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REDUCING GREENHOUSE GAS EMISSIONS IN TRANSPORT: ALL IN ONE BASKET?

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SUMMARY

Analysis after analysis has shown consistently that if policy-makers aiming to meet climate goals are looking for the most-efficient, least-distortionary way to target emissions growth, there is simply nothing better than abandoning all emissions regulations except for one: A straight, revenue-neutral carbon tax. Nothing works through more channels, at a lower cost.

Alas, policy-makers are not always looking for the most-efficient, least-distortionary way to target emissions growth. That's because many of those same analyses show that in order to reach emissions targets, the price on carbon would have to be so punitive as to be politically unbearable, raising the price of gasoline, for example, by about a dollar a litre. That leads politicians to mix in other policies that are less visible to the consumer but also less efficient, less effective and more expensive in abating carbon dioxide.

The recently negotiated Pan-Canadian Framework on Clean Growth and Climate Change intends to follow that model, relying on a blend of different policies to help reach Canada's Paris climate targets. But while the government seems therefore determined to rule out the possibility of a nothing-but-a-carbon-tax plan, it is possible, through the careful application of just the right sort of emission-reduction approaches, to reduce the costs of abatement in a key policy target — namely, road transportation — to a level that at least approaches the lower cost of a carbon tax.

The government will likely consider several options in trying to reduce emissions from road transportation. Typical tools include requiring manufacturers to meet standards for new vehicles that mandate fuel economy and greenhouse gas emissions; gasoline taxes; taxes on emissions-intensive vehicles; subsidies

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for low-emission or zero-emission vehicles; and subsidies for public transit. Indications are that a low-carbon fuel standard (LCFS) will play a significant role in the Pan-Canadian Framework.

Applied carefully, an LCFS combined with a mandate for automakers to sell more electric vehicles would be an appropriate policy for Canada to achieve meaningful emissions reductions at a tolerable cost, given other policy measures already committed to. Subsidies for electric vehicles, however, should be avoided as they turn out to be one of the least cost-effective policies to reduce emissions.

Requiring car makers to sell more electric vehicles will lead to higher prices for standard internal-combustion vehicles as automakers are forced to spread the cost of the electric-vehicle mandate across their non-electric models. That in turn will lead to cheaper electric cars and pricier non-electric cars, making it likelier that consumers will gravitate in increasing numbers to electric cars, helping reduce emissions. Meanwhile, as the LFCS standard is raised, drivers of internal-combustion vehicles will face an even higher cost of filling up, again prompting more drivers to consider switching to electric vehicles. The combined effect — achievable at close to the cost of a carbon tax — will make it more expensive to drive a gasoline-powered car, similar to the effect of a carbon tax on drivers, but less visible and so less politically risky.

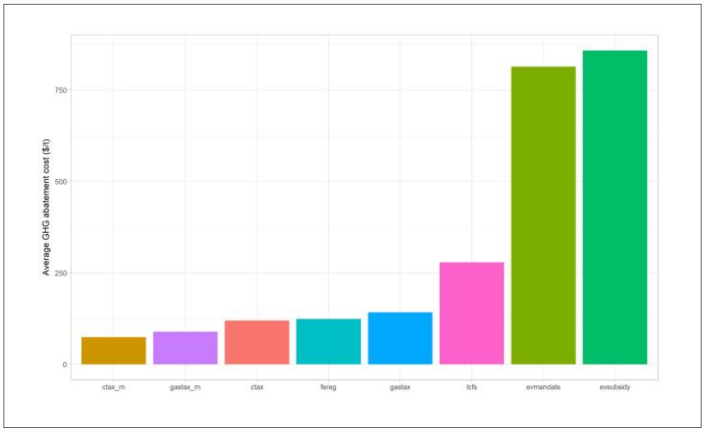
1. INTRODUCTION

Passenger on-road transport emissions, primarily associated with driving cars and light trucks, make up a significant share of all greenhouse gas emissions in Canada. The transport sector is also one of the most visible sources of emissions, since most Canadians regularly travel by vehicle. Moreover, in addition to producing greenhouse gas emissions, private vehicles generate a number of other social costs, including accidents, congestion and local air pollution (Parry and Small, 2005). As a result, provincial and federal governments in Canada have targeted passenger vehicles with a large number of different types of policies. For example, governments have used fuel economy standards and greenhouse gas intensity standards for new vehicles, gasoline taxes, taxes and subsidies on new vehicles, support for public transit and other policies aimed at reducing emissions from the passenger transport sector. Under the newly negotiated Pan-Canadian Framework on Clean Growth and Climate Change, several new policies are likely to be added to this list. Three are particularly prominent: a carbon price, to be imposed by provinces and backstopped by the federal government; a clean fuel standard; and an electric vehicle strategy.[1]

This policy brief summarizes the results of a related working paper,[2] in which we consider the cost-effectiveness of these and other policies aimed at reducing greenhouse gas emissions from the transport sector. The working paper describes a new economic model focused on the Canadian passenger-transport sector that we use to assess alternative policies for reducing greenhouse gas emissions from transport. A key feature of the model is its general equilibrium in nature, meaning the model allows us to consider – in a simple manner – the way in which policies in the transport sector interact with taxes and other policies already in place in the broader economy. In addition, because the model follows a standard microeconomic framework, it allows us to estimate the cost of alternative policies using a widely accepted framework.

FIGURE 1

Average cost for reducing greenhouse gas emissions by 9.1 per cent relative to business as usual with alternative individual policies. The costs reflect a medium-run (roughly seven-year) time horizon.



