Assessing Canada-British Columbia Climate Policy Design and Interaction

by

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Abstract

This study tests alternative climate policy scenarios to provide useful information to decision-makers. The first component of this project evaluates how Canada, when viewed from a national perspective, can best achieve a greenhouse gas target. This was done by using the hybrid energy-economy model CIMS to simulate and compare policy approaches. For the second component, I modeled British Columbia to explore policy designs for integrating provincial climate policy with the broader national targets and efforts. Special emphasis was placed on designing policies that could gradually align initiatives by all regions and all levels of government in Canada with a similar, nation-wide marginal cost of emissions reduction. To account for the uncertainty of future natural gas production, I incorporate a sensitivity analysis by modeling each scenario in British Columbia twice, either under the assumption that liquefied natural gas is developed or absent in the province.

Keywords: climate policy; hybrid energy-economy model; British Columbia; flexible regulations; liquefied natural gas; harmonization between regions

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GHG	Greenhouse gas
UNFCCC	United Nations Framework Convention on Climate Change
ECCC	Environment and Climate Change Canada
B.C.	British Columbia
CLP	Climate Leadership Plan
LNG	Liquefied natural gas
tCO2e	Tonne of CO_2 equivalent
EITE	Emissions-intensive and trade-exposed
GDP	Gross domestic product
CAPP	Canadian Association of Petroleum Producers
NEB	National Energy Board
NIR	National Inventory Reports
BAU	Business-as-usual
PZEV	Partial zero emissions vehicle
LCFS	Low carbon fuel standard
LP	Low price
HP	High price
U.S.	United States
EIA	Energy Information Administration
bcm/y	billion cubic meters per year
CCS	Carbon capture and storage

Chapter 1.

Introduction

At the 2015 United Nations Climate Change Conference in Paris, the Canadian federal government agreed to reduce greenhouse gas (GHG) emissions 30% below 2005 levels by 2030 (UNFCCC, 2015). The previous federal government established a more distant yet stricter target at the Copenhagen Accord in 2009, where it agreed to reduce GHG emissions 65% below 2006 levels by 2050 (Copenhagen Accord, 2009). Research indicates that preventing catastrophic climate change will require a concerted global effort to meet ambitious national targets (Allan *et al.*, 2007). Both the Paris Agreement and the Copenhagen Accord are attempts for world leaders to coordinate GHG emission reduction efforts. However, to date, Canada missed all its past national GHG reduction targets.

Some critics believe this lack of success with climate policy can be attributed to a lack of political will. In fact, some politicians claim climate change mitigation should not be a priority for Canadians because climate policy could be a detriment to the economy and cost jobs. Others argue it is not critical for Canada to reduce GHG emissions since the country is only responsible for roughly 2% of global GHG emissions (Biber, 2016). However, the current leader of the Liberal federal government and Prime Minister of Canada, Justin Trudeau, argues that Canada should lead by example. Moreover, Trudeau claims that even if other countries do not work as earnestly to reduce GHG emissions, Canada will gain a competitive advantage by its early shift towards a low carbon economy (Trudeau, 2016).

The current Canadian government not only established and confirmed the 2030 and 2050 national targets, it also repeatedly affirmed the need for climate policy implementation in cooperation with other levels of government in Canada (ECCC, 2016). Thus, a number of working groups have been established to design and propose climate policies for different emission sources and economic sectors. Based on statements from the federal government, it appears plans for a national framework will not erase or supersede the efforts already made at provincial and territorial levels. In fact, the Pan-Canadian Framework, developed in collaboration with the territories and provinces, announces that local efforts can remain complementary to a broader national initiative, rather than be replaced altogether (ECCC, 2016).

There are a variety of opinions amongst experts and politicians in regard to how provincial and federal efforts could be coordinated while meeting Canada's targets in a cost sensitive way. Some economists feel carbon pricing should be the key policy tool, citing its cost-efficiency and ability to harmonize national initiatives—despite the controversial public perception of pricing schemes (Canada's Ecofiscal Commission, 2014). In fact, Environment and Climate Change Canada (ECCC) pointed to carbon pricing as a necessary component of Canada's GHG emission abatement efforts (ECCC, 2016). To this end, the federal government recently announced a backstop carbon price effective in all provinces, starting at $10 per tCO2e GHG in 2018 and increasing by $10 every year until reaching $50 in 2022 (ECCC, 2017).

