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Clearing the Air

Transportation, Land Use and Carbon Emissions in Metro Vancouver

EMRG

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SERIES

This is the fourth in a series of reports and case studies investigating challenges and opportunities for reducing carbon pollution from the transportation sector in Canadian cities. davidsuzuki.org/project/sustainable-transportation/

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FOREWARD

In Metro Vancouver, we're beyond the need to answer whether we have an emissions problem from transportation. Representing 45 per cent of our region's total emissions, the answer is a resounding "yes." The challenge now is to assess and prioritize the policies that will drive down emissions in this sector with the speed and ambition needed to meet our climate goals.

This study models the potential for smart growth policies to drive down personal transportation emissions in the region while accounting for the role of other senior government policies to reduce transportation emissions. If the goal is to reduce carbon emissions to levels close to zero by 2050, the modelling finds senior government policies are projected to have the biggest impact during the study time frame. Under B.C.'s zero emission vehicle mandate, the B.C. low carbon fuel standard and the federal vehicle emission standards, the modelling indicates that emissions will be dramatically reduced regardless of land-use policies and despite population growth expected in the region.

This might seem surprising, but on reflection it makes sense. We might imagine an electrified future when urban sprawl leads to long commutes and roads choked with transit buses, single-occupant cars, autonomous vehicles and delivery trucks. If all those vehicles are zero emitting, overall transportation emissions would be low as would levels of happiness for those stuck in hours of traffic. Total energy use by the transportation sector in this kind of sprawl would be wastefully high and require more renewable energy capacity be added to the grid.

An ambitious smart growth policy scenario was modelled in which sprawl is reduced, alternative transportation infrastructure is enhanced and population, employment and amenities densities are increased in urban centres and along rapid transit corridors. The analysis suggests that this smart growth path would have a fairly small incremental impact on end-use GHG emissions from personal transportation in the region to 2050, in the context of senior government policies mentioned above. This corresponds to similar findings in our "Shifting Gears" report. Smart growth policies, shifting to zero-emission public transit and mobility pricing are found to be complementary in terms of their impact on emissions from personal transportation.

These results, however, do not diminish the importance of land use decisions and good urban design on the livability and health of our region. While assessing policies for their potential to reduce emissions is essential to reaching our region's climate goals, policies that promote livability, social equity and affordability make a region where people thrive. Smart growth policies, which include only those policies that affect the built environment directly, provide an alternative to urban sprawl and its negative consequences while promoting important co-benefits, including health and improved mobility options for non-drivers. Compact development helps preserve agricultural land, parks and recreational areas. Transit-oriented development, initiatives to increase cycling and walking and improvements to accessibility and public transit allow people to forgo car use. If smart growth policies and mobility pricing are successful in reducing driving, they may mitigate traffic congestion and prevent traffic collisions. Many studies find that compact urban form is correlated with higher physical activity and better health through active transportation. Since land use decisions affect the built environment and hence emissions more slowly than electrification, over the very long run smart growth policies will have a big climate benefit by reducing the transportation sector's overall energy needs.

The climate emergency requires bold action and policies from all levels of government. The Metro Vancouver region benefits from progressive senior government policies that are shifting how we move. In regions that do not benefit from such progressive transportation emission policies, smart growth policies will pay more dividends over the long term and may be of higher value in bending the emissions curve downward. Given the scale of the changes needed, local-level interventions will remain an important part of the climate response. They are key to shaping the clean, green, livable environment that communities and people envision.

Theresa Beer,
David Suzuki Foundation

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EXECUTIVE SUMMARY

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The results of international and, in many cases, national greenhouse gas mitigation efforts have been disappointing, and an increasing number of cities have set their own ambitious GHG reduction targets. In some cases, whole metropolitan areas have also committed to targets. The metropolitan region of Metro Vancouver in British Columbia is one of these and has adopted a 2050 carbon-neutral target and a 2030 interim target to reduce GHG levels 45 per cent below the 2010 baseline. To achieve its targets, significant per person GHG reductions will be necessary, as Metro Vancouver is expecting its population to grow by over one million by 2050.

Many of the initiatives that cities and metropolitan areas take to reduce GHG emissions encourage or require changes to the built environment. Together, these changes are often referred to as "smart growth." The concept of smart growth was developed as an alternative to urban sprawl, which is widely recognized as having undesirable impacts. In this report, we characterize smart growth as the use of zoning to increase population, employment and amenities density in urban centres, combined with investments to improve and expand public transit and active transportation infrastructure. We provide a deep dive into the potential of this strategy to reduce end-use GHG emissions from personal transportation in the Metro Vancouver context. We also consider mobility pricing as a possible complement to changes to the built environment.

In addition to GHG emission reduction, numerous co-benefits may be associated with smart growth. These include preservation of green space, increasing the cost-effectiveness of infrastructure development and improvements to public health. To systematically evaluate all the potential co-benefits of smart growth was outside the scope of this project; however, we consider three that are of particular interest in the Metro Vancouver region: livability, social equity and affordability.

The main research questions addressed in our report are:

1. What is the potential for smart growth to reduce end-use GHG emissions from personal transportation in the Metro Vancouver context?
2. What is the potential for smart growth combined with zero-emission transit and mobility pricing to reduce GHG emissions from personal transportation in the Metro Vancouver context?
3. What are the potential co-impacts of smart growth on livability, equity and affordability?

APPROACH

We address the first two questions by undertaking a modelling exercise specific to Metro Vancouver. The land use models that are typically used for this type of analysis incorporate significant spatial detail and are therefore capable of simulating highly nuanced smart growth alternatives. However, if they track energy consumption and GHG emissions, this tends to be based on an overly simplistic representation of the vehicle technology mix. The model we use accounts for energy consumption and GHG emissions based on an explicit representation of the technology mix, realistically simulates how people select transportation modes and technologies, captures key spatial relationships necessary to consider smart growth, and offers the ability to simulate interactions with federal and provincial government policies. Because the model does not quantify livability, equity and affordability outcomes, we address the third of our research questions based on a literature review.

We developed three different modelling scenarios: a *Limited Effort* scenario, which assumes limited effort at the local level to reduce transportation GHG emissions and implement smart growth policies; a *Smart Growth and Zero-Emission Transit* scenario, which includes ambitious smart growth policies and transitioning transit to a zero-emission fleet; and a *+Mobility Pricing* scenario, which combines policies under the *Smart Growth and Zero-Emission Transit* scenario with a mobility price averaging $5 per weekday per vehicle.

To realistically assess the potential for smart growth in the Metro Vancouver context, we included in our scenarios not only the alternative local government policy paths described above, but also key policies at other levels of government that influence GHG emissions from personal transportation in the region. All three scenarios take into account a set of current and announced federal and provincial policies (senior government policies) that include the B.C. Zero Emission Vehicle mandate, the B.C. Low Carbon Fuel Standard and federal vehicle emission standards. Because we consider smart growth in the context of the specific policy mix that currently exists in B.C., we analyze overlap and complementarity between smart growth policies and senior government policies and offer conclusions and recommendations accordingly.

FINDINGS

The model simulations we conducted reveal similar end-use GHG emissions trajectories from personal transportation for each of the three scenarios, with emissions falling dramatically over time, as illustrated in Figure ES-1. Under the *Limited Effort* scenario, emissions fall from 3.9 Megatonnes carbon dioxide equivalents in 2015 to 0.4 Mt CO_2e by 2050. The *Smart Growth and Zero-emission Transit* scenario could reduce GHG emissions to 0.3 Mt CO_2e and the *+Mobility Pricing* scenario to 0.2 Mt CO_2e by 2050. The GHG differences between the three scenarios are greatest before 2045, after which the trajectories start to approach each other. While the local level policies we simulated contribute little additional GHG reductions in 2050, they lower the total amount of CO2e released to the atmosphere between 2020 and 2050 by 5.8 Mt CO_2e under the *Smart Growth and Zero-Emission Transit* scenario and by 11.5 Mt CO_2e under the *+Mobility Pricing* scenario, relative to the *Limited Effort* scenario.

Figure ES-1. Personal transportation end-use GHG emissions by scenario.

The deep emission reductions observed over time across all three scenarios are the result of significant changes in the types of vehicles driven. Figure ES-2 shows the forecast percentages of cars and light trucks on the road by vehicle type under the *Limited Effort* scenario. These shares are fairly consistent across all the scenarios we tested. Cars and trucks are divided into three categories: conventional internal combustion engine vehicles that were purchased before the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations, which we will refer to as the federal vehicle emission standards, were introduced in 2011; internal combustion vehicles that were purchased under the increasingly more stringent federal standards; and zero-emission vehicles (ZEVs). The federal vehicle emission standards require new vehicles to be less carbon intensive than the previous model year until 2025, after which the performance standards stay constant. In response to this policy, new vehicles purchased are increasingly more fuel efficient and less carbon intensive in our simulations.

Furthermore, an increasing number of people buy ZEVs (including battery electric vehicles, plug-in hybrids and hydrogen fuel cell vehicles) in our simulations, such that the vast majority of vehicles on the road are ZEVs by 2050. The main factors behind the trend toward ZEVs are the B.C. ZEV mandate and the B.C. Low Carbon Fuel Standard. However, the share of ZEVs is influenced by other policies as well, such as the B.C. carbon tax and the federal vehicle emission standards. The provincial and federal policies not only impact market shares directly but can also result in changes in the availability and upfront costs of vehicles, which can affect consumer decisions. In addition, our simulations take into account changes in consumer preferences over time, which can occur as an emerging technology becomes increasingly mainstream.

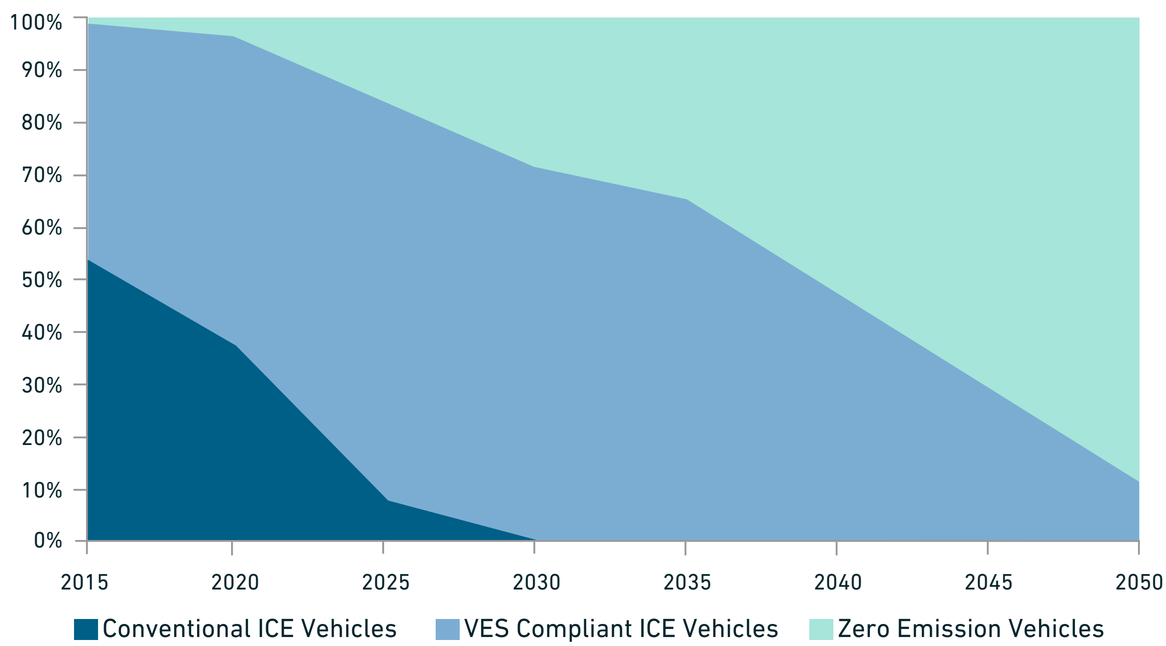


Figure ES-2. Percentage of different types of personal transportation cars and trucks on the road (ICE = Internal Combustion Engine; VES = Vehicle Emission Standard).

The GHG emissions trajectories presented in Figure ES-1 mask important differences in personal travel behaviour across the scenarios. In the *Limited Effort* scenario, vehicle kilometres travelled (VKT) by cars and light trucks increase substantially over time as Metro Vancouver's population increases (Figure ES-3). Even though total VKT increases in our simulation, GHG emissions fall as driving becomes increasingly less carbon intensive. While the increase in driving under this scenario does not prevent dramatic GHG reductions, it could lead to other negative externalities such as traffic congestion and more vehicle collisions. VKT grow more slowly in the *Smart Growth and Zero-Emission Transit* scenario. More people choose transit over driving, as an increasing number of residents are near rapid transit and overall transit accessibility in the region is improved. In the *+Mobility Pricing* scenario, VKT decline significantly after 2025 with the introduction of the mobility pricing system and then slowly increase toward 2050 with population growth (although not rising above pre-2025 levels).

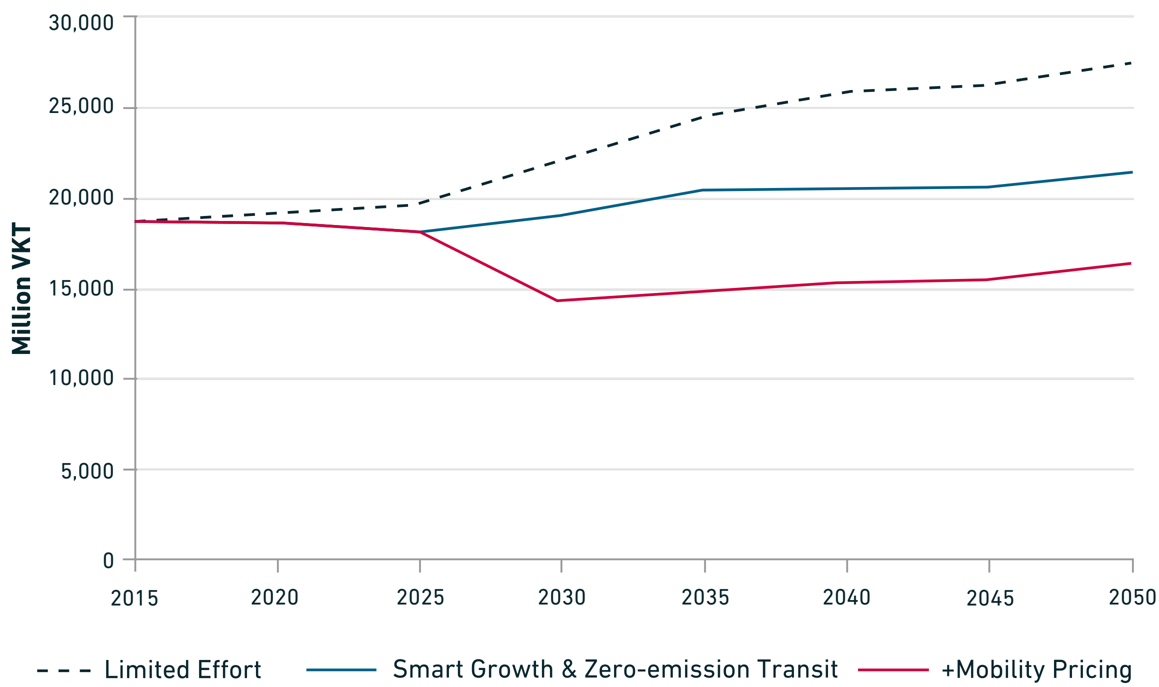


Figure ES-3. Personal transportation VKT by scenario.