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1 The Pan-Canadian Framework (http://publications.gc.ca/site/eng/9.828774/publication.html) outlines four potential actions in addition to carbon pricing to reduce emissions from the transport sector (Environment and Climate Change Canada, 2016). We focus on the zero emission vehicle strategy and the clean fuel standard, which have received the most attention. At the time of writing, both policies remain under development, such that details are not available.

2 Rivers, N. and R. Wigle, 2018, "An Evaluation of Policy Options for Reducing Greenhouse Gas Emissions in the Passenger Transport Sector: The Cost-Effectiveness of Regulations versus Emissions Pricing," *LCERPA Working Paper 2018-1* (http://www.lcerpa.org/public/papers/LCERPA_2018_1.pdf).

As expected, we find that a carbon tax is a much more cost-effective approach for reducing emissions compared to other policies, including a fuel economy regulation, clean fuel standard or zero emission vehicle mandate. Whereas the average cost of emissions reductions achieved under a carbon tax without revenue recycling is $113 per tonne to reduce emissions by 9.1 per cent, the average cost for a clean fuel standard or zero emission vehicle mandate that reduce emissions by the same quantity are all between $199 and $806 per tonne (as shown in Figure 1).[3] Moreover, the average cost for a carbon tax can be substantially reduced if it is made revenue-neutral, such that revenues from the carbon tax are used to reduce other taxes. In this case, our analysis suggests that the average cost of emission reductions falls to $76 per tonne or emissions reduced (to reduce emissions by 9.1 per cent over about seven years). The carbon tax emerges as the most cost-effective policy because it takes advantage of the maximum number of channels to reduce emissions. The carbon tax provides incentives to travel less, to switch modes from private car to other less greenhouse gas-intensive modes, to use lower carbon fuels and to buy more fuel-efficient vehicles. None of the other policy instruments provides all those incentives.

The economic advantage of carbon taxes relative to other policies has been well known for some time (Keohane and Olmstead, 2016), and so our first findings are not surprising. Despite their clear economic advantages, however, it is politically difficult to impose high carbon taxes. Policy-makers instead often turn to other regulations which may be less politically controversial. In practice, policy-makers typically impose multiple regulations to reduce greenhouse gas emissions – this is the approach the federal government proposes. The advantage of multiple regulations over individual regulations is that they can target more margins for reducing greenhouse gases than individual regulations, and so better approach the cost-effectiveness of a carbon tax.

Our research question focuses on how government should design its forthcoming package of regulations to be as cost-effective as possible. We consider in particular the two components of the Pan-Canadian Framework that are still being designed – the forthcoming zero emission vehicle policy and clean fuel standard – and assume that the approach to carbon pricing and vehicle fuel efficiency regulations are fixed. We find that there is a role for both the clean fuel standard as well as the zero emission vehicle standard in reducing emissions, and that when they are used together, they achieve substantially improved cost-effectiveness compared to when either instrument is imposed on its own. Our model suggests that to be as cost-effective as possible, most of the abatement required for most reduction targets should come from the clean fuel standard, but we find that a modest zero emission vehicle mandate is a recommended part of the package, particularly when the reduction target is tighter. For example, to achieve a further eight per cent reduction in passenger transport emissions beyond the effect of the announced changes in carbon pricing and fuel economy regulations, a low carbon fuel standard that requires a 4.3 per cent reduction in the emissions intensity of fuels coupled with a requirement that three per cent of new vehicle sales are zero emission reduces emissions relatively cost-effectively. For a more stringent approach, a 7.3 per cent reduction in emissions intensity of fuels (via a clean fuel standard) coupled with a 5.2 per cent zero emission vehicle mandate also reduces emissions relatively cost-effectively (albeit, still at a higher cost than a carbon tax). This combination would reduce emissions a further 12 per cent beyond already announced measures.

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[3] This measure of cost captures the change in welfare associated with each policy, both as a result of changes in behaviour as well as costs of new technologies. Importantly, the measure only captures costs of reducing emissions, and not the benefit associated with reduced emissions (which is the same across all policies we compare).

The rest of the paper proceeds as follows. In the next section, we outline key trends in greenhouse gas emissions in the passenger-transport sector. This helps to convey the magnitude of the challenge facing policy-makers in generating deep greenhouse gas reductions. In Section 3 we very briefly describe the model used and go through the key results of the analysis. Finally, in Section 4 we provide a discussion of the policy relevance of our findings. The accompanying technical paper provides a much more complete description of the analysis and results.

2. GREENHOUSE GAS EMISSIONS FROM PASSENGER TRANSPORT

Greenhouse gas emissions from on-road passenger transport reached about 75 Mt CO_2e in 2014, representing about 11 per cent of total emissions in Canada.[4] Greenhouse gas emissions from this sector have grown by about 10 per cent between 1990 and 2014. However, encouragingly, emissions have been stable in the sector since about 2002 (see Figure 2).

Despite some progress in stabilizing emissions over the past decade in the sector, to achieve substantial reductions in emissions it will be necessary to significantly accelerate efforts. There are four key ways that decarbonization can take place in this sector: through improvements in vehicle fuel economy, through an increase the share of (low carbon) public and active transport, through reductions in the greenhouse gas intensity of fuel, and/or by reducing overall travel demand. Figure 2 shows that since 1990, vehicle fuel economy, the greenhouse gas intensity of fuel and the share of low carbon travel have all improved, while travel demand has increased. These trends have resulted in an increase in absolute greenhouse gas emissions from passenger transport, but a decline in per capita emissions.