However, studies strongly suggest this national carbon price trajectory, along with all other Canadian policies implemented and even proposed thus far, will not be sufficient to meet the 2030 target (Sawyer and Bataille, 2016). Canadian leaders acknowledge this, and outline their intent in the Pan-Canadian framework (2016) to implement complementary policies that would work alongside the carbon price backstop by reducing barriers to low carbon technologies. This means either existing complementary policies will need to be increased in stringency or new policies introduced.

Canada's climate targets are perhaps more challenging if their achievement also requires full agreement between the provinces and the federal government. Unfortunately, this degree of coordination often proves difficult in Canada. For example, although most provinces implemented some form of carbon pricing and the federal government announced a unilateral national carbon backstop price, there are some provincial and territorial governments opposed to carbon pricing in principle, arguing that this carbon price will be unfairly imposed on them (Biber, 2016).

Moreover, abatement efforts may face further challenges given some of the major uncertainties facing Canada's energy-economy system, key examples being liquefied natural gas (LNG) development in B.C. and oil sands growth in Alberta. In particular, the British Columbia government under previous premier Christy Clark expressed concern for how a federal emissions reduction framework would affect current and emerging provincial climate policies, and how to best proceed with GHG abatement efforts.

1.1. Objectives of this research

The objective of my study presented in this report is to assess alternative climate policy scenarios which could potentially meet federal targets to provide useful information to climate policy-makers and stakeholders in Canada and especially in British Columbia. The scenarios I present are highly relevant to current discussions at the Canadian national and B.C. provincial level. The method I use to test these scenarios is to apply a well-known energy-economy simulation model called CIMS. This tool enables me to determine the effectiveness of different types of policies at different levels of stringency in terms of their progress towards GHG reduction targets and the likely types of technologies and energy forms that would enable this transition to a low-carbon economy.

Due to challenges and uncertainty surrounding policy interactions of different levels of government — in particular between the B.C. government and the federal government — my project consists of two major components. The first component evaluates how Canada, when viewed from a national perspective, can best achieve its GHG targets. The second component focuses on assessing the appropriate contribution B.C. could make to those national targets, when considering differences in the province’s GHG reduction costs and in its current mix of climate policies.

1.1.1. National study objectives

For the first component of this project, I collaborated with Tiffany Vass, a fellow master’s student in the School of Resource and Environmental Management at Simon Fraser University, in exploring alternatives to the implementation of a single nation-wide carbon tax. This resulted in us releasing a public report in September 2016 entitled "Is Win-Win Possible? Can Canada's Government Achieve It's Paris Commitment... and Get Re-Elected?", in which we designed and simulated a package of policies able to meet Canada's 2030 national emissions target. This package of policies consisted of market-based regulations designed to approximate the efficiency of carbon pricing, which we then compared to carbon pricing alone as the alternative policy approach to achieve the 2030 target and continued reductions to 2050 (Jaccard *et al.*, 2016).

We took the following steps to meet these objectives:

1.) We simulated the ongoing effects of existing policies at the federal and provincial levels for the period of 2005 to 2050, using the hybrid energy-economy model CIMS.

2.) We simulated a carbon price path that achieved the 2030 target and continued reductions to 2050.

3.) We simulated an alternative policy package of market-oriented regulations that also achieved the 2030 target and continued reductions to 2050.

1.1.2. Provincial study objectives

For the second component of this project, I separately modeled B.C. to explore policy designs for integrating provincial climate policy with the broader national targets and efforts. Special emphasis was placed on designing policies that could gradually align initiatives by all regions and all levels of government in Canada to be approximately consistent with a singular nation-wide marginal cost of GHG emissions reduction.