Our results highlight the overlap that exists between the smart growth policies we simulated and existing senior government policies promoting energy efficiency and fuel switching. We find that ambitious smart growth land use policies offer fairly small additional GHG reductions from personal transportation in the Metro Vancouver context when combined with current and announced federal and B.C. policies. Smart growth policies can lower energy use by reducing driving. However, as cars and light trucks become more energy efficient and less carbon intensive in response to senior government policies, lowering VKT has an increasingly smaller impact on GHG emissions. There is less policy overlap between the key federal and provincial policies and investments in a zero-emission transit fleet because the senior government policies more directly target the decarbonization of cars and light trucks than transit vehicles. Policy overlap in terms of GHG emissions is not necessarily problematic if analysts are aware of it and account for it when estimating the reduction potential of a policy mix. Smart growth and other local level policies might be able to offset some worsening of GHG pollution in the case of erosion of senior government policies; for example, through a change in government.

We would expect ambitious smart growth policies to have a larger impact on GHG emissions in a different geographical context with weaker senior government GHG policies, as there would be less policy overlap. For jurisdictions with significant upstream emissions from electricity production, these upstream emissions could also result in a greater role for smart growth, in the context of increasing electrification of the personal transportation sector. However, it is important to note that policies that aim to reduce the demand for driving and/or improve energy efficiency, such as those that are part of smart growth strategies, cannot replace fuel switching policies. Ultimately, fuel switching will be required to reduce combustion GHG emissions to levels close to zero as human beings will continue to use significant amounts of energy.

The literature review we carried out suggests that smart growth policies may contribute to increased livability, social equity and affordability; however, such co-benefits cannot be automatically assumed. Although there are clear livability benefits associated with better access to amenities and transportation networks, factors such as crime, noise and litter can potentially undermine these, and not everyone prefers neighbourhoods with smart growth characteristics. Families with children in particular may not experience an improvement in livability. The relationships between smart growth policies and social equity and affordability are complex, and unintended impacts can occur if social objectives are not explicitly included in smart growth policy design and impacts monitored through measurable indicators. Smart growth may need to be combined with other policies such as housing assistance, affordable housing units and community land trusts to address equity and affordability concerns.

RECOMMENDATIONS

These recommendations are based on our analysis of the potential impact that changes to the built environment could have in Metro Vancouver, given the existing senior government policy context. As such, our focus is on the role of changes to the built environment at the regional level, and on factors that should be considered to avoid unintended consequences that may detract from the benefits. The recommendations are directed toward Metro Vancouver as a regional district, as well as Metro Vancouver municipalities and other local authorities, such as the region's transit provider, TransLink. We recommend that the provincial government maintain and strengthen the B.C. policies addressed in Recommendation 1, as these are expected to have an important role in lowering B.C. and Metro Vancouver's road transportation GHG emissions. Provincial government support would also be beneficial to many of the other recommendations that follow.

Recommendation 1: Our modelling highlighted the importance of current and announced senior government policies relative to changes to the built environment in reducing end-use GHG emissions from personal transportation in Metro Vancouver. This finding suggests that efforts on the part of local governments to preserve and enhance these senior government policies are worthwhile and perhaps even more important than the pursuit of changes to the built environment when it comes to GHG emission reductions. Specifically, we recommend the following.

- Support B.C.'s Low Carbon Fuel Standard and advocate for tougher regulation over time.
- Support the B.C. Zero Emission Vehicle mandate and campaign for an accelerated timeline of 50 per cent ZEV sales in 2025 and 100 per cent in 2030.
- Support the federal vehicle emission standards for passenger cars and light trucks.
- Support and advocate for strengthening of the federal and/or provincial carbon tax.

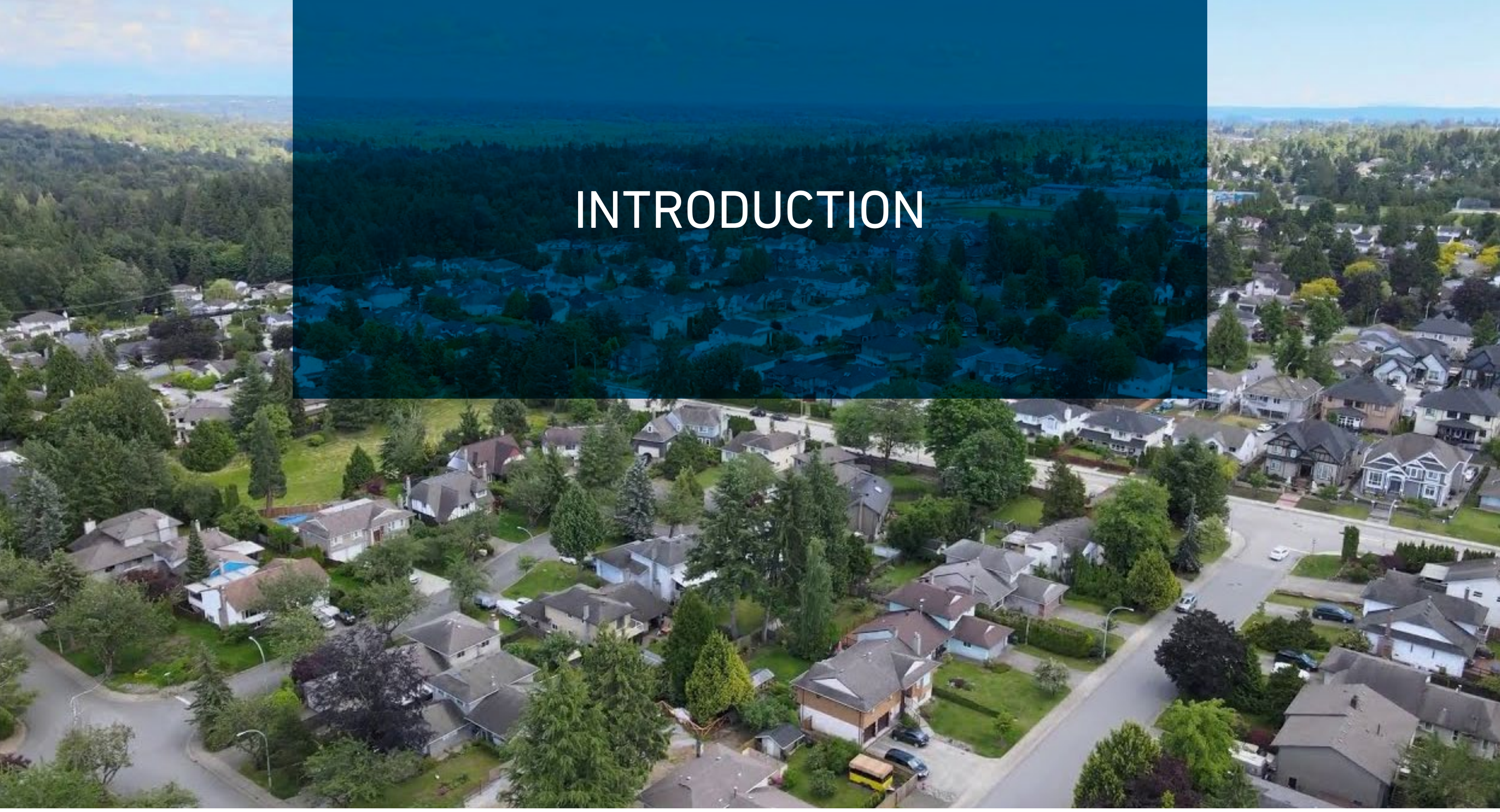
Recommendation 2: Shift the public transit fleet to zero-emission vehicles. Replacing gasoline and diesel using buses with zero-emission vehicles increases the potential for smart growth and mobility pricing policies to reduce GHG emissions as current and announced federal and provincial policies ramp up and will ultimately result in additional GHG reductions beyond what these senior government policies can achieve.

Recommendation 3: Improve co-ordination and sharing of expertise and administrative capabilities between local authorities and between these authorities and the provincial government. Efforts are already underway in terms of improving coordination between authorities, and there would be benefits to building on these.

Recommendation 4: To ensure that livability benefits of smart growth are realized, examine and address possible negative impacts, such as crime, noise and lack of cleanliness. The needs of families with children may also require further consideration to prevent a loss of families to suburban areas.

Recommendation 5: Take a careful, evidence-based approach in assessing and addressing the potential for significant negative impacts of smart growth on equity and affordability. To maintain and even advance equity and affordability, local authorities should incorporate clear social objectives into land use and infrastructure planning, identify other policies and actions that will be necessary to support these objectives, and monitor impacts.

Recommendation 6: Consider mobility pricing but address equity and affordability concerns. Future research investigating the equity and affordability impacts of different mobility pricing designs, including revenue recycling strategies, in the Metro Vancouver context could be of value.



INTRODUCTION

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The results of international and, in many cases, national greenhouse gas mitigation efforts have been disappointing, and an increasing number of cities have set their own ambitious GHG reduction targets. Examples are San Francisco, New York City, Amsterdam and Vancouver, which have all committed to GHG reductions equal to or greater than 80 per cent compared to 1990 levels (San Francisco Municipal Transportation Agency, 2020; New York City, 2020; City of Amsterdam, 2020; City of Vancouver, 2020).

Many cities are embedded in a metropolitan area, which can consist of multiple cities as well as suburban and rural areas. The exchange of people and goods between municipalities within a metropolitan area is often high and collaboration between these different entities can increase the effectiveness of land use and transportation strategies to reduce GHG emissions. In some cases, whole metropolitan areas commit to regional GHG targets. The metropolitan region of Metro Vancouver in British Columbia is one of these and has adopted a 2050 carbon neutral target and a 2030 interim target to reduce GHG levels 45 per cent below the 2010 baseline (Metro Vancouver, 2019a).

As Metro Vancouver's greatest source of GHG emissions, transportation is an obvious focal point for reductions. In the 2019 report "Shifting Gears," the David Suzuki Foundation undertook a review of the available literature to explore the role that different types of transportation policies can play in achieving Metro Vancouver's GHG reduction targets. Following Sperling and Eggert (2014), policy options were divided by type of mitigation action, referred to as "three legs of the stool": switching to low-carbon fuels, energy efficiency and travel reduction, with travel measured as vehicle kilometres travelled. Our report provides a deep dive into the potential GHG reduction contribution in the Metro Vancouver context of the policies and actions that were considered as part of the third category in the "Shifting Gears" report: changes to the built environment (including increased density, increased diversity and transit-oriented development), initiatives to increase cycling and walking, improvements to public transit, and road pricing. Our primary focus is on the first three categories, which we include as part of an overarching concept of smart growth; however, we also consider road pricing as a potential complement to this strategy.

The concept of smart growth was developed as an alternative to urban sprawl, which is widely recognized as having undesirable impacts, including the consumption of vast areas of land. In this report, we characterize smart growth as the use of zoning to increase population, employment and amenities density in urban centres, combined with investments to improve and expand the transit and active transportation infrastructure. The residents of the resulting walking- and biking-friendly mixed-use neighbourhoods with good access to transit, services and amenities are expected to have a reduced demand for driving. Cities can use zoning and rezoning bylaws to achieve greater densities in urban centres by allowing for higher densities, reducing minimum lot size, providing density-targeted development permission and establishing urban containment boundaries that restrict development outside the boundary (Ewing and Rong, 2008). Local governments can further expand transit, walking and biking infrastructure to incentivize mode shifting from driving to alternative transportation modes.

There are cases in which the terminology used in our report is defined slightly differently than in the "Shifting Gears" report. When we use the term "built environment," we refer to all human-made structures, including buildings, roads, bike paths, transit and other infrastructure. We define "land use" as management and modification of the built and natural environment. Another small difference with the "Shifting Gears" report is that we categorize smart growth policies and mobility pricing as policies that can not only reduce the demand for driving, but also improve energy efficiency. These policies disincentivize driving and at the same time incentivize transportation mode shifting to transit and active transportation. Switching from driving to transit reduces energy use as transit is generally more efficient than driving.

Some definitions of smart growth include additional transportation demand management policies, such as road pricing, parking pricing and trip-reduction programs. For the purposes of this report, we define smart growth as including only those policies that affect the built environment directly. Other transportation demand-management policies that involve pricing are categorized as mobility pricing.

In addition to GHG emission reduction, numerous co-benefits may be associated with smart growth. Compact development can limit sprawl, thereby preserving agricultural land, parks, conservational and recreational areas and other green land. Urban density can further increase the cost-effectiveness of infrastructure development (Voith and Crawford, 2004; Alexander and Tomalty, 2002; Clark, 2013); for example transit expansions or district energy systems. Another potential benefit of compact development is health benefits. Many studies find that compact urban form is correlated with higher physical activity through active transportation (Ewing and Cervero, 2010). If an increase in moderate physical activity through active transportation can be achieved, it can result in significant public health benefits (Frank and Engelke, 2001; Frank et al. 2006; Smith et al., 2017), especially if walking and biking safety are considered in network design (Stevenson et al., 2016). To systematically evaluate all the potential co-benefits of smart growth was outside the scope of this project; however, we consider three that are of particular interest in the Metro Vancouver region: livability, social equity and affordability.