Canada's Paris commitment requires a 30 per cent reduction in greenhouse gas emissions relative to 2005 levels by 2030. GHG emissions from on-road passenger transport in 2014 were about 1.5 per cent below 2005 levels, such that they must fall by roughly two per cent per year until 2030 to hit the Paris target.[5] Given an ongoing increase in population of over one per cent per year, the reduction in per capita GHGs from transport will need to reach roughly three per cent per year. For reference, the reduction in per capita GHG emissions since 2005 – a period of rising oil prices and the introduction of new vehicle

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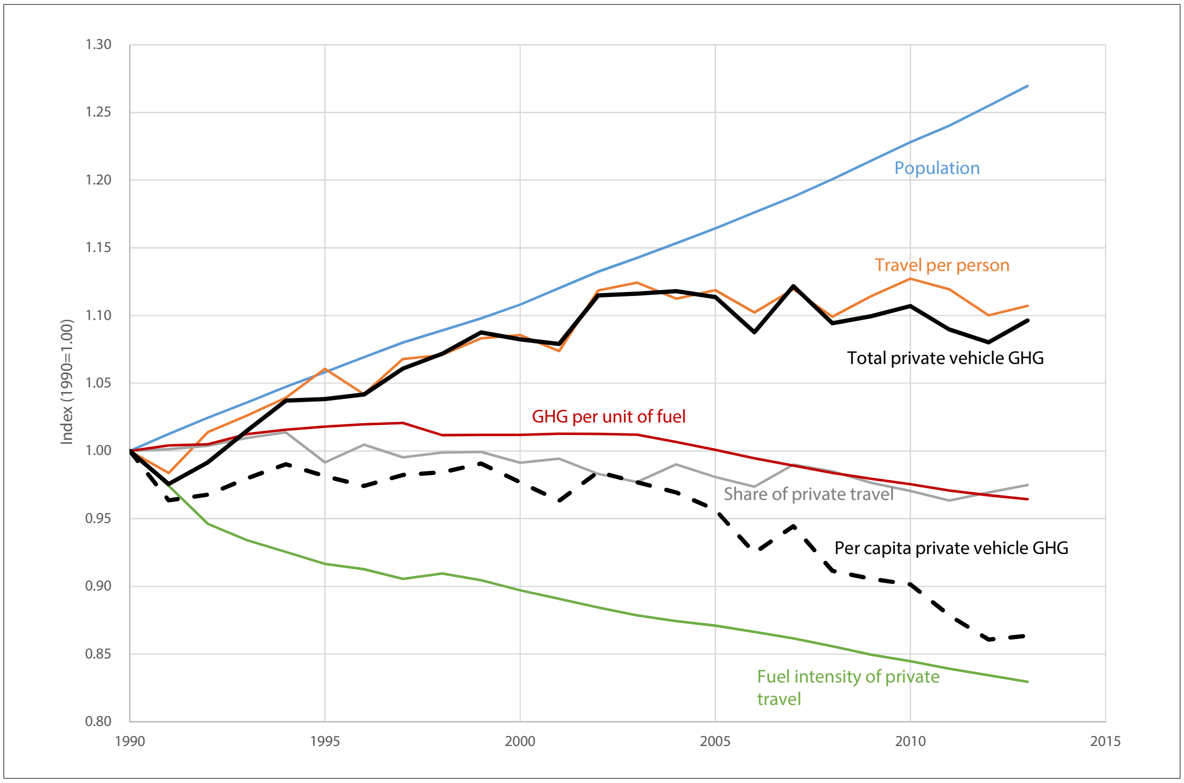
4 Natural Resources Canada, Comprehensive Energy Use Database. These figures only include emissions released by combustion in the transport sector, and do not include the upstream emissions required to produce fuel. We do include upstream emissions in the model that is described later in this report. Including upstream emissions increases total transport sector emissions to about 86 Mt CO_2e.

5 The Paris target applies to total emissions, not to emissions from on-road transportation specifically, but this still provides a useful benchmark for analysis.

FIGURE 2

Decomposition of on-road private vehicle greenhouse gas emissions. Calculations by authors using data from CANSIM 0051-0001 and Natural Resources Canada's Comprehensive Energy Use Database.



greenhouse gas regulations – was only about one per cent per year (shown by the dashed line in Figure 2). This highlights the need for aggressive policies to substantially reduce GHG emissions from passenger transport.

2.1 Policy options for reducing greenhouse gas emissions

Governments have a wide range of policies at their disposal for addressing greenhouse gas emissions from passenger vehicles, and governments in Canada have been relatively pro-active in experimenting with these. However, there remain many policy options in the transport sector that Canadian governments have not used extensively, notably including distance-based taxes or charges and congestion charges. Our analysis does not include policies designed to address urban form. In our related working paper, we outline the model that we use to simulate these various policies. Here, we provide a brief description of the experience in Canada with these policies.

Carbon tax

A tax (or price) on carbon dioxide emissions provides a market-based incentive that can help to induce emitters to account for the social cost of greenhouse gas emissions in making transport decisions. It is possible for revenue from a carbon tax to be used to reduce other taxes in the economy, provide offsetting rebates to low-income or other households, or increase investment in low carbon infrastructure. Carbon prices have been applied on transport fuels in British Columbia, Alberta, Ontario and Quebec. The Pan-Canadian Framework on Climate Change stipulates that all provinces must have carbon prices in place by 2018, increasing from \$10/t CO_2e to \$50/t by 2022.[6]

Fuel tax

Fuel excise taxes have been applied in Canada (and other countries) at the provincial, municipal and federal levels for several decades. They have typically been implemented as a revenue generation tool, but because the consumption of gasoline is closely tied to greenhouse gas emissions as well as a number of other social costs (accidents, congestion) they can play a role in reducing greenhouse gas emissions.