Simulating B.C. required choosing a target for 2030 since B.C. under the Clark government (2011-2017) did not have one. I based B.C.'s 2030 target on my calculated estimate of the province's likely cost-effective proportion of Canada's emissions reductions under the Paris target (for more details see section 6.1). While B.C. does have a 2050 target, I chose to replace this with a target derived from its cost-effective share of achieving Canada's national 2050 target. For this latter task, I used national modeling results from Tiffany Vass, who focused on the national modeling for her research (Vass, 2016).

Thus, I executed the following steps to meet my research objectives:

1.) I first simulated the ongoing effects of existing implemented policies in B.C. for the period 2005 to 2050. At this initial stage, I excluded those policies announced in the 2016 B.C. Climate Leadership Plan, which at the time of my analysis was the latest statement of climate policy intent of the B.C. government of Premier Christy Clark.

2.) I next simulated the effects of those policies explicitly announced in B.C.'s 2016 Climate Leadership Plan, extending their implementation and thus effect through to 2050.

3.) I then simulated different carbon price paths until I found the one that would best enable B.C. to make a cost-effective contribution to the national 2030 and 2050 targets.

4.) Finally, I explored an alternative policy package that would enable B.C. to make a comparable contribution to the 2030 and 2050 national targets without using explicit carbon pricing – in other words, without increasing its carbon tax. This policy package emphasized market-oriented regulations, sometimes referred to as flexible regulations or flex-regs.

Chapter 2.

Background

2.1. Harmonization between different levels of government

Past climate policy development in Canada has been fragmented and uncoordinated. To improve the effectiveness and cost-efficiency of these initiatives, research indicates that there can be significant benefits to harmonizing policies at the federal and/or provincial levels (Tuerk et al., 2009; Burtraw et al., 2013; Taraska, 2016). This goal may be difficult, in part due to confusion surrounding responsibility between different levels of government, as well as differences in priorities and circumstances between regions in Canada, which themselves change over time depending on the shifting priorities of different governing parties.

A lack of coordination from the federal government or amongst the provinces could hinder national targets. If provinces are working individually, efforts across the country are likely to be staggered in terms of stringency and coverage. The likely outcomes would be greater emission leakage from industries relocating to regions with less stringent policies, as well as efficiency losses as some provinces pay high costs for GHG reduction that could be achieved by provinces who are currently doing less (Bodansky *et al.*, 2014).

Within the last decade, many of Canada's climate policies have been initiated by the provinces —with limited intervention from the federal government, especially during the 2006 – 2015 leadership of former Prime Minister Stephen Harper. The current federal government under Justin Trudeau agreed to allow provinces to implement either a carbon tax or a cap-and-trade program. However, if a province is unwilling to implement its own carbon price the federal government will step in with a price floor, which it refers to as a “backstop” carbon price.

Recently, the federal government elaborated on these plans by detailing two elements that will be used to introduce the backstop price. A carbon levy will be imposed on all emissions except those of major industrial emitters (Government of Canada, 2017). The latter will be subject instead to an emission intensity reduction obligation, which it refers to as an “output-based intensity” requirement. To meet this obligation, industries must either abate GHG emissions or buy surplus permits from other industries to exceed their benchmark intensity obligation (i.e. the maximum intensity facilities can operate at without paying for credits). However, unlike the similar Specified Gas Emitters Regulation in Alberta, the benchmark will not be based on historic facility emissions. Instead it will be chosen based on the specific product the industry produces (Alberta Government, 2017).

However, there is still considerable uncertainty as to the mix and stringency of Canada's climate policies. In particular, it is still unclear how cooperation between the provinces and the federal government will progress. In this study, I seek to provide analysis that will be of help to the governments of B.C. and Canada, and other interested parties, as they pursue climate policy harmonization and integration. In the next section, I describe the climate policy context in B.C., as well as some of the circumstances particular to B.C. which may affect how its policy is or can be designed.