The main research questions addressed in our report are:

1. What is the potential for smart growth to reduce end-use GHG emissions from personal transportation in the Metro Vancouver context?
2. What is the potential for smart growth combined with zero-emission transit and mobility pricing to reduce GHG emissions from personal transportation in the Metro Vancouver context?
3. What are the potential co-impacts of smart growth on livability, equity, and affordability?

In the "Shifting Gears" report, the David Suzuki Foundation (2019) concluded that increasing population density, diversity of land uses (for example a mix of residences, offices and commercial areas), connectivity of street networks, and destination and transit accessibility combined with investments that incentivize active transportation and transit travel — what we jointly refer to as smart growth — can play a "supportive" to "minor" role in achieving Metro Vancouver's GHG targets. It is important to note that the "Shifting Gears" report considered both personal and freight transportation and that smart growth strategies might play a slightly larger role if only considering personal transportation GHG emissions. The "Shifting Gears" report identified federal and provincial energy efficiency and fuel switching policies, namely light- and heavy-duty federal vehicle emission standards, the B.C. Low Carbon Fuel Standard, and the B.C. Zero Emission Vehicle mandate, as "major" mitigation policies that can make a significant contribution toward the 2050 GHG reduction target (DSF, 2019).

Our analysis tests the findings of "Shifting Gears" by undertaking a modelling exercise specific to Metro Vancouver. The land use models that are typically used for this type of analysis incorporate significant spatial detail and are therefore capable of simulating highly nuanced smart growth alternatives. However, if they track energy consumption and GHG emissions, this tends to be based on a simplistic representation of the vehicle technology mix that is not responsive to changes in financial costs and other factors that are known to influence how people make vehicle purchase decisions. These factors can change over time and across scenarios, affecting the market shares of vehicles that have different efficiency levels and use different energy sources, including gasoline, electricity, biofuels and hydrogen. In turn, these changes in market shares can influence energy and emissions in ways that would not be picked up by a conventional land use model. The model we use accounts for energy consumption and GHG emissions based on an explicit representation of the technology mix, realistically simulates how people select transportation modes and technologies, captures key spatial relationships necessary to consider smart growth, and offers the ability to simulate interactions with federal and provincial government policies. Because the model does not quantify livability, equity and affordability outcomes, we assess these co-impacts based on a literature review. In addition, we conducted four interviews that included 14 practitioners working in the area of the built environment and smart growth at relevant public agencies to enrich our perspective.

We developed three different modelling scenarios: a *Limited Effort* scenario, which assumes limited effort at the local level to reduce transportation GHG emissions and implement smart growth policies; a *Smart Growth and Zero-Emission Transit* scenario, which explores the reduction potential of smart growth policies and transitioning transit to a zero-emission fleet; and a *+Mobility Pricing* scenario, which combines policies under the *Smart Growth and Zero-emission Transit* scenario with a mobility price averaging $5 per weekday per vehicle. These scenarios were designed to test ambitious yet potentially feasible land use and pricing policies. For example, the smart growth scenario includes major biking and public transit network enhancements but does not include dramatic road capacity reductions that would likely not be politically viable in the region.

To realistically assess the potential for smart growth in the Metro Vancouver context, we included in our scenarios not only the alternative local government policy paths described above but also key policies at other levels of government that influence GHG emissions from personal transportation in the region. All three scenarios take into account a set of current and announced federal and provincial policies (senior government policies) that include the B.C. Zero Emission Vehicle mandate, the B.C. Low Carbon Fuel Standard and federal vehicle emission standards. Because we consider smart growth in the context of the specific policy mix that currently exists in B.C., we analyze overlap and complementarity between smart growth policies and senior government policies and offer conclusions and recommendations accordingly.

We provide more background on the Metro Vancouver and B.C. context in Section 2. We then describe our study approach in Section 3, including detailed modelling scenario descriptions. Section 4 presents and analyzes the findings of the modelling exercise and literature review. In Section 5, we summarize the study findings and discuss our conclusions, and in Section 6, we provide policy and other recommendations for Metro Vancouver and B.C.

BACKGROUND

PHOTO: Stephen, Unsplash

Metro Vancouver is B.C.'s most densely populated regional district. In 2016, 2.5 million people lived in Metro Vancouver (B.C., 2019a), which represents more than 50 per cent of B.C.'s population (B.C., 2018). The regional district consists of 21 municipalities, the Tsawwassen First Nation and Electoral Area A, which covers all other areas within the Metro Vancouver region that are not governed by a municipality or a First Nation.

The regional district guides long-term regional land use planning through Regional Growth Strategies (RGS). Most of these strategies are prepared and rely on collaboration with other local authorities. Municipalities usually control land use and have the jurisdictional power to implement zoning and rezoning policies (B.C., 2020a). In their official community plans, municipalities need to show how their land use plans align with the broader regional land use targets stated in the RGS. Metro Vancouver's transit authority, TransLink, plans and manages transit investments, collects transit fees and fuel charges on gasoline and diesel to raise funds and develops long-term transit strategies. TransLink's plans also need to be in line with long-term regional land use goals (TransLink, 2020a and b).

B.C. and the Metro Vancouver regional district have both adopted an 80 per cent GHG reduction target below 2007 levels by 2050 (B.C., 2020b; MV, 2017). B.C. further committed to a 40 per cent reduction target below 2007 levels by 2030 and a 60 per cent reduction by 2040 (B.C., 2020b). Likewise, Metro Vancouver set an interim 33 per cent GHG reduction target below 2007 levels by 2020. Recently, Metro Vancouver's GHG targets were updated to a 2030 interim target at 45 per cent below 2010 levels and a carbon neutral target for 2050 (MV, 2019a). Carbon neutrality means that all remaining GHG emissions in 2050 would have to be offset.

Metro Vancouver emitted 14.7 million megatonnes of carbon dioxide equivalents (CO2e) in 2019 (MV, 2020a), which is more than 20 per cent of B.C.'s total GHG emissions (B.C., 2020b). In 2015, 31 per cent of Metro Vancouver GHG emissions were from light-duty vehicles, followed by buildings at 26 per cent and industry at 17 per cent (MV, 2019a). To achieve its 2030 GHG target at eight Mt and the 2050 carbon neutral target, significant per person GHG reductions will be necessary, as Metro Vancouver is expecting its population to grow by over one million by 2050. This report explores the GHG reduction potential of built environment changes, zero-emission transit and mobility pricing for Metro Vancouver's largest source of GHG emissions, the personal transportation sector.

APPROACH

PHOTO: Andrew McQuillan

MODELLING METHODOLOGY

We used the CIMS-Urban model to answer our research questions regarding the potential quantitative impact of smart growth policies, zero-emission public transit infrastructure and mobility pricing on GHG emissions from the personal transportation sector in Metro Vancouver. For this type of analysis, a number of model attributes are required. We introduce four critical model characteristics below. CIMS-Urban has been designed to incorporate all of these.

First, a model used to simulate smart growth policies must take into account spatial relationships. Policies targeting land use and the built environment do not act uniformly across a city and, depending on location and design, affect only some residents' behaviour. For example, increasing the safety of bike paths in one area of the city might lead those living and working in and around this area to bike more, while it would likely have much less effect on other residents.

Given that we are interested in the expected impacts of policies rather than outcomes under a set of optimal circumstances, the second critical model attribute is a realistic characterization of human behaviour in estimating mode shares. Rather than simplistically representing decision-making as a function of financial cost and, in the context of travel, a function of travel distance or time, a model must also take into account non-financial considerations related to risk perception, symbolic values and differences across individuals. For example, convenience, comfort and perceived status are not equivalent between driving a car and taking the bus, and these factors influence mode selection for some people.

A model must track the energy consumed by technologies like cars, light trucks and public transit vehicles and translate this energy consumption into GHG emissions. To ensure that the simulation results are representative of potential outcomes in the real world, the third criterion is that a model track energy and emissions based on a representation of the technology mix that is responsive to both financial and non-financial costs. When making vehicle purchase decisions, consumers have options that vary in terms of both energy efficiency and energy type (gasoline, electricity, biofuel, hydrogen, etc.). In selecting a vehicle, they are expected to consider financial costs such as vehicle costs and fuel costs; however, people also have non-financial preferences for attributes such as power, range, fuel availability and environmental performance that vary among vehicle types. These financial and non-financial costs can change over time and across scenarios, affecting the market shares of different vehicle types. In turn, these changes in market shares can influence energy and emissions.

Fourth, it is necessary that a model be capable of simulating the multi-faceted interactions between local, provincial or state and national policies. Two policies can be additive, overlapping, redundant or more than the sum of two. To gain a better understanding of the GHG reduction potential of urban policies, using a model that accounts for these interactions is critical. Some important senior government policy options, such as zero-emission vehicle standards, are targeted at specific technologies. Therefore, to meet this criterion, a model should explicitly represent energy-using technologies.

Energy-economy models were designed to track energy consumption and GHG emissions; however, they generally lack a spatial component. Many land use models, on the other hand, are spatially detailed and account for travel time; however, if they track energy and GHG emissions, this does not tend to be based on a representation of the technology mix that is responsive to financial and non-financial costs and the changes in these costs that may occur as a result of government policy or other factors.

CIMS-Urban, being an energy-economy model linked to a GIS land use model, brings together the strengths of both model types (Jaccard et al., 2019). The model accounts for energy consumption and GHG emissions based on explicit simulation of the technology mix, incorporates evidence-based behavioural parameters representing the non-financial costs of alternative travel modes and personal transportation technologies, captures spatial relationships and allows the user to simulate the combined effect of multi-level government policies. The land use and infrastructure model keeps track of changes such as increased density and transit expansions. These changes in turn influence the non-financial costs used by the energy-economy model to calculate transportation mode share.

Non-financial costs associated with a transportation mode vary across a city or region and can be influenced by the built environment. For example, the non-financial costs of taking transit are expected to be lower in areas close to frequently running transit lines than in those with poor transit service. CIMS-Urban can capture this relationship, while also accounting for the fact that transportation mode non-financial costs are also influenced by other variables such as topography, weather and symbolic values — those related to social status, for example — that cannot be altered through land use changes.

In CIMS-Urban, the built environment influences non-financial costs by altering the quality of transportation networks. For the analysis described in this report, network quality indices were calculated by mode for each of 1,556 traffic analysis zones in mainland Metro Vancouver. The network quality indices for walking, cycling and transit in the model describe how easily residents can access destinations such as commercial districts by these travel modes. The cycling network quality index also accounts for differences in bike route designs by assigning a score to each bike path segment. The bike path scores are based on the following ranking from highest to lowest: off-street path, neighbourhood shared lane, major street painted bike lane, paved shoulder and major street shared lane without a designated bike path. In addition to access, the transit network quality index considers transit frequency and differentiates between rapid transit (rapid bus lines, Skytrain, SeaBus, and the West Coast Express) and regular transit. The network quality index for driving follows a different logic from that of walking, cycling and transit. It is based on road capacity and traffic levels rather than accessibility.

Both the energy-economy model (CIMS) and the GIS land use model were developed within Simon Fraser University's Energy and Materials Research Group (EMRG) in the School of Resource and Environmental Management. The GIS land use model was developed by Zuehlke (2017) and further advanced by Budd (2019). CIMS-Urban was originally applied to the single city context. Förg (2020) expanded it to the multi-city level and updated some of the methodology to be able to account for inter-city commuting streams. An in-depth description of the CIMS-Urban methodology, as well as full details regarding inputs and assumptions for the Metro Vancouver version used here, may be found in Förg (2020).

MODELLING SCENARIOS

We simulated three scenarios to the year 2050 with the same current and announced provincial and federal policies, but different local level policy assumptions. In the first scenario, called *Limited Effort*, we assumed that there would be little effort by local authorities in Metro Vancouver to mitigate personal transportation GHG emissions. In the second scenario, *Smart Growth and Zero-Emission Transit*, we assumed that local authorities would jointly implement ambitious land use policies following smart growth principles to reduce personal transportation GHG emissions. In addition, we assumed that TransLink would transition its transit fleet to zero-emission vehicles. In the last scenario, *+Mobility Pricing*, we assumed that smart growth policies and a transition to zero-emission transit would be implemented along with mobility pricing averaging $5 per weekday per vehicle after 2025.

Senior Government Policies Included in All Scenarios

All three scenarios include the same current and announced provincial and federal policies. For detailed descriptions of how these policies were modeled, see Förg (2020).

- The B.C. carbon tax rising to $50 in 2021 (B.C., 2020c).
- B.C.'s Clean Energy Act, which mandates that at least 93 per cent of B.C.'s electricity is generated from low-carbon resources (*Clean Energy Act*, SBC 2010, c. 22). The renewable generation share is currently even higher at 98 per cent (Canada Energy Regulator [CER], 2020).
- The federal Passenger Automobile and Light Truck Greenhouse Gas Emissions Regulations, which require new vehicles to improve CO_2e emission performance relative to the previous model year every year from 2011 to 2025, after which the performance standard remains constant (CER, 2018; Government of Canada, 2018). In our modelling, we assume these standards function primarily by improving the energy efficiency of new vehicles. We will refer to this policy as the federal vehicle emission standards.
- The B.C. Low Carbon Fuel Standard (LCFS) rising to a 20 per cent carbon intensity reduction requirement for transportation fuels relative to 2010 in 2030 (*Greenhouse Gas Reduction [Renewable and Low Carbon Fuel Requirements] Act*, SBC 2008, c. 16; B.C. Reg. 394/2008).
- The B.C. Zero Emission Vehicle (ZEV) mandate, which requires an annual minimum of light-duty vehicle sales to be zero-emission vehicles — electric vehicles, plug-in hybrids and hydrogen vehicles — starting at 10 per cent in 2025 and rising to 30 per cent by 2030 and 100 per cent by 2040 (B.C., 2019b).
- A $6,000 plug-in electric light-duty vehicle subsidy, which is roughly the average amount receivable for plug-in hybrids and battery electric vehicles through combined federal and provincial incentives (B.C., 2020d). We assumed that this subsidy would be available until 2040 after which all newly sold light-duty vehicles are required to be zero-emission vehicles.

Limited Effort Scenario

Under this scenario, we assumed that there would be limited effort by Metro Vancouver local authorities to reduce transportation GHG emissions and guide urban development toward more complete and compact communities. General spatial population patterns and growth trends would remain constant over time, with population growing in both urban centres and in low-density suburban and rural areas. Furthermore, we assumed that the service quality and accessibility of each personal transportation mode would stay essentially unchanged, at least in relative terms. We represented this assumption in the model by holding constant the average non-financial costs — such as those associated with inconvenience and safety concerns — for walking, biking, transit and driving.