Low carbon (clean) fuel standard/renewable fuel standard

Governments across Canada, at both the federal and provincial levels, have implemented renewable fuel standards to promote the blending of renewable fuels such as ethanol and biodiesel into gasoline and diesel, respectively. Renewable fuel standards specify a minimum proportion of renewable fuels to be included in overall fuel sales. A closely related policy is the low carbon fuel standard or LCFS, which has been implemented in British Columbia (as well as California). A low carbon fuel standard specifies a maximum life cycle emissions level for the overall fuel mix. The Pan-Canadian Framework envisions a low carbon fuel standard playing a significant role in reducing greenhouse gas emissions from the transport sector.[7]

Fuel economy regulations

The federal government has used fuel economy and greenhouse gas intensity regulations to help reduce fuel consumption and greenhouse gas emissions from new vehicles for several decades. These regulations can be effective in reducing the greenhouse gas emissions intensity of new vehicles, but do not affect the older vehicle stock, and do not provide incentives to reduce driving or choose lower carbon fuels. The existing passenger vehicle greenhouse gas intensity standards are indexed to vehicle size (i.e., become less stringent for larger footprint vehicles), which implicitly provides a subsidy for larger cars. This may render the policy less cost-effective in reducing emissions.

Electric vehicle subsidies

For several years, British Columbia, Ontario and Quebec have offered large subsidies to stimulate the purchase of electric vehicles. Consumers appear to have responded to these policies, with electric vehicle market shares in these provinces substantially above those of other provinces.[8] Electric vehicle subsidies promote low carbon vehicle technology, but do not induce consumers to reduce driving or switch modes.

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6 Details of the carbon price are provided in the Technical Paper from Environment and Climate Change Canada (2017) (https://www.canada.ca/content/dam/eccc/documents/pdf/20170518-2-en.pdf).

7 Discussions are currently underway regarding the potential design of this policy. See the Environment Canada Discussion Paper (https://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=D7C913BB-1) for details.

8 Electric vehicle sales in 2016 made up 0.7 per cent of total vehicle sales in Ontario, Quebec, and British Columbia, but only 0.1 per cent of sales in other provinces.

Zero emission vehicle regulations

Quebec has recently implemented a zero emission vehicle mandate, which requires that zero emission vehicles make up a given percentage of new vehicle sales by 2025. Quebec's policy is modelled on a similar policy in California. The federal government has announced the development of an electric vehicle strategy, which could take the form of a zero emission vehicle mandate.

2.2 Cost-effectiveness

To consider the cost-effectiveness of these various policies that reduce greenhouse gas emissions from the transport sector, it is useful to consider the four possible pathways by which greenhouse gas emissions can be reduced: by reducing overall travel demand, promoting mode switching from private transport to public transport (or other lower carbon transport options such as walking and cycling), improving fuel economy and decarbonizing transport fuels. Each of these decarbonization options has associated costs, and the marginal costs of actions in each of these categories are likely to rise as the reduction target rises.

The direct incentives that each type of public policy generates are summarized in Table 1. As stated above, a carbon tax – by increasing the price associated with carbon emissions – provides incentives for decarbonization across all four potential actions. A fuel tax is similar, but provides fewer incentives for decarbonizing fuels, since in Canada excise taxes generally do not differentiate between renewable fuels and gasoline (when the two are blended). Fuel economy regulations require manufacturers to improve new vehicle fuel economy, but may actually cause increases in travel demand, as more fuel-efficient vehicles are cheaper to drive. Similar incentives are generated by a low-emission vehicle mandate or by subsidies on low-emission vehicles. A low carbon fuel standard requires improvements in the greenhouse gas intensity of fuels. If this requirement indirectly causes increases in fuel prices, this policy can have indirect effects on other decarbonization actions.

Two conclusions can be drawn from this discussion. First, unless there are significant indirect effects caused by any of these individual policy options, pursuing deep decarbonization with any other single measure than a carbon tax is likely to be relatively expensive. This is true because other measures rely on a limited number of abatement channels, with the result that the ones they choose are likely to eventually become expensive. Second, although individual policies do not provide incentives across all decarbonization pathways in the same way as a carbon tax, it may be possible to implement combinations of policies that do. For example, from Table 1, it is apparent that a fuel tax and a low carbon fuel standard provide incentives across the range of decarbonization actions. A carefully chosen combination of these two policies is therefore likely to approximate the cost-effectiveness of a carbon tax.

TABLE 1 DIRECT INCENTIVES TO REDUCE TRANSPORT GHG EMISSIONS GENERATED BY ALTERNATIVE POLICIES

Policy	Reduce travel demand	Induce mode switching	Improve fuel economy	Decarbonize Fuels
Carbon tax	yes	yes	yes	yes
Fuel tax	yes	yes	yes	no[a]
Fuel economy regulations	no	no	yes[b]	no
Electric vehicle mandate	no	no	yes	no
Low carbon fuel standard	no	no	no	yes
Public transit subsidies	no	yes	no	no

[a] A fuel excise tax provides incentives for consumers to switch from fuels to electricity, but not from one liquid fuel to another.

