 to 2020 and then increase slightly due to growing marine activity.
- VOC emissions show a declining trend until 2020, after which the emissions are projected to increase due to an increase in emissions from chemical products use.
- NH_3 emissions are projected to continue to increase in the future. Agricultural activities such as manure management, livestock and fertilizer application are the major contributors.
- DPM emissions show a declining trend from 1990 to 2030. The decrease in emissions is due to cleaner diesel fuels, more stringent engine emission standards for both light and heavy-duty vehicles and non-road engines, and reductions due to Metro Vancouver's bylaw for non-road diesel engines. DPM emissions from marine and rail are projected to increase after 2015 due to increased activity in these sectors.

Greenhouse Gases

- In Metro Vancouver and FVRD, on-road vehicles and heating (e.g. buildings) are the two major sources of greenhouse gas emissions. Two cement plants also contribute significantly to GHG emissions in Metro Vancouver. In Whatcom County, industrial sources such as refineries, the aluminum smelter and power plants are the most significant sources of GHG emissions.
- GHG emissions increased steadily between 1990 and 2000 in Metro Vancouver. In 2010, there were some reductions in GHG emissions due to reduced production at an electric power generation plant in Metro Vancouver and some reduction in fuel consumption (i.e. natural gas and gasoline) possibly due to rising fuel prices.
- With the implementation of new tailpipe standards for GHGs, emissions from cars and trucks are projected to decline, with heating becoming the dominant source of GHG emissions by 2030