Smart Growth and Zero-Emission Transit Scenario

The *Smart Growth and Zero-Emission Transit* scenario is based on the main built environment goals in the Regional Growth Strategy 2040. The RGS is a regional long-term strategy for sustainable land use and was developed by the Metro Vancouver regional district in collaboration with other local authorities, such as municipalities, the Tsawwassen First Nation and Metro Vancouver's transit provider, TransLink. The RGS 2040 seeks to avoid sprawl and create denser and more complete urban centres and Frequent Transit Development Areas (FTDAs) that promote walking, biking and transit use, provide good access to services and amenities, and reduce trip distances (MV, 2017). Figure 1 shows the priority areas for concentrated growth as identified in the RGS. Urban centres are depicted in red and FTDAs in blue.

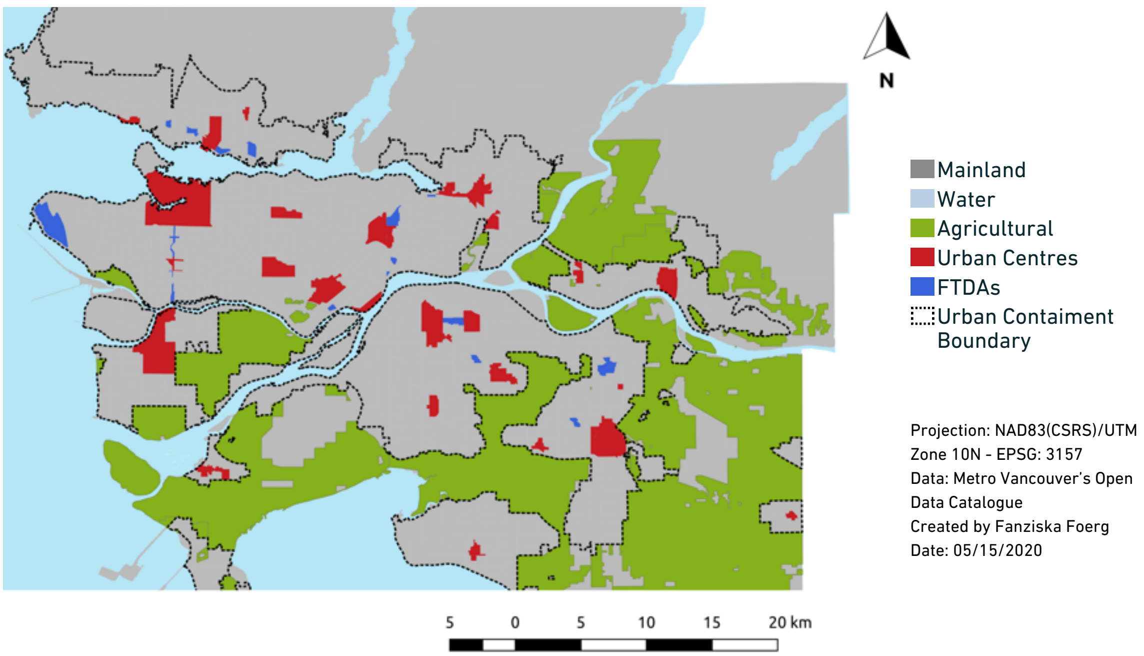

Figure 1: Urban containment boundary, urban centres, and FTDAs (Förg, 2020).

In contrast to the *Limited Effort* scenario, we assumed that local authorities would go to great lengths to realize complete and compact communities in accordance with the RGS goals. In this scenario, aggressive zoning policies would direct almost 85 per cent of new population and employment and the majority of new commercial areas to urban centres and FTDAs to increase density in these areas, shorten the distances between people's homes and jobs, as well as other destinations such as grocery stores and coffee shops, and create more complete mixed-use centres. All new growth is assumed to be located within the urban containment boundaries (dashed black line in Figure 1) and outside the provincial Agricultural Land Reserve (green area) to preserve green space and protect agricultural land. These assumptions exceed Metro Vancouver's current target to locate 68 per cent of dwelling unit growth and 77 per cent of job growth in urban centres and FTDAs (MV, 2020b and c). Between 2006 and 2016, 40 per cent of job growth and 43 per cent of dwelling unit growth occurred in urban centres and FTDAs (ibid). Our assumptions result in more than half of all jobs and 40 per cent of total population in mainland Metro Vancouver (excluding Bowen Island) being located within urban centres and FTDAs by 2050 (Table 1).

Table 1: Percentage of employment and population in urban centres and FTDAs under the Smart Growth and Zero-Emission Transit scenario.[i]

	2015	2030	2050
Employment in urban centres and FTDAs	44%	48%	51%
Population in urban centres and FTDAs	26%	33%	40%

We further assumed that major biking and public transit network enhancements would be undertaken. The biking network would be expanded and many of the existing shared bike lanes would be replaced with separated lanes. The rapid transit network would be expanded beyond what is outlined in TransLink's 10-year investment plan and the 30-year regional transit network concept from *Transport 2040* (TransLink, 2013b and 2018). In our analysis, the rapid bus network would be expanded significantly and the frequency of all other buses, which we consider as regular transit, would be increased at a rate 50 per cent faster than population growth. Figure 2 shows assumed rapid transit expansions by the year 2050. We considered rapid trains, rapid buses such as the new R-line buses, the SeaBus, and the West Coast Express as rapid transit, based on frequency and right-of-way characteristics.

i These numbers are based on a population and employment forecast received from the Metro Vancouver regional district but altered to fit our assumption that 85 per cent of new growth would occur in urban centres and FTDAs.

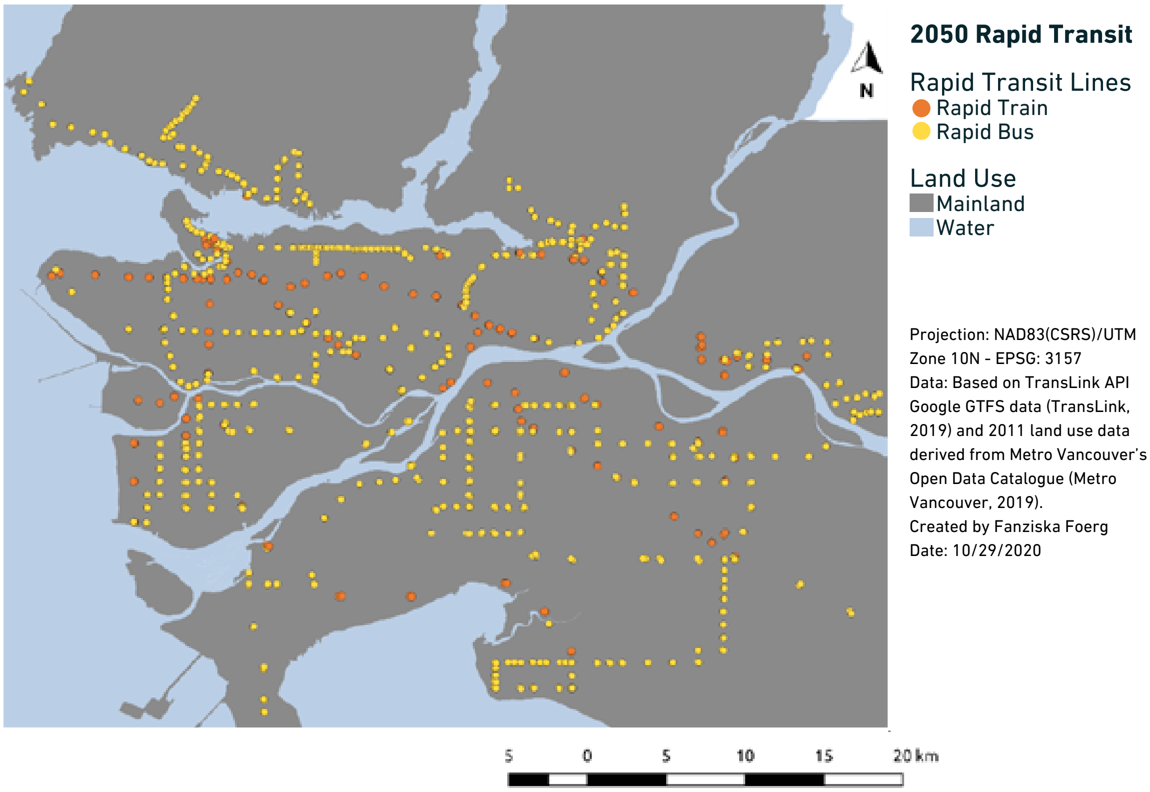

Figure 2: Assumed rapid transit expansions by 2050.

In addition to these smart growth policies, we assumed that TransLink would transition its transit fleet to zero-emission vehicles, which include electricity and hydrogen-powered vehicles in our simulation. Under this scenario, TransLink would increasingly add zero-emission vehicles to the fleet and would only purchase zero-emission vehicles after 2030. This assumption is in line with recently released TransLink goals (MJB and A, 2020).

Mobility Pricing Scenario

In this scenario, we added a mobility price to the smart growth land use and transit fuel switching policies from the *Smart Growth and Zero-Emission Transit* scenario. We assumed that, after 2025, a form of mobility pricing would be charged across Metro Vancouver during weekdays, resulting in an average cost of $5 per weekday per vehicle, which is equivalent to an annual cost of $1,300 per vehicle (assuming 260 weekdays per year). In our simulation, this mobility price is constant across the different spatial units and over time, apart from being adjusted for inflation. We assumed that our simulated mobility pricing system would result in the same additional annual costs for all Metro Vancouver drivers. In reality, some drivers would pay more than others depending on the type of mobility pricing system in place and where they live and travel.

The most obvious interpretation of the mobility pricing scenario is as representing a road pricing policy; however, it could equally represent any policy that increases the financial or non-financial cost per vehicle by the amount indicated. This could occur, for example, through parking pricing or changes to insurance pricing (financial costs) or reduced parking supply (a non-financial cost related to inconvenience). For a review of the effectiveness, cost-effectiveness, equity impacts and political acceptability of different types of mobility pricing please refer to the 2020 "Pricing It Right for Climate" David Suzuki Foundation report.

LITERATURE REVIEW

The primary objective of our literature review is to explore how smart growth–oriented land use change might affect affordability, equity and livability. We used search engines such as Google Scholar, Web of Science and Microsoft Academic to search for keywords like "equity," "affordability," "livability," "density" and "accessibility," mostly in combination with "smart growth," "transit-oriented development," "compact development," "built environment" and "urban form." We further used articles, books and reports found through our literature search to identify new sources.

We only included literature that we identified as sufficiently rigorous, judged by criteria such as whether the source is evidence-based and whether it includes an objective discussion and appropriate citations. While journal articles and books were prioritized, we also considered grey literature if the source fulfilled the above criteria. We prioritized literature with greatest relevance for our research topic, applicability to the Metro Vancouver and B.C. context and more recent publication dates (as available). We primarily focused on the North American context but also included some insightful European studies. In addition, we put greater weight on systematic reviews than single case studies as the outcomes of the latter can be mixed and context-dependent. Systematic reviews allow the authors to consider a broader evidence base and gain a better overview.

FINDINGS

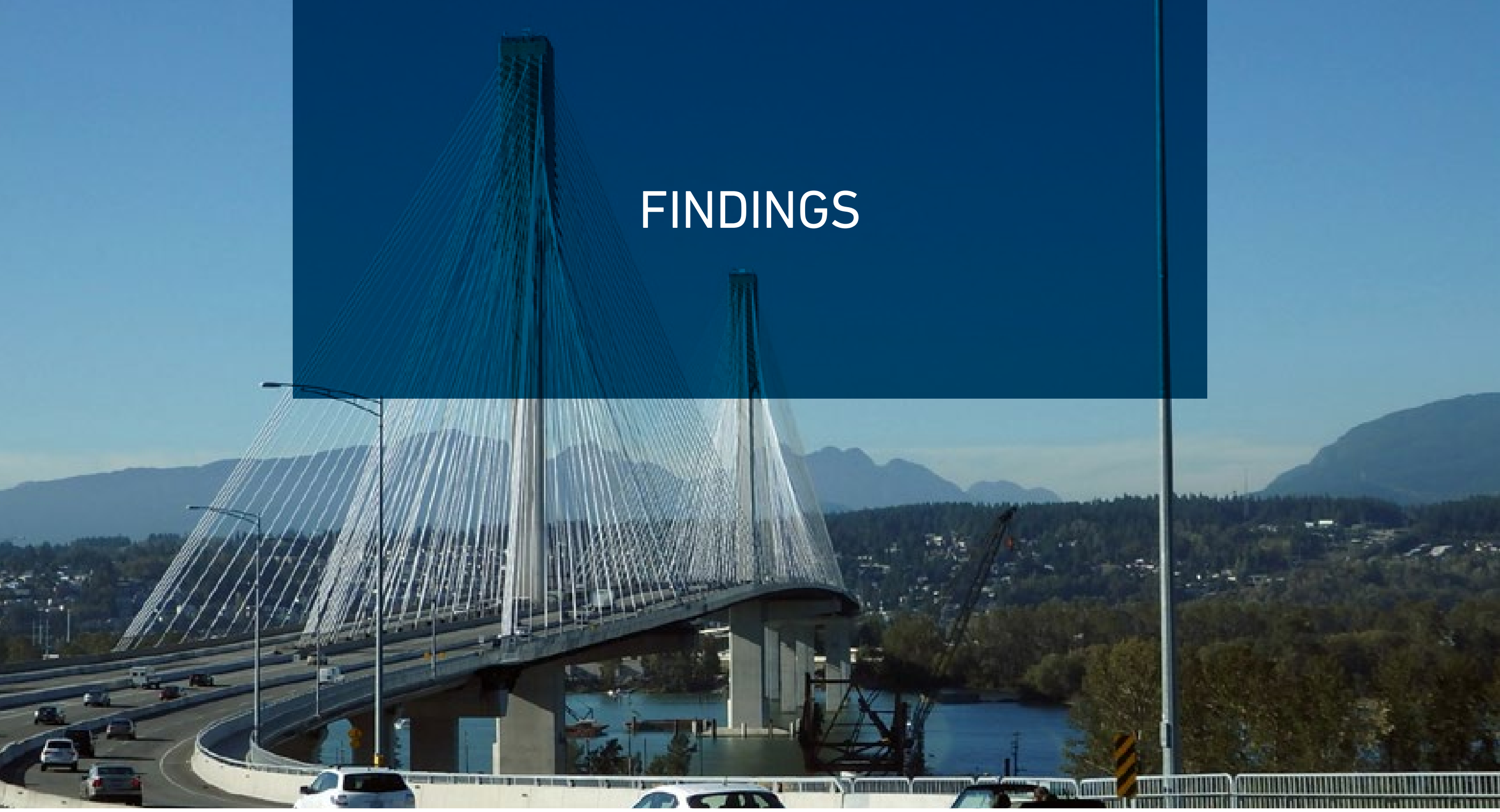

PHOTO: Dgarte, CC0 1.0

MODELLING RESULTS

Here we present and compare the modelling results for Metro Vancouver in terms of GHG emissions, energy consumption and vehicle kilometres travelled across the three simulated scenarios described in Subsection 3.2: ***Limited Effort***, which assumes little effort at the local level to reduce GHG emissions; ***Smart Growth and Zero-Emission Transit***, which includes ambitious smart growth policies and transitioning transit to a zero-emission fleet; and ***+Mobility Pricing***, which adds mobility pricing to the previous scenario.