[b] Fuel economy regulations require improvements in the new vehicle fleet, but not in existing vehicles.

3. METHODOLOGY AND FINDINGS

We use a general equilibrium model of the Canadian economy to simulate the impacts of various policy options in road passenger transportation. The model[9] is calibrated to reflect decisions on roughly a seven-year time horizon. Over this time period, approximately half of the vehicle stock is chosen under the new policies, and half is chosen prior to the introduction of the new policies. Model parameters are chosen to replicate as best as possible the key transportation-related choices we flagged in Table 1.

As well as comparing the cost-effectiveness of alternative regulatory approaches to reducing emissions – such as a clean fuel standard or a zero emission vehicle standard – with market-based approaches, such as a carbon tax, we also attempt to provide some insight into the current policy choice confronting federal policy-makers in Canada. In particular, Canada has already committed to a carbon-pricing strategy and has recently implemented vehicle greenhouse gas intensity standards. It is currently in the process of designing a clean fuel standard and an electric vehicle strategy. We thus focus our attention on the optimal combined choice of these latter two policies, and consider the cost-effectiveness of this combined package of transport sector policies.

3.1 Individual policies

We begin by comparing the cost-effectiveness of individual policies aimed at reducing greenhouse gas emissions from passenger transport. We use the model to calculate the economic cost, measured as the value of lost consumption, associated with reducing greenhouse gas emissions using each policy. We gradually increase the stringency of each policy in our model, which allows us to measure the marginal change in cost associated with a small increase in stringency of each policy. In Figure 3, we then compare the marginal abatement cost imposed by each of the individual policies that we simulate.

For virtually all greenhouse gas abatement targets, the revenue-neutral carbon tax, in which revenue from the carbon tax is used to reduce other tax rates in the economy, is the most cost-effective policy. This is an anticipated result, given the structure of our model. Our calculations suggest that to reduce emissions from on-road passenger transportation by about five Mt CO_2e per year within seven years would require a carbon tax of about \$85/t CO_2e. On its own, the \$50/t tax

[9] Further details of the model are available in a related working paper.

agreed upon in the Pan-Canadian Framework is likely to reduce emissions by two to three Mt CO_2e per year in the near term. The model suggests that significant emission cuts from on-road transport over a seven-year period would require a high carbon tax. For example, cutting emissions from the sector by 20 per cent over five years could require a carbon tax over \$400/t CO_2e or more (for reference, a \$400/t CO_2e tax would add \$1/L to the price of gasoline).

While the revenue-neutral gasoline tax and carbon tax impose similar costs at modest abatement targets, for more stringent emissions abatement goals the revenue-neutral carbon tax becomes progressively more cost-effective. This occurs because it encourages the substitution of low carbon liquid fuels for gasoline, which is not facilitated by the gasoline tax.

We simulate two variants of the carbon tax and gasoline tax: a revenue-neutral version and a non-revenue-neutral version. The revenue-neutral version uses the revenue from the environmental tax to reduce the pre-existing tax on income. The "standard" version rebates revenue to households directly, without changing pre-existing tax rates. Consistent with other analyses, we find that the revenue-neutral approach reduces the cost of achieving an environmental goal. However, both the revenue-neutral and standard tax policies induce greenhouse gas abatement in a much more cost-effective manner than other individual policies, especially for more stringent environmental targets.

Among policies other than the carbon tax, those targeting electric vehicles stand out as being particularly costly. Electric vehicle subsidies, in particular, achieve little reduction in greenhouse gas emissions in our model, and do so at a high cost. This outcome occurs because electric vehicle subsidies only affect one margin in the model – providing incentive for consumers to switch from internal combustion to electric vehicles. The narrow base makes this policy approach costly. Moreover, because they subsidize transport activities, they encourage additional transport demand, which works against the main objective of the policy. The EV mandate is somewhat more cost-effective than the EV subsidy. This is because the EV mandate functions through manufacturer cross-subsidization of EV vehicles from conventional vehicle margins. By making conventional vehicles more expensive, the EV mandate discourages greenhouse gas emissions from private transport.

The fuel economy standard is nearly as cost-effective as the straight gasoline tax and carbon tax at low levels of emission abatement, but rapidly becomes much less cost-effective as additional emissions abatement is pursued. This is because the fuel economy standard does not encourage substantial reductions in transport demand and does little to encourage decarbonization of fuels.[10]

The model suggests that, on its own, the low carbon fuel standard is substantially less cost-effective than the market-based policies that we simulate. As shown in Figure 3, to achieve a 9.1 per cent reduction in annual emissions over about seven years as we will discuss later, the marginal abatement cost of the low carbon fuel standard is dramatically higher than a revenue-neutral carbon tax. One feature of the LCFS is that its marginal abatement cost curve includes small kinks where blending limits impinge on the ability of low carbon fuels to reduce emissions further. These are particularly relevant in the near-term scenarios that we examine, but may become less important over the longer term as new technologies allow greater integration of renewable fuels.