2.2. Climate policy in B.C.

B.C. has enjoyed a reputation as a climate policy leader. This stems from the province's implementation in the period 2007 to 2009 of a low carbon fuel standard, a clean electricity standard, and a carbon tax. In particular, the province's carbon tax garnered much attention from academics and the media. The carbon tax was the first of its kind in North America (Jaccard, 2012). It is revenue neutral, with a large proportion of funds returned as income and corporate tax breaks, or lump sum payments to low income families. Additionally, the tax has broad coverage, as it applies an even price signal to all fossil fuel combustion emissions, which account for about 75% of total provincial GHG emissions. The tax started at $10 per tCO2e in 2008 and rose to $30 per tCO2e in 2012 — where it remained frozen (B.C. Ministry of Finance, 2013).

The B.C. government under Christy Clark was criticized by climate action advocates because of its freezing of the carbon tax, and its plan to expand natural gas extraction through the development of liquefied natural gas (LNG) facilities on the coast for export to east Asia and other potential markets. The Clark government countered these concerns by claiming climate policies could be implemented allowing B.C. to meet its emission targets and still develop LNG. This would be achieved by offsetting an increase in emissions from LNG through emission reductions elsewhere —such as from transportation and buildings (Government of B.C., 2016). The Clark government also indicated it would reduce emissions in the natural gas sector, in particular, upstream of the production of liquefied natural gas. This includes plans to electrify extraction and processing activities which are currently isolated and predominantly use fossil fuels to power their operations (Government of B.C., 2016). In sum, the government's LNG Strategy claimed facilities in B.C. will be some of the cleanest in the world (Government of B.C., 2016).

The B.C. government (2011-2017) claimed these plans would satisfy climate commitments and strengthen the economy. However, analysis by Environment Canada (2014) shows the province will widely miss its 2020 target, whether or not LNG is developed. Were the current BC government to follow through in the plan to develop LNG on the coast of B.C. it would be relevant for policy-makers to know its effect on provincial GHG emissions. In particular, it may be beneficial to know whether LNG and associated shale gas expansion can occur without increase in BC GHGs.

Furthermore, the only other provincial target is for 2050, avoiding the 2030 timeframe that virtually every national government in the world committed to in Paris in 2015. A lack of interim goals makes it more challenging to know whether the province is on the right track, making it easier for politicians to appear sincere even if their climate efforts are negligible. Therefore, it may be valuable to explore what B.C.'s contribution should be to Canada's national commitment for the 2030 timeframe.

These circumstances present several challenges for B.C. Will the current government strengthen its existing policies, or will new policies be implemented? Complicating these issues is the array of potential climate policy options. In the next sections I review some of the possible criteria that can be used to assess these policies, as well as some of the concerns and trade-offs that may be beneficial to consider when designing climate policies.

2.3. Assessing climate policy

Climate policy can range from simple to complex. There is an array of policy options to choose from, including: subsidies, information campaigns, regulations, carbon pricing, and government funding and management decisions. To complicate the matter, policies can either work independently or as a package. For example, regions in Canada can link up to implement policies, such as the cap-and-trade program linking Quebec, Ontario, and California; or work in isolation, such as the carbon tax in B.C. Furthermore, within each policy there are countless potential design features and decisions to be made.

Policy analysts note that when assessing climate policy, one might apply several criteria. In this section, I review four criteria which are commonly referred to in academia when assessing climate policies: (1) economic efficiency, (2) effectiveness, (3) administrative feasibility, and (4) political acceptability (Jaccard, 2006).

The economic efficiency of a policy refers to its cost relative to other policy options. Different policies may be able to bring about a similar reduction in GHGs. However, one policy may achieve this at a lower cost to society. For example, subsidies are often considered inefficient because it is difficult to predict what technology or activity should be funded over others. One term to describe this is "picking winners" where a government or funding agency chooses the technology most likely to become commercially viable instead of letting market activity dictate this. However, the government may pick a loser, thus wasting money on a technology that ends up being high-cost relative to alternatives. It is also possible that a subsidy will be awarded to an action that would take place without the subsidy. This is called "free-riding," where an individual or firm receives money from a program that tries to incentivise new behaviour, but instead supports routine behaviour (