In the ***Limited Effort*** scenario, vehicle kilometres travelled increase substantially over time as Metro Vancouver's population increases, while VKT grow more slowly under the ***Smart Growth and Zero-Emission Transit*** scenario (Figure 3). In the ***+Mobility Pricing*** scenario, VKT decline significantly after the introduction of the mobility pricing system and then slowly increase toward 2050 with population growth (not rising above pre-2025 levels).

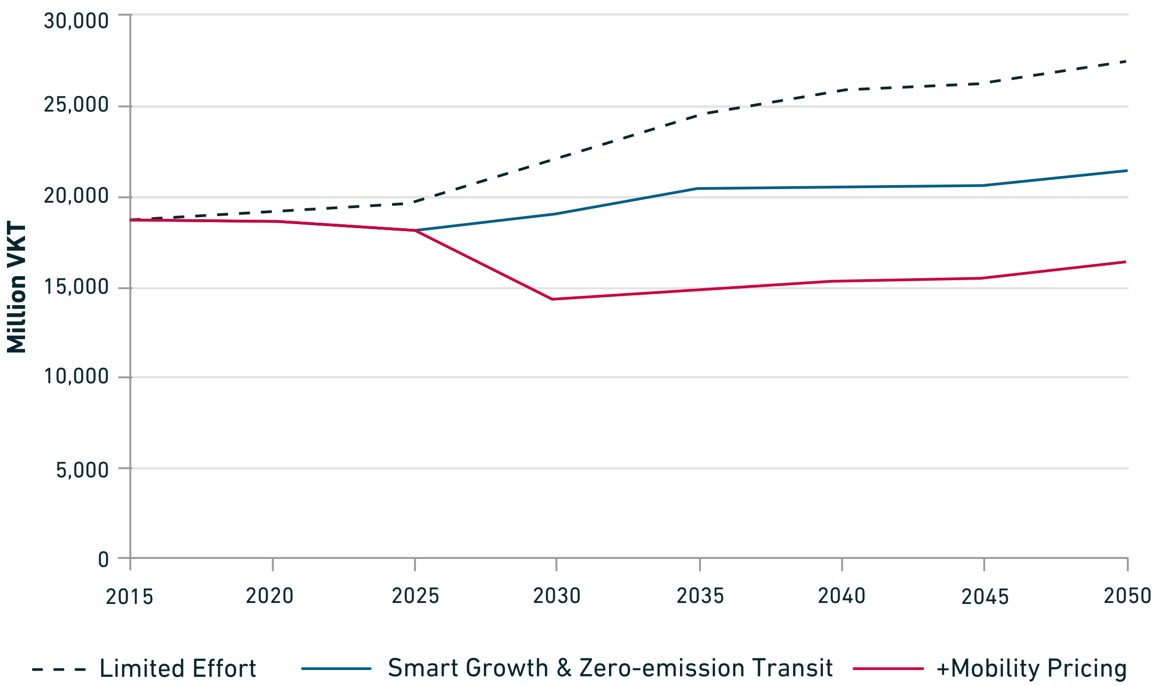

Figure 3. Personal transportation VKT by scenario.

While the trends in vehicle kilometres travelled are quite different between the three scenarios, personal transportation GHG emissions fall dramatically over time across all three, as illustrated in Figure 4. Although the CIMS model system can be used to assess upstream emissions from energy production, only emissions from end-use fossil fuel consumption within Metro Vancouver are reported here (electricity consumed in the region is almost exclusively from near-zero-emission hydropower). Under the *Limited Effort* scenario, GHG emissions fall from 3.9 megatonnes carbon dioxide equivalents in 2015 to 0.4 Mt CO_2e by 2050. The *Smart Growth and Zero-Emission Transit* scenario could reduce GHG emissions to 0.3 Mt CO_2e and the *+Mobility Pricing* scenario to 0.2 Mt CO_2e by 2050. The GHG differences between the three scenarios are greatest before 2045 after which the trajectories start to approach each other. While the local level policies contribute little additional GHG reductions in 2050, they lower the total amount of CO2e released to the atmosphere between 2020 and 2050 by 5.8 Mt CO_2e under the *Smart Growth and Zero-Emission Transit* scenario and by 11.5 Mt CO_2e under the *+Mobility Pricing* scenario, relative to the *Limited Effort* scenario.

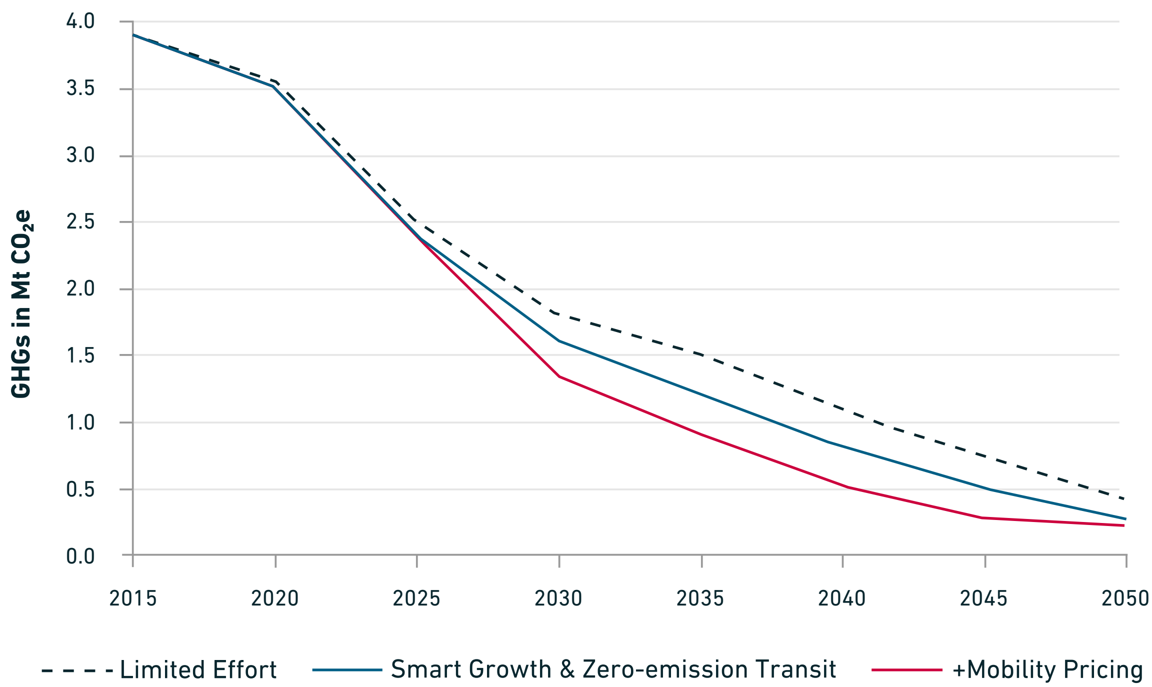

Figure 4. Personal transportation end-use GHG emissions by scenario.

These observations lead to several questions: What causes GHG emission reductions under the *Limited Effort* scenario? What are the main drivers of the additional reductions under the *Smart Growth and Zero-Emission Transit* and *+Mobility Pricing* scenarios? And why are the three vehicle kilometres travelled trajectories so different but the three GHG emission trajectories so close throughout — even approaching each other toward 2050? The subsections below investigate and discuss these questions.

Limited Effort Scenario

Figure 5 shows personal transportation GHG emissions, as well as personal travel demand by transportation mode for the *Limited Effort* scenario. Travel demand is measured in person kilometres travelled (PKT). Total demand is an exogenous model input, while transportation mode split is simulated by the model. We calibrated 2015 travel demand and mode shares until three conditions were met: 1) GHG emissions in that year aligned with an estimate for personal transportation based on data provided by Metro Vancouver, 2) energy use was similar to light-duty vehicle energy use in the 2012 Community Energy & Emissions Inventory (CEEI) data (B.C., 2016), and 3) mode share by PKT was equal to 2011 Trip Diary Data (TransLink, 2013a). We assumed that per capita travel demand as estimated for 2015 would stay constant over time. This means that Metro Vancouver travel demand grows linearly with population in our simulation.

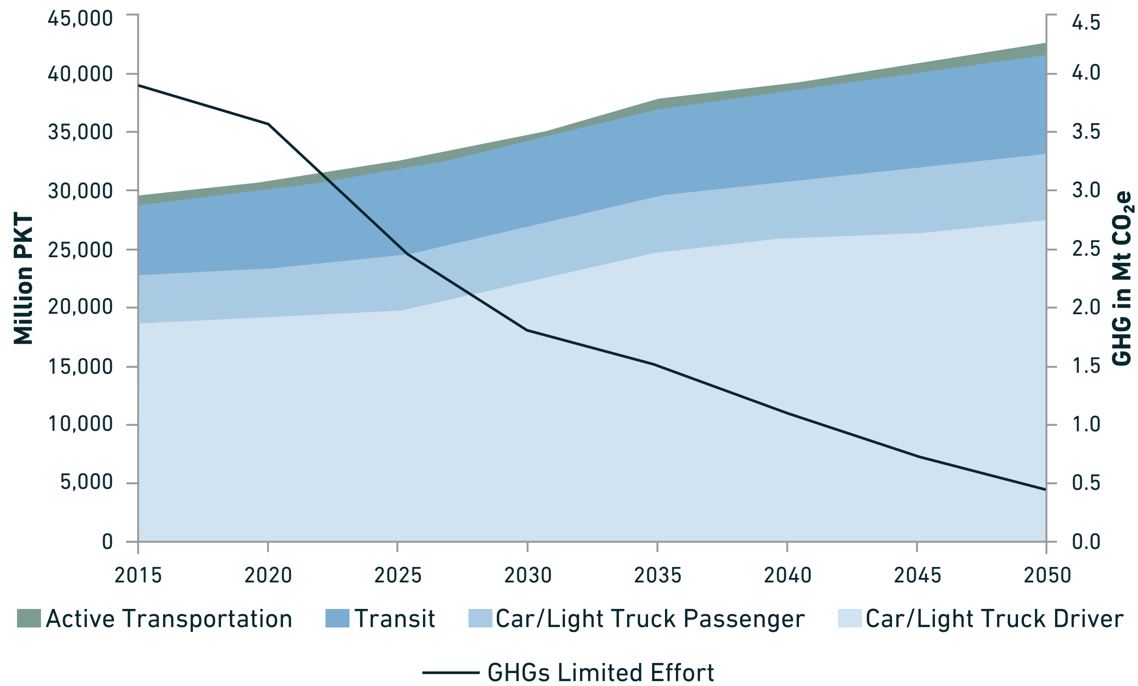

Figure 5. Limited Effort scenario: Personal travel demand by transportation mode in PKT and end-use GHG emissions.

The mode shares in Figure 5 combine PKT for walking and biking into one category as active transportation. Transit PKT include travel by trains, which run on electricity in Metro Vancouver, fossil fuel–using buses and zero-emission buses, which include hydrogen, electric trolley, battery electric and plug-in hybrid electric buses in our simulations. Car and light truck PKT are divided between passengers and drivers. PKT by drivers translates directly into vehicle kilometres travelled. In the *Limited Effort* scenario, transportation mode shares remain fairly constant as percentages over time. Car and light truck driver PKT combined with passenger PKT fluctuates at around 77 per cent of total PKT. Total driver PKT (equal to VKT), rise as a result of an increasing population.

There are significant changes over time in the types of vehicles driven. Figure 6 shows the forecast percentages of cars and light trucks on the road by vehicle type under the *Limited Effort* scenario. These shares are fairly consistent across all of the scenarios we tested. Cars and trucks are divided into three categories: conventional internal combustion engine vehicles that were purchased before the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations, which we will refer to as the federal vehicle emission standards, were introduced in 2011; internal combustion vehicles that were purchased under the increasingly more stringent federal standards, and zero-emission vehicles. The federal vehicle emission standards require new vehicles to be less carbon-intensive than the previous model year until 2025, after which the performance standards stay constant (Government of Canada, 2018). In response to this policy, new vehicles purchased are increasingly more fuel-efficient and less carbon-intensive in our simulations (this is consistent with the Canada Energy Regulator [CER], 2018). Over time, more fuel-efficient vehicles replace less efficient ones as these reach the end of their life.