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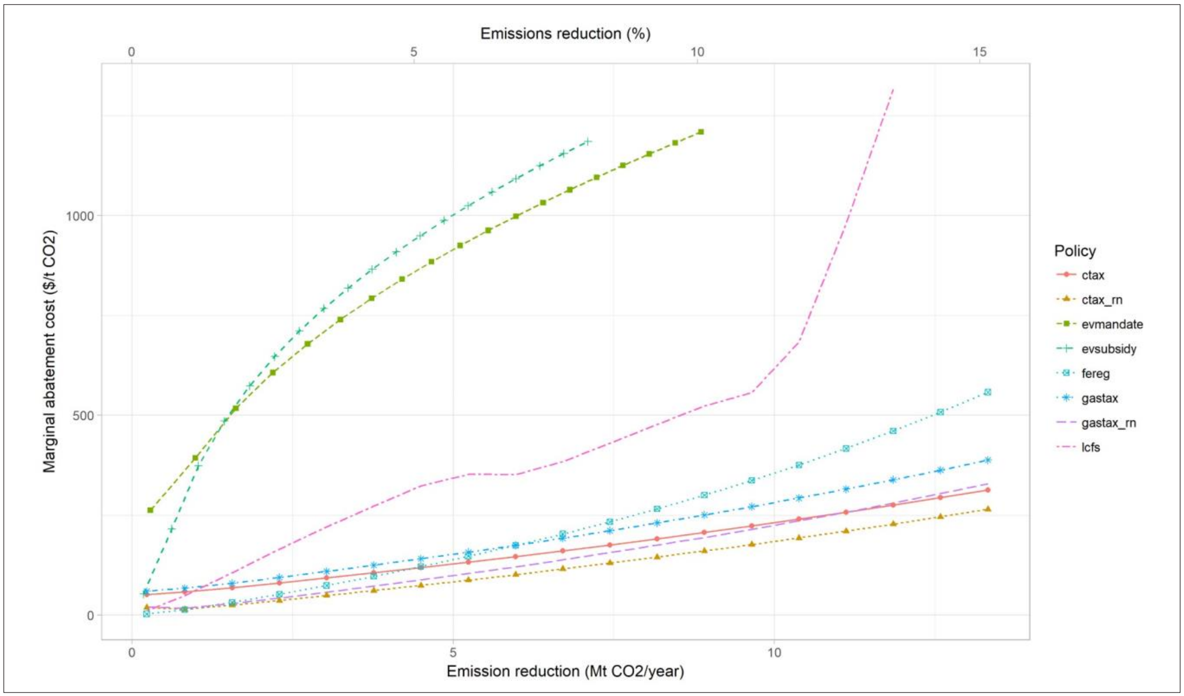
[10] The way we model the fuel economy standard is somewhat idealized in comparison to the real-world implementation of this policy. In particular, we don't use size thresholds like the policy does in reality.

FIGURE 3

Marginal abatement curve for individual policies. The marginal abatement curves reflect a medium-run (roughly seven-year) time horizon.



Because the costs of policies we model are, not surprisingly, sensitive to model parameterization, we conducted a sensitivity analysis. The revenue-neutral carbon tax remains the most cost-effective of any of the individual regulatory options for the range of parameters considered (see the related working paper for details). We also observe that for the domain of our sensitivity analysis, the marginal abatement cost curves for the EV mandate and carbon tax do not shift dramatically in response to parameter changes, whereas the curve for the LCFS shifts markedly for some of the parameter changes. The key sensitivity parameters relate to the cost and emission intensity of renewable fuels.

Table 2 provides an overview of our findings for each instrument applied individually to reduce transport emissions by about 9.1 per cent[11] over a roughly seven-year period. Carbon or fuel taxes have total cost at or below $27 per person per year, whereas the remaining instruments have progressively higher total costs.[12]

[11] This translates to a reduction of about eight Mt a year.

[12] The sole exception is a revenue-neutral fuel tax which has similar costs to the revenue-neutral carbon tax.

TABLE 2 OVERVIEW OF SINGLE POLICIES

	MAC	Welfare ($ person)	Stringency
Carbon Tax (Revenue Neutral)	130	-17	$175/t CO_2e
Carbon Tax	176	-27	$175/t CO_2e
Fuel Tax (Revenue Neutral)	156	-20	27 ¢/l
Fuel Tax	211	-32	27 ¢/l
LCFS	430	-62	10.1% reduction in GHG intensity of fuel
EV Mandate	1125	-181	11.2% of new cars are ZEVs
EV Subsidy	1185	-191	14.6% of new cars are ZEVs
Fuel Economy Regulation	233	-28	23.1% improvement in fuel economy

3.2 What Mix of Policies?

The prior section simulated a number of individual transport policies and showed that carbon taxes are able to reduce transport sector emissions at substantially lower cost than individual regulatory policies. In practice, however, policy-makers do not typically implement a single regulation to reduce emissions, but instead use a number of regulations concurrently. This is the approach taken by the Pan-Canadian Framework, which proposes a carbon price, clean fuel standard and electric vehicle strategy on top of previously implemented regulations governing the greenhouse gas intensity of new vehicles. In this section, we focus on (1) how to optimally choose this combination of policies – in particular the two policies currently being designed, and (2) the cost-effectiveness of the package of policies.

In each case, these policies are modelled as additional to what we will call our policy baseline. That includes the already committed carbon price benchmark of $50/t (in 2022) and fuel economy regulations tight enough to improve the fuel economy of the vehicle fleet by five per cent.[13] In our model, these together are enough to reduce transport sector emissions by four per cent from the baseline (initial) values.[14]

To simplify the issue, we focus specifically on an EV mandate as described earlier since most economic analyses favour the EV mandate over EV subsidies. We consider combinations of EV mandate and LCFS policies that achieve from one to 13 per cent further emission reductions from our policy baseline. This amounts to reductions from our benchmark case (before the reductions brought about by the carbon tax and fuel economy regulations) of 6.5 per cent to 18 per cent. We use our model to select the lowest cost combination of EV mandate and LCFS to achieve increasingly stringent transport emission reductions. The option of just using one or the other instrument is also considered.

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[13] This value is intended to reflect added tightness to light duty fuel economy regulations attributable to fleet-wide average GHG intensity limits that were layered on pre-existing fuel economy regulations. See http://www.transportpolicy.net/standard/canada-light-duty-fuel-consumption-and-ghg/ ?title=canada:_light-duty:_fuel_consumption_and_ghg.

[14] For simplicity, we do not model other policies that affect passenger transport, which have been applied by federal or provincial governments. One reason for the small reductions in greenhouse gas emissions from these and other policies that we simulate is that we focus on the medium-run (seven-year) reductions in emissions, when only about half the vehicle fleet has turned over.

FIGURE 4

Loss-minimizing combinations of EV target share and LCFS share. The label indicates percentage reduction in emissions, from one to 16 per cent beyond emission reductions induced by the carbon price and vehicle greenhouse gas intensity regulations. The EV target is the percentage of new vehicle sales required to be electric. The LCFS target is the percentage reduction in the greenhouse gas intensity of vehicle fuels required by the clean fuel standard.

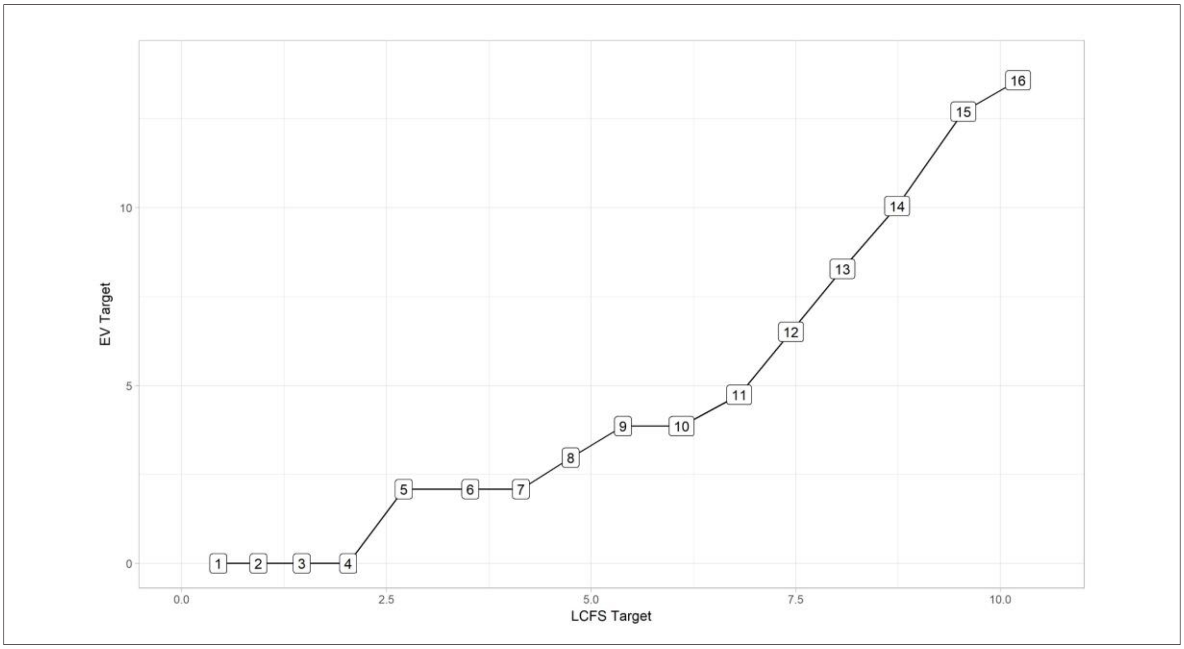


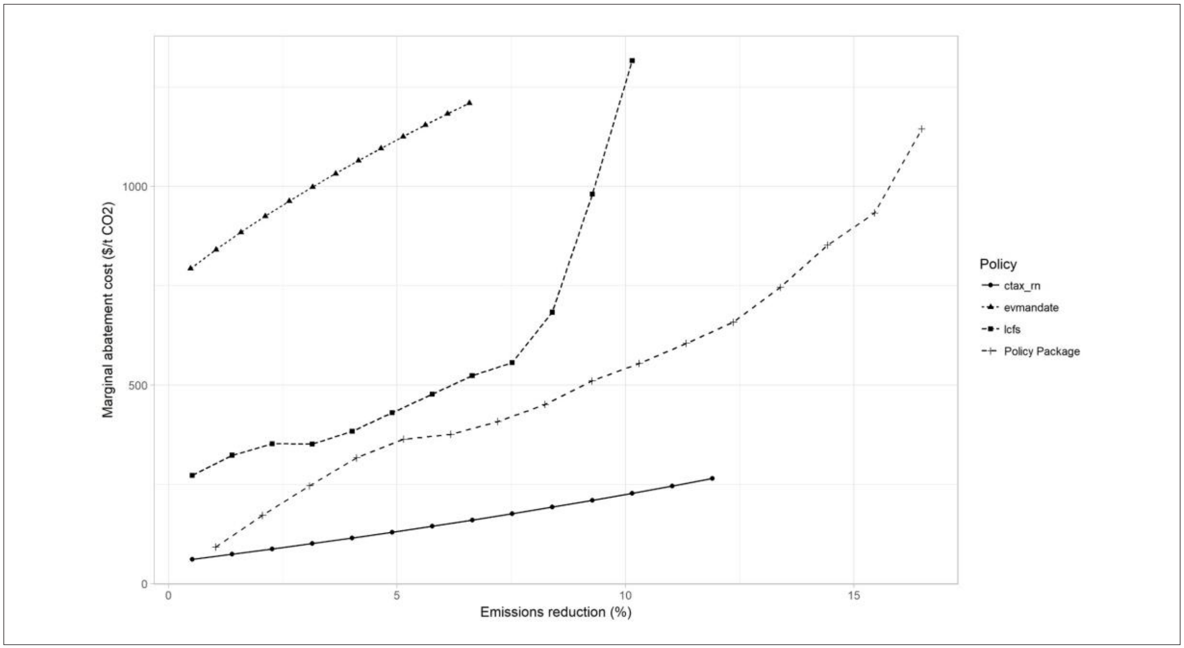
Figure 4 shows combinations of EV target and LCFS share which minimize the total economic cost (foregone consumption) associated with our central case parameter configuration. The EV target defines the target share of EVs in new vehicle sales. A value of zero means that an EV mandate is not part of the loss-minimizing policy. Any positive value shows the ratio of new EV sales to total new vehicle sales. The LCFS target defines the required reduction in fuel full cycle greenhouse gas intensity under the clean fuel standard. The first point on the curve represents the policy combination for a target reduction of one per cent, with each subsequent point representing a further one per cent reduction (relative to the policy baseline). Each point is labelled with the percentage emission reduction associated with that policy combination. The end point represents the policy combination associated with a 16 per cent reduction of passenger road transportation emissions (relative to the policy baseline). For example, to reduce emissions by 10 per cent below the policy baseline, the optimal combination of policies would include a six per cent LCFS and a four per cent EV mandate.