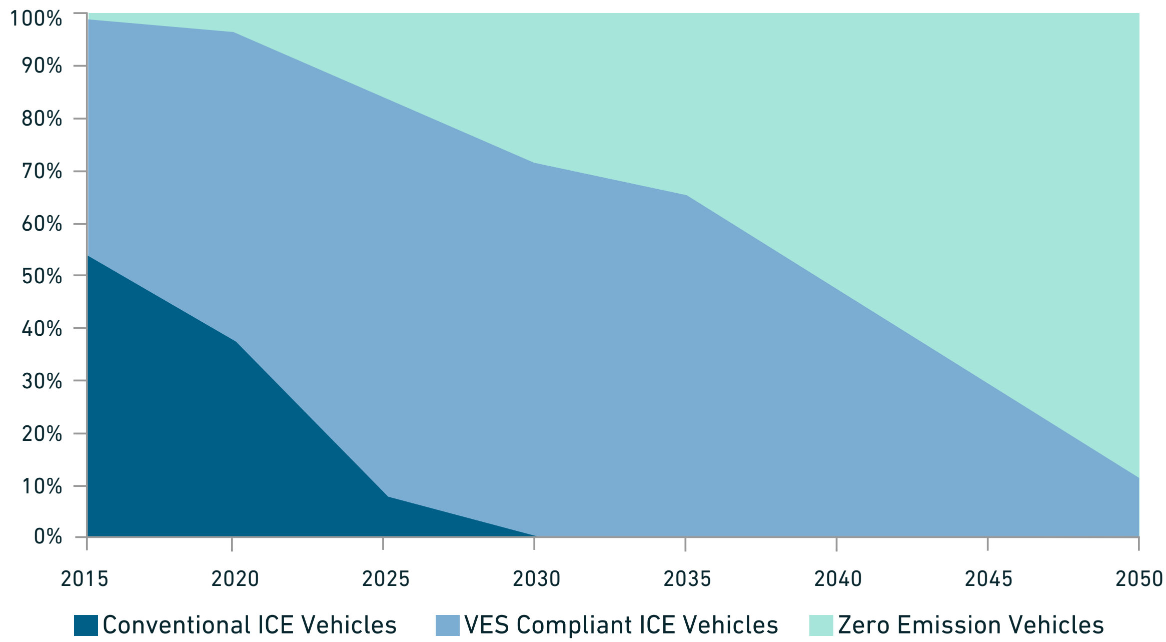

Figure 6. Percentage of different types of personal transportation cars and trucks on the road (ICE = Internal Combustion Engine; VES = Vehicle Emission Standard).

Furthermore, an increasing number of people buy ZEVs in our simulations, such that the vast majority of vehicles on the road are ZEVs by 2050. Our ZEV category is aligned with that of the B.C. government and includes battery electric vehicles, plug-in hybrids and hydrogen fuel cell vehicles.[ii] All vehicles in this category can be operated without directly emitting GHGs.[iii] The main factors behind the trend toward ZEVs are the B.C. ZEV mandate and the B.C. Low Carbon Fuel Standard. However, the share of ZEVs is influenced by other policies as well, such as the B.C. carbon tax and the federal vehicle emission standards. The B.C. ZEV mandate requires B.C. auto suppliers to sell an increasing minimum percentage of light-duty ZEVs, starting at 10 per cent in 2025, rising to 30 per cent by 2030 and to 100 per cent by 2040 (B.C., 2019b). The B.C. Low Carbon Fuel Standard mandates transportation fuels to be 10 per cent less carbon-intensive than in 2010 by 2020, with the standard rising to 20 per cent by 2030 (*Greenhouse Gas Reduction [Renewable and Low Carbon Fuel Requirements] Act*, SBC 2008, c. 16; B.C. Reg.

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ii It has been hypothesized that electric vehicle users drive more because their operating costs are lower, and perhaps even because they have less "driver's guilt." However, recent empirical evidence from California suggests that electric vehicles travel substantially less than the U.S. fleet average (Burlig et al., 2021), We did not assume any difference in VKT between electric vehicles and conventional vehicles in this analysis.

iii To be truly GHG emission free, upstream GHG emissions in the production of fuels used in zero-emission vehicles also need to be close to zero. In B.C., the upstream GHG intensity of electricity is low, as 98 per cent of electricity is produced from renewable sources (Canada Energy Regulator [CER], 2020).

394/2008). This can be achieved through increasing the use of electricity or hydrogen in vehicles, reducing GHG emissions in the production processes of fuels and increasing the use of biofuels, which can be blended with gasoline and diesel. The provincial and federal policies not only impact market shares directly but can also result in changes in the availability and upfront costs of vehicles, which can affect consumer decisions. In addition, our simulations take into account changes in consumer preferences over time, which can occur as an emerging technology becomes increasingly mainstream.

Senior government policies are the main reason for the GHG reductions in personal transportation under the *Limited Effort* scenario. Even though total VKT increase in our simulation, GHG emissions fall as driving becomes increasingly less carbon-intensive. While the increase in driving under this scenario does not prevent dramatic GHG reductions, it could lead to other negative externalities such as traffic congestion and more vehicle collisions.

Smart Growth and Zero-Emission Transit

Under this scenario, we assumed that local authorities would adopt smart growth land use policies and transition transit to a zero-emission vehicle fleet. Figure 7 shows transportation mode choice under the *Smart Growth and Zero-Emission Transit* scenario. It also includes GHG emissions for this scenario and compares them to the *Limited Effort* scenario and an additional sub-scenario that only includes smart growth policies and senior government policies (no transition to zero-emission transit).

In response to our simulated smart growth policies, VKT grow more slowly in the Smart Growth and Zero-Emission Transit scenario than under the Limited Effort scenario (Figure 7). More people choose transit over driving, as an increasing number of residents are near rapid transit and overall transit accessibility in the region is improved. The transit PKT share increases from 21 per cent in 2015 to 37 per cent in 2050. The active transportation mode share also rises in response to the creation of more walking- and biking-friendly neighbourhoods; however, the change is less than one percentage point. Part of the reason for the fairly small change in active transportation is that walking and biking are associated with significant non-financial costs due to the requirement of physical activity, difficulty in carrying goods and exposure to weather. These non-financial costs cannot easily be offset by increasing the walking- and biking-friendliness of an area.

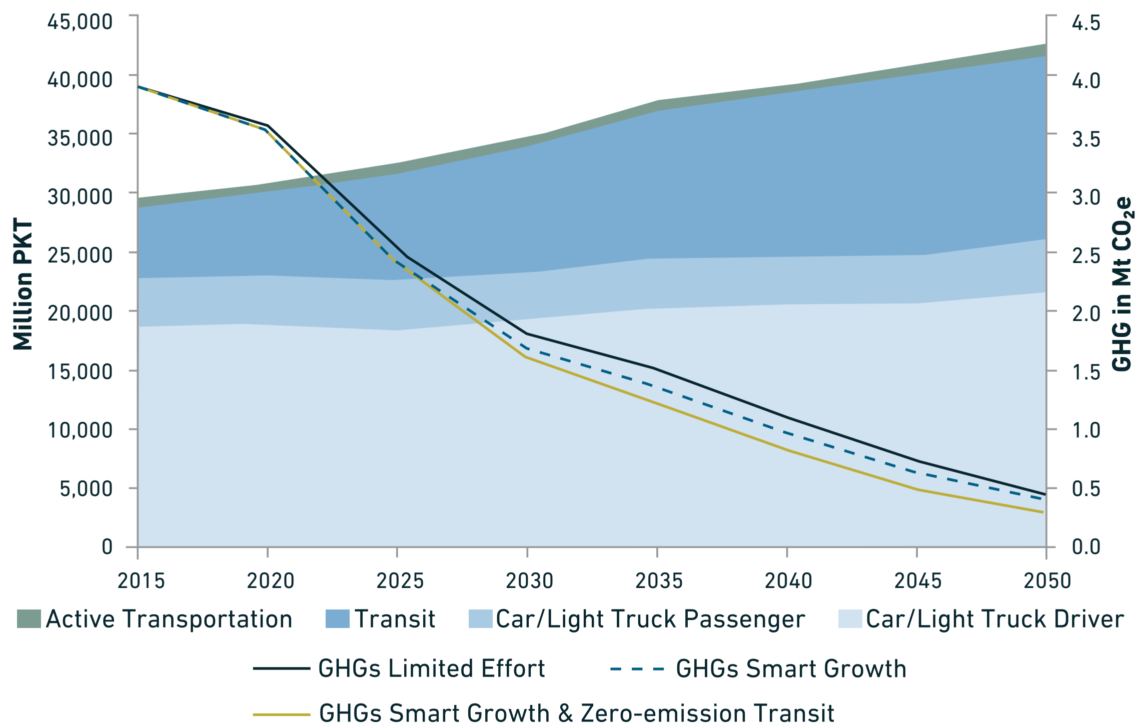

Figure 7. *Smart Growth and Zero-Emission Transit* scenario: Personal travel demand by transportation mode in PKT and end-use GHG emissions.

In our simulations, smart growth policies reduce GHG emissions somewhat compared to the *Limited Effort* scenario, as more people choose transit over driving. Toward 2050, however, these additional reductions decline, as can be seen by the blue line — which represents a sub-scenario with smart growth policies only (no transitioning transit to a zero-emission fleet) — approaching the *Limited Effort* GHG trajectory in Figure 7. The reason for this trend is overlap between the smart growth policies and senior government policies promoting energy efficiency and fuel switching. Smart growth policies can lower energy use by reducing driving. However, as cars and light trucks become more energy-efficient and less carbon-intensive in response to senior government policies, lowering VKT has an increasingly smaller impact on GHG emissions.

Additional GHG reductions are achieved when a transition to zero-emission transit vehicles is added to our simulated smart growth policies and senior government policies. This is shown as the difference between the blue and the black line in Figure 7. As long as driving produces GHG emissions, switching from driving to transit can reduce emissions by lowering energy consumption, as transit is usually more energy efficient. If transit is operated without any GHG emissions, then the switch to transit can result in even greater reductions. The GHG difference between the smart growth sub-scenario and the *Smart Growth and Zero-Emission Transit* scenario is the result of fossil fuel–using buses being replaced by zero-emission buses and trains in the *Smart Growth and Zero-Emission Transit* scenario. The overall GHG reduction effect of switching from driving to zero-emission transit declines as driving becomes less carbon-intensive. Even so, the transition to a zero-emission transit fleet in the *Smart Growth and Zero-Emission Transit* scenario results in lower GHG emissions in 2050 compared to the *Limited Effort* scenario.

It is important to note that we assumed no changes in per capita travel demand in our modelling and that total travel demand under the *Smart Growth and Zero-Emission Transit* scenario is therefore the same as under the *Limited Effort* scenario. While total travel demand is an exogenous assumption in our analysis, the model simulates how PKT are distributed across the various transportation modes and how this is impacted by land use policies, the provision of transportation infrastructure and other policies at the local and senior government levels.

While there is evidence that vehicle kilometres travelled are negatively correlated with compact development features, the relationship between the built environment and total travel demand in person kilometres travelled is more uncertain. This uncertainty can be seen in the varied outcomes of studies that try to measure the relationship between the built environment and travel variables as elasticities[iv] (for example, see the varied outcomes of studies included in the meta-analysis by Ewing and Cervero, 2010). According to Handy (2017), "Studies rarely use the same land use measures as previous ones, their travel data come from different sources, each applying its own survey method, and they employ varied statistical techniques from the simple to the sophisticated" (p. 26). A theoretical and empirical literature review with a German and wider European perspective even found that, while the built environment and travel demand are interrelated, transportation growth might be more strongly related to other societal factors such as economic growth (Holz-Rau and Scheiner, 2019). They concluded that the causal relationship between land use and travel demand is uncertain due to limited robust evidence and that the impact of land use change on travel demand should not be overestimated.

Due to uncertainty surrounding our assumption that per capita travel demand would stay constant over time under all scenarios, we conducted a sensitivity test for the *Smart Growth and Zero-Emission Transit* scenario. In this model run, we assumed that the Metro Vancouver average per capita travel demand would drop at the same rate as distance from homes to commercial and institutional districts declines in response to the smart growth policies. This is likely an optimistic assumption, as the literature generally finds an inelastic relationship between built environment variables (here distance to the nearest commercial areas) and travel behaviour variables (here PKT per capita) (Ewing and Cervero, 2010; Stevens, 2017). An inelastic relationship means that a one per cent change in the built environment variable would result in a smaller than one per cent change in the travel behaviour variable. Under this assumption, 2050 Metro Vancouver average per capita PKT would be 16 per cent below the 2015 level. The sensitivity test indicated that GHG emissions would be a bit lower under this assumption, with a maximum difference relative to the original *Smart Growth and Zero-Emission Transit* assumptions trajectory of 0.18 Mt CO_2e in 2035. After 2035, this difference

iv Elasticities describe by what percentage a dependent variable, such as transit trips, changes in response to the percent change of an independent variable, such as population density.

would decline and by 2050 GHG emissions under the alternative assumption would only be 0.05 Mt CO_2e lower. This, again, is due to the overlap of smart growth policies with efficiency improvements and fuel switching due to senior government policies. Reducing energy demand by lowering VKT or PKT has less of a GHG effect if energy use for travel is already being reduced through energy efficiency and is also increasingly less carbon-intensive.

Overall, we find that ambitious smart growth land use policies offer fairly small additional GHG reductions in the Metro Vancouver context when combined with current and announced federal and B.C. policies. Our findings are in line with the "Shifting Gears" report, which identified federal vehicle emission standards, the B.C. ZEV mandate and the B.C. LCFS as important policies for achieving Metro Vancouver's GHG targets, while land use policies were classified as having a "supporting" to "minor" role. We would expect ambitious smart growth policies to have a larger impact on GHG emissions in a different geographical context with weaker senior government GHG policies, as there would be less policy overlap. For jurisdictions with significant upstream emissions from electricity production, these upstream emissions could also result in a greater role for smart growth, in the context of increasing electrification of the personal transportation sector. However, it is important to note that policies that aim to reduce the demand for driving and/or improve energy efficiency, such as those that are part of smart growth strategies, cannot replace fuel switching policies. Ultimately, fuel switching will be required to reduce combustion GHG emissions to levels close to zero as human beings will continue to use significant amounts of energy.

Policy overlap in terms of GHG reduction is not necessarily problematic. While smart growth policies cannot replace senior government fuel switching policies, they can potentially mitigate some worsening in GHG pollution if senior government policies are eroded; for example, through a change in government. Other potential benefits include greater cost-effectiveness of infrastructure investments such as transit and district energy systems, green space preservation and improved public health. Smart growth policies may also contribute to increased livability, social equity and affordability, as discussed in subsection 4.2 below. However, it is critical to be aware of policy overlap and not to overestimate the GHG reductions that can realistically be achieved through a policy mix.

+Mobility Pricing

Under the *+Mobility Pricing* scenario, we combined policies from the *Smart Growth and Zero-Emission Transit* scenario with a mobility price, which we assumed would be implemented after 2025 at an average cost of $5 per weekday per vehicle. The mobility price, smart growth policies and transition to zero-emission transit are complementary. In our simulation, these policies not only slow VKT growth but also lead to a total reduction in driving over time (Figure 8). VKT, which are equivalent to driver PKT, are lowest in 2030 and then slowly increase with population growth (not rising above pre-2025 levels). The combined PKT share of car and light truck drivers and passengers declines to 51 per cent by 2050. The active transportation PKT share increases by about one percentage point by 2050 and the transit share rises to 46 per cent in 2050.