Looking only at the marginal abatement cost curves of the individual policies would have suggested that the EV mandate would play no role in the optimal (loss-minimizing) policy mix. This turns out not to be the case in any of our parameter configurations. The specific case of our central case parameters is illustrated in Figure 5. While the marginal abatement cost curves of both the EV mandate and LCFS are above the carbon tax, the policy package including a combination of LCFS and EV mandate is always below either the EV mandate curve or the LCFS curve.

There are many interactions among these policy instruments. In the case of an LCFS and EV mandate, the LCFS will cause an increase in the price of fuel. Initially, the increase is modest, but as the LCFS target gets larger, the cost rises due in part to limitations posed by the existing stock of vehicles. As the cost of fuel goes up, it becomes easier to convince drivers to adopt EVs. The operation of the EV mandate also interacts with the LCFS. As the share of EVs rises it becomes less costly to comply with a given LCFS because the total quantity of higher cost renewable fuels is reduced as a smaller share of the fleet is composed of internal combustion vehicles.

FIGURE 5

Marginal Abatement Cost Curves: Selected Individual Policies and Recommended Policy Package. **ctax_rn** is the revenue-neutral carbon tax; **evmandate** is the electric vehicle mandate; **lcfs** is the low carbon fuel standard; **policy package** is the optimal combination of policy instruments as described in the text.



4. CONCLUSIONS

The reduction of greenhouse gas emissions from road transport is a key policy goal. Like most others, we find that the carbon tax has the lowest marginal abatement cost of all instruments, meaning that using a carbon tax on its own would minimize the social cost of a given emissions reduction goal. This is in part because the carbon tax gives appropriate incentives at all the relevant margins, whereas the other instruments do not.

Individual regulatory instruments, such as a low carbon fuel standard, zero emission vehicle mandate or fuel economy regulation, are costly to achieve substantial emission reductions. Nonetheless, when we simulate a combination of regulatory instruments – such as Canadian governments are currently considering – we find that it is possible for the cost-effectiveness of a regulatory approach to be substantially improved. This conclusion requires judicious choice of policies to combine. Our research suggests that a low carbon fuel standard plus a relatively weak zero emission vehicle mandate would be an appropriate policy combination in Canada, given other policy measures already committed to.

Our finding that a blend of LCFS and EV mandate lowers cost relative to using one alone arises in part because by using both instruments together, we exploit the low cost segments of each marginal abatement cost curve. Because of our focus on the near term (about seven years) the LCFS marginal abatement cost curve eventually gets quite high as a result of the constraints imposed by the existing vehicle fleet, which for the most part is unable to use higher-ratio blends of some renewable fuels. Using both instruments results from more than just taking advantage of low cost portions of the marginal abatement cost curve, since the LCFS and EV mandate interact. As the share of EVs expands, the cost of satisfying a given LCFS standard falls, because less of the higher cost low carbon fuels need to be produced. Likewise, as the LCFS standard is raised, the cost of fuel for internal combustion cars rises, making it easier to convince drivers to purchase an EV.

There are many qualifications to our findings. As with any simulation study of this type, our results depend on a number of parameters, some of whose values are not estimated or on which there does not exist a consensus.[15] We also do not address two additional issues relevant to policy choice. Our model also does not allow us to assess distributional impacts since we only have one representative consumer. A further consideration is the argument that support for EVs is about enabling a significant transition from fossil fuel-powered vehicles to electric vehicles. The argument is that providing adequate supports will give market incentives for better infrastructure (charging stations in particular). Finally, we do not represent the added benefits resulting from a move to more EVs, the reduction in local air pollutants. Moving to electric vehicles from even low carbon fuels is likely to reduce local air pollution further. The benefits from such local air quality improvements can easily outweigh the benefits from reducing greenhouse gas emissions.

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[15] See the working paper for a sensitivity analysis around key parameters.

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