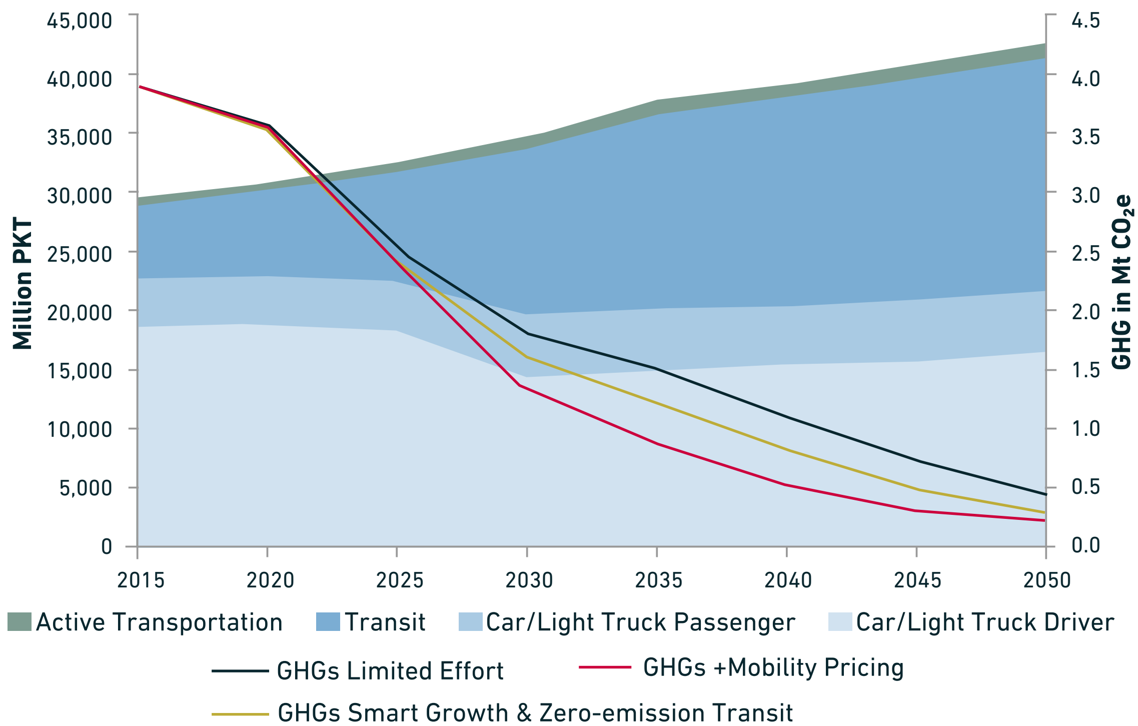

Figure 8. *+Mobility Pricing* scenario: Personal travel demand by transportation mode in PKT and end-use GHG emissions.

It is worth noting that our simulation does not account for a potential driving rebound effect. If driving decreases as under *+Mobility Pricing* and congestion is therefore reduced, some people who previously chose other transportation modes to avoid traffic may switch to driving if they are willing to pay the mobility price. Such a rebound could result in a smaller effect on VKT than shown here. Future research could further explore how rebound might affect the policy effectiveness of smart growth and mobility pricing.

A greater reduction in VKT combined with more mode shifting to zero-emission transit results in additional GHG reductions under the *+Mobility Pricing* scenario compared to the *Smart Growth and Zero-Emission Transit* scenario (Figure 8). Toward 2050, GHG levels under the two scenarios start to approach each other, again due to overlap with senior government efficiency and fuel-switching policies. As driving becomes less carbon-intensive in response to senior government policies, the GHG reduction potential of reducing driving declines. Despite convergence of the GHG trajectories by the end of the simulation period, between 2025 and 2050, the *+Mobility Pricing* policy mix results in a smaller total amount of CO_2e being released into the atmosphere than under the other scenarios. Furthermore, this policy mix could potentially lead to greater reductions in road congestion and traffic collisions, due to the overall decline in driving.

There are, however, equity concerns and opposition to mobility pricing in Metro Vancouver. A 2018 study by the Mobility Pricing Independent Commission found that 34 per cent of

Metro Vancouverites supported mobility pricing, while 32 per cent were undecided and 34 per cent opposed it. Opposition to mobility pricing tends to be especially high when it is first implemented. However, if the mobility price successfully reduces traffic congestion, opposition can decline over time (Mobility Pricing Independent Commission, 2018). Some of the equity impacts from mobility pricing in Metro Vancouver could potentially be mitigated by distributing all or a proportion of the revenue generated to low- and medium-income households.

Energy Use by Scenario

In all three scenarios, energy use is significantly reduced between 2015 and 2050 and the portion of energy from low-carbon sources is increased (Figure 9). These changes are in large part due to senior government policies. The federal vehicle emission standards result in new vehicles becoming increasingly more energy-efficient, and the B.C. LCFS and the B.C. ZEV mandate increase the number of battery electric and plug-in hybrid vehicles on the road in our simulations. These plug-in electric vehicles not only use low-carbon electricity but are also three to five times more energy-efficient than conventional internal combustion engine vehicles.

Total energy use, as forecast by the model, is slightly lower in the *Smart Growth and Zero-Emission Transit* scenario than in the *Limited Effort* scenario. This is because local level smart growth policies cause VKT to grow more slowly than under the *Limited Effort* scenario. The driving share of PKT declines over time as people switch to public transit, which uses less energy. Low-carbon fuel use is higher than under the *Limited Effort* scenario, as we assumed that transit would be transitioned to a zero-emission fleet. Energy use reductions are greater under the *+Mobility Pricing* scenario, as adding the mobility price to smart growth policies leads to a reduction in driving over time instead of only a slowing of growth in driving. Although the share of low-carbon fuel use is slightly higher than under the *Smart Growth and Zero-Emission Transit* scenario in 2050, the amount of low-carbon fuel consumed is slightly lower due to reduced use of zero-emission cars and light trucks, accompanied by a shift to zero-emission transit, which is more energy-efficient, and active transportation.

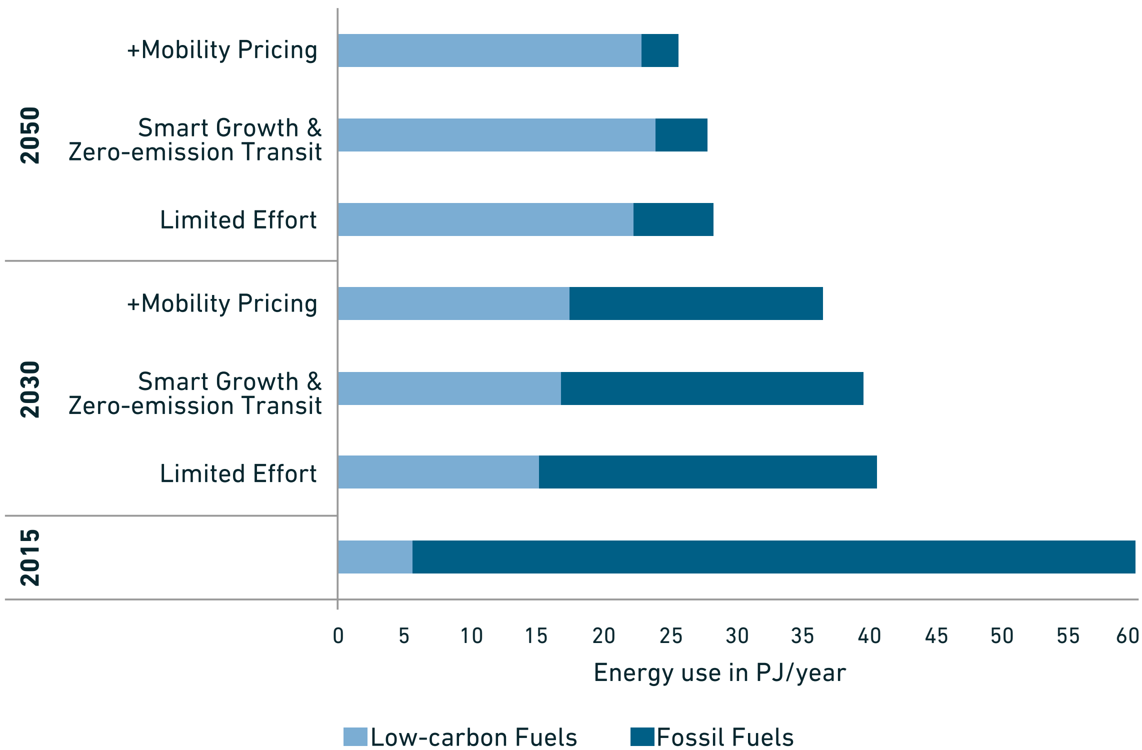

Figure 9. Personal transportation energy use for 2015, 2030 and 2050 by scenario.

FINDINGS FROM THE LITERATURE REVIEW

Over the past few decades, the concept of smart growth, which we will use interchangeably with the term compact development, has gained popularity among planners and academics. While the definition of smart growth is not clear-cut and has been interpreted in different ways (Downs, 2005; Jamme et al., 2019), it generally describes development that seeks to reduce sprawl and car dependency by: 1) directing growth to existing neighbourhoods and thereby increasing population, employment and amenity density in these areas and 2) creating more transit-, walking- and biking-oriented, mixed-use neighbourhoods. The concept was developed as a more sustainable alternative to sprawl, which is widely recognized as having undesirable impacts such as vast consumption of land leading to loss of green space, traffic congestion, high costs for outward infrastructure expansions and limited housing type options if combined with traditional zoning that often favours low densities and single-family homes (Downs, 2005; Harmon, 2003; Carlson and Mathur, 2004). As defined above, smart growth involves not only increasing population density, but also creating complete mixed-use areas that have a high density of jobs and amenities. However, when we use the term "density" in the following subsections, we are primarily referring to population density as this is the most commonly used variable to measure density in the literature we reviewed.

Smart Growth and Livability

"Livability" is a term that is often used but seldom clearly defined and therefore subject to interpretation. In our analysis, we define livability as the desirability to live in a place and/or the subjective well-being of its residents. Both depend on human preferences, which can change over time and vary depending on factors such as socio-economic characteristics and cultural context (Ruth and Franklin, 2014).

Many aspects of smart growth are generally seen as attractive, such as enhancing walking and biking networks and access to amenities, services and rapid transit (Tian et al., 2015). Levine and Frank (2007) conducted a survey in Atlanta, Georgia, on transportation and land-use preferences and current neighbourhood choices. While they found that many preferred auto-dependent single-family neighbourhoods, they also found an undersupply of compact neighbourhoods. Not all those who preferred denser, mixed-use, walking-, biking- and transit-oriented areas with good access to amenities — under the condition of a cost of living comparable to where they were currently residing — were living in such areas. Similarly, Frank et al. (2014) found unmet demand for compact neighbourhoods in Metro Vancouver. This unmet demand is an indicator that neighbourhoods with smart growth characteristics can lead to livability benefits for some.

Mouratidis (2019) investigated the relationship between subjective well-being and compact versus sprawled neighbourhoods through a survey conducted in Oslo, Norway. Oslo has both a high-quality city centre and high-quality suburban areas with low crime rates and an extensive transit system. Even the city centre has relatively low traffic levels due to car restrictions and little overcrowding as density is only moderately high by world standards. In this context, Mouratidis found that residents living in compact urban areas showed higher relationship satisfaction, and had better self-recorded physical health and similar leisure satisfaction compared to residents living in sprawled areas, but experienced more anxiety and had a less positive perception of their living environment. The negative effects seemed to cancel out the positive, resulting in a non-significant relationship between compact urban form, happiness and life satisfaction. While compact urban centres offer better access to amenities and jobs, more transportation options that enable walking and biking to destinations, a larger social network and more opportunities for making new acquaintances, less dense areas can provide stronger neighbour ties, access to nature, quietness, cleanliness and higher perceived safety (Mouratidis, 2019; Wirth, 1938). After controlling for factors such as noise, perceived safety and cleanliness, anxiety and negative perception of the neighbourhood were reduced and an overall positive relationship between compact urban form and life satisfaction was found. The author concluded that moderately high-density development might be able to increase subjective well-being as long as factors such as crime, noise and litter are mitigated (Mouratidis, 2019).

When discussing well-being and life satisfaction, however, it is important to note that preferences for the desired type of neighbourhood and home might be quite varied. Tian et al. (2015) found varying preferences between age cohorts in Utah. Young, childless professionals and seniors were more attracted to denser neighbourhoods with compact development features than families with children, who generally preferred single-family neighbourhoods with transit access. Even independent of age or family status, human preferences are diverse. Some might seek an urban lifestyle, while others might prefer suburban and rural communities. Levine and Frank (2007) found a range of land-use and transportation preferences in a stated-preference survey conducted in Atlanta, Georgia. While they reported unmet supply for neighbourhoods with more smart growth characteristics, they also found wide support for less dense, car-dependent neighbourhoods. Some people may not benefit from compact development, while others may experience livability enhancements depending on personal preferences.

Smart Growth and Equity / Affordability

The relationships between smart growth and social equity and affordability are complex. Some raise the concern that smart growth could lead to reduced affordability and widening social inequity. Others hypothesize that smart growth policies can increase affordability and social equity. In the following, we discuss these potential co-impacts jointly because the two aspects of social sustainability tend to be interrelated.

One important goal of smart growth is to shift away from car dependency to greater destination accessibility by walking, biking and transit. This can be especially beneficial for low-income groups (Allen and Farber, 2020), as car ownership is usually significantly more expensive than using alternative transportation modes. Low-income households in areas with poor transit access and low walking and biking destination accessibility can face transportation poverty, which can lead to social exclusion if participation in daily activities is restricted (Lucas, 2012; Ermagun and Tilahun, 2020). Targeted accessibility enhancements through walking, biking and especially transit can lower the risk for social exclusion.

Transit and active transportation infrastructure investments, however, do not necessarily result in greater social equity. If enhancements are focused on high-income neighbourhoods — as in the case of transit expansions to reduce driving in middle class suburban areas, for example — they may have little benefit for low-income groups (Manaugh and El-Geneidy, 2012). To achieve social equity through transportation planning, clear objectives and indicators that can monitor change are important. A common issue, however, is that social equity is difficult to measure (Lehtonen, 2004; Stanley and Vella-Brodrick, 2009) and therefore often overlooked (Manaugh and El-Geneidy, 2012).

Manaugh et al. (2015) analyzed how social equity is incorporated and measured in 18 North American metropolitan areas' transportation plans, including large cities such as Atlanta, New Orleans, Vancouver, Ottawa and Montreal. They found that the majority of these plans did not include clear objectives and measurable indicators for social equity. Metro Chicago, Boston, San Francisco and San Diego's transportation plans were among the ones with the most specific objectives and clearly defined measures. The authors suggest a number of indicators that could be used to measure social equity in the transportation context. These include changes in accessibility to desired destinations by socio-economic group with a focus on the disadvantaged, differences in transportation costs expressed as a percentage of household income for low-, medium- and high-income groups, and differences in travel time between car and transit travel to essential destinations and between income groups.

The question of social equity further extends to how compact development influences combined housing and transportation affordability. Affordability is often used as a measure of costs relative to income. An interesting question that arises is: Does compact development increase or decrease housing affordability? The answer is much debated and empirical findings are varied. For example, Bereitschaft (2019) and Dale and Newman (2009) found that neighbourhoods with aspects of compact development such as good walkability and destination accessibility in three U.S. cities (Charlotte, NC, Pittsburgh, PA, and Portland, OR) and three Canadian cities (Vancouver, B.C., Victoria, B.C., and Toronto, ON) had lower housing affordability. Wassmer and Baass (2006), on the other hand, argue there is no evidence that densification of urban centres decreases housing affordability. Their finding is based on measuring the relationship between centralized versus sprawled areas and housing affordability after controlling for many other causal variables such as socio-economic characteristics of residents, household growth, structural characteristics of houses and type of households. It is important to note, however, that the variables the authors controlled for could in some cases be linked to density; for example, if households with higher socio-economic status are more likely to seek out neighbourhoods with smart growth characteristics (and therefore higher density).

The fact that housing affordability can be influenced by many other factors, including housing demand and supply, in-migration, investment and market speculation, makes the relationship between compact development and housing affordability complex (Dawkins and Nelson, 2002; Addison et al., 2013; Downs, 2002; Phillips and Goodstein, 2000; Jun, 2006) and predictions of how affordability will be impacted through smart growth policies difficult. Urban growth boundaries, which are a common smart growth strategy that restrict development outside defined boundaries to limit sprawl, theoretically reduce supply by restricting developable land. However, compact development strategies also advocate for rezoning to allow for higher population densities. This can increase housing supply and allow for a more diverse housing mix in areas that were previously subject to density restrictions and single-family home zoning (Addison et al., 2013). Higher-density residential zoning, however, does not necessarily guarantee more affordable housing (Alexander and Tomalty, 2002).

Empirical studies have found higher land values in neighbourhoods with high walkability, amenity accessibility and proximity to light rail (Bartholomew and Ewing, 2011; Rauterkus and Miller, 2011). This could be an indicator of unmet demand for housing in compact urban areas, as found by Frank et al. (2014) and Levine and Frank (2007), combined with willingness and ability to pay a premium to live in a neighbourhood with such characteristics. There is therefore concern about gentrification and the displacement of current residents due to the smart growth–oriented redevelopment of existing low- and medium-income neighbourhoods and brownfield[v] development (Quastel et al., 2012; Dale and Newman, 2009). While better transit accessibility and shorter trip distances in compact neighbourhoods can lower transportation costs, this might not always be sufficient to offset housing cost increases (Bereitschaft, 2019). If compact urban areas become unaffordable for lower income groups, they might be forced to move into less desirable neighbourhoods and potentially face transportation poverty and social exclusion (Miles et al. 2010).

The effect that compact development strategies will have on affordability and social equity can be difficult to predict, especially as many other factors such as housing demand-supply imbalance also play an important role. In their 2013 literature review, Addison et al. conclude that government intervention is necessary to ensure the enhancement of housing affordability. They also note that developers seldom pursue social equity on a voluntary basis and instead seek to maximize their profit. This holds true for any type of development, sprawled or compact. Some policies mentioned in the literature that might help to counter gentrification and increase low- and medium-income groups' competitiveness in the housing market are tax credits and housing subsidies for low- and medium-income households, public-owned housing and affordable housing units and community land trusts[vi] (Addison et al., 2013; Harmon, 2003).

v Brownfields are former industrial or commercial areas that often have some pollution but can be remediated (Dale and Newman, 2009).

vi Community land trusts are a tool that can provide low- and medium-income households with the opportunity to own a home. A community owned NGO purchases land and effectively removes it from the speculative market. The NGO then sells the right to build a home on the land to medium- and low-income households (Harmon, 2003).

CONCLUSIONS

PHOTO: Nate Foong, Unsplash

We modelled an ambitious smart growth policy scenario for Metro Vancouver in which sprawl is reduced, alternative transportation infrastructure is enhanced and population, employment and amenities densities are increased in urban centres and along rapid transit corridors. Our analysis suggests that this smart growth path would have a fairly small incremental impact on end-use GHG emissions from personal transportation in the region to 2050, given current and announced senior government policies.[vii] Under the B.C. ZEV mandate, the B.C. LCFS and the federal vehicle emission standards, our modelling indicates that emissions will be dramatically reduced regardless of land-use policies and despite forecast population growth in the region. These senior government policies are expected to make a significant contribution toward meeting the climate targets that Metro Vancouver and B.C. have established. Our findings are in line with the summary and synthesis of literature presented in the “Shifting Gears” report, which identified federal vehicle emission standards, the B.C. ZEV mandate and the B.C. LCFS as important policies for achieving Metro Vancouver’s GHG targets, while land-use policies were classified as having a “supporting” to “minor” role.

Smart growth policies, shifting to zero-emission public transit and mobility pricing are complementary in terms of their impact on GHG emissions from personal transportation. Smart growth increases the attractiveness of alternative transportation modes, including public transit. The emission reduction potential of this strategy is therefore enhanced when the transit fleet is switched to zero-emission vehicles. Mobility pricing also enhances smart growth policies by making driving more expensive. According to our simulations for Metro Vancouver, between 2030 and 2040, smart growth, zero-emission transit and mobility pricing jointly achieve an annual reduction of 0.5 to 0.6 Mt CO_2e below the level associated with a scenario

vii We note that after our modelling exercise was completed, the Canadian government announced (on December 11, 2020) a further increase in its backstop carbon price and rising stringencies for other regulations, with a 2030 level for the carbon tax of $170. Should all these policies be implemented and sustained, our findings of a modest contribution to GHG reduction from smart growth would be reinforced.

that includes current and announced senior government policies but limited local efforts. These additional reductions decline toward 2050 due to an increase in policy overlap between smart growth and mobility pricing policies on the one hand and provincial and federal energy efficiency and fuel-switching policies on the other. While the local level policies contribute little additional GHG reductions in 2050, we estimate that they lower the total amount of CO_2e released to the atmosphere between 2020 and 2050 by 11.5 Mt CO_2e.

The overlap between policies can be understood by considering the actions that these policies encourage. Smart growth and mobility pricing policies can lower energy consumption in the personal transportation sector by reducing driving. However, the associated GHG reductions decline if cars and light trucks become more energy-efficient and less carbon-intensive and would even drop to zero if fuel switching to zero-emission fuels is fully realized. The federal vehicle emission standards increase the fuel efficiency of new cars and light trucks and the B.C. LCFS and ZEV mandates raise low-carbon fuel use in vehicles. The potential GHG reduction impact of smart growth and mobility pricing policies is therefore lessened as the senior government policies tighten over time.

There is less policy overlap between the key federal and provincial policies and investments in a zero-emission transit fleet because the senior government policies more directly target the decarbonization of cars and light trucks than transit vehicles. Without additional investment in zero-emission transit, there will still be gasoline and diesel buses on the road in 2050. While the B.C. LCFS could lower the carbon intensity of gasoline and diesel, it is currently scheduled to remain frozen at a 20 per cent carbon intensity reduction requirement for transportation fuels after 2030.

In a different geographical context with weaker senior government policies impacting GHG emissions from personal transportation, smart growth and mobility pricing policies would likely have a greater effect than found here, as there would be less policy overlap. For jurisdictions with significant upstream emissions from electricity production, these upstream emissions could also result in a greater role for smart growth, in the context of increasing electrification of the personal transportation sector. Policies that reduce energy use, however, cannot replace fuel-switching policies. If the goal is to reduce GHG emissions to levels close to zero, fuel switching will be required, as we cannot curtail our energy use proportionately.

Policy overlap in terms of GHG emissions is not necessarily problematic if analysts are aware of it and account for it when estimating the reduction potential of a policy mix. Smart growth and other local level policies might be able to offset some worsening of GHG pollution in the case of erosion of senior government policies; for example, through a change in government. Furthermore, two policies might overlap in their potential to reduce GHG emissions but have other positive effects that are non-overlapping.

Although our findings indicate limited potential for smart growth policies and mobility pricing to reduce end-use GHG emissions from Metro Vancouver's personal transportation sector given the current senior government policy environment, there are other reasons to consider these local level interventions. If smart growth policies and mobility pricing are successful in reducing driving, they may mitigate traffic congestion and prevent traffic collisions. Other potential benefits include greater cost-effectiveness of infrastructure investments such as transit and district energy systems, green space preservation and improved public health.

Smart growth policies may also contribute to increased livability, social equity and affordability; however, such co-benefits cannot be automatically assumed. Our literature review indicates that although there are clear livability benefits associated with better access to amenities and transportation networks, factors such as crime, noise and litter can potentially undermine these, and not everyone prefers neighbourhoods with smart growth characteristics. Families with children in particular may not experience an improvement in livability. The relationships between smart growth policies and social equity and affordability are complex, and unintended impacts can occur if social objectives are not explicitly included in smart growth policy design and impacts monitored through measurable indicators. Smart growth may need to be combined with other policies such as housing assistance, affordable housing units and community land trusts to address equity and affordability concerns.

RECOMMENDATIONS

PHOTO: Aditya Chinchure, Unsplash

This section provides recommendations based on our analysis of the potential impact that changes to the built environment could have in Metro Vancouver, given the existing senior government policy context. As such, our focus is on the role of changes to the built environment at the regional level, and on factors that should be considered to avoid unintended consequences that may detract from the benefits. The recommendations are directed toward Metro Vancouver as a regional district, as well as Metro Vancouver municipalities and other local authorities, such as the region's transit provider, TransLink. We recommend that the provincial government maintain and strengthen the B.C. policies addressed in Recommendation 1, as these are expected to have an important role in lowering B.C. and Metro Vancouver's road transportation GHG emissions. Provincial government support would also be beneficial to many of the other recommendations that follow.

RECOMMENDATION 1

Our modelling highlighted the importance of current and announced senior government policies relative to changes to the built environment in reducing end-use GHG emissions from personal transportation in Metro Vancouver. This finding suggests that efforts on the part of local governments to preserve and enhance these senior government policies are worthwhile and perhaps even more important than the pursuit of changes to the built environment when it comes to GHG emission reductions. Specifically, we recommend the following.

- Support B.C.'s Low Carbon Fuel Standard and advocate for tougher regulation over time. Under its current design, the LCFS will remain at a 20 per cent carbon intensity reduction requirement (relative to 2010) for transportation fuels after 2030.
- Support the B.C. Zero Emission Vehicle mandate, which will require 10 per cent of light-duty vehicle sales in B.C. to be ZEVs in 2025, rising to 30 per cent in 2030, and 100 per

cent in 2040. Campaign for an accelerated timeline of 50 per cent ZEV sales in 2025 and 100 per cent in 2030. This accelerated target for 100 per cent ZEV sales is equivalent to the targets of other jurisdictions, such as the U.K. and Sweden. Norway plans to achieve 100 per cent ZEV sales by 2025.

- Support the federal vehicle emission standards for passenger cars and light trucks.
- Support and advocate for strengthening of the federal and/or provincial carbon tax.

Our findings and recommendations echo those in the 2019 David Suzuki Foundation "Shifting Gears" report, which also identified the LCFS, the ZEV mandate and the federal vehicle emission standards as key drivers of regional GHG reductions in the transportation sector (DSF, 2019).

RECOMMENDATION 2

Shift the public transit fleet to zero-emission vehicles. Replacing gasoline and diesel buses with zero-emission vehicles increases the potential for smart growth and mobility pricing policies to reduce GHG emissions as current and announced federal and provincial policies ramp up and will ultimately result in additional GHG reductions beyond what these senior government policies can achieve.

RECOMMENDATION 3

A theme that emerged from our interviews is that improving co-ordination and sharing of expertise and administrative capabilities between local authorities and between these authorities and the provincial government is required to support smart growth policies and objectives. In some cases, there appears to have been a disconnect between development of communities and the infrastructure to serve those communities, including schools and transit networks. Efforts are already underway in terms of improving co-ordination between authorities and there would be benefits to building on these.

RECOMMENDATION 4

Our modelling suggests a limited role for changes to the built environment in personal transportation end-use GHG mitigation in Metro Vancouver. This finding elevates the importance of achieving other benefits from reshaping the built environment. To ensure that livability benefits are realized, local authorities should investigate and address possible negative impacts, such as crime, noise and lack of cleanliness. The needs of families with children may also require further consideration to prevent a loss of families to suburban areas. Some of our interviewees voiced an interest in the potential for livability to be enhanced (and embodied carbon possibly reduced) through an approach to compact development that diverges from the paradigm of areas of concentrated density connected by rapid transit. The concept of designing neighbourhoods in which basic amenities are within a 15- or 20-minute walking distance is relevant here.

RECOMMENDATION 5

Take a careful, evidence-based approach in assessing and addressing the potential for significant negative impacts of smart growth on equity and affordability. To maintain and even advance equity and affordability, local authorities should incorporate clear social objectives into land-use and infrastructure planning, identify other policies and actions that will be necessary to support these objectives, and monitor impacts. Our interviews revealed that, while there is currently a lot of discussion around issues of equity and affordability, little is being done to define specific equity-related targets or measure impacts. It is certainly challenging to quantify aspects of equity; however, measurement is not impossible and this is an important area for future study. In terms of supporting equity and affordability, our literature review indicated that smart growth may need to be combined with other policies such as housing assistance, affordable housing units and community land trusts. An interviewee suggested that some restriction of access to housing in the region may also be necessary. Addressing affordability and equity might require collaboration with senior governments.

RECOMMENDATION 6

Consider mobility pricing but address equity and affordability concerns. Future research investigating the equity and affordability impacts of different mobility pricing designs, including revenue recycling strategies, in the Metro Vancouver context could be of value.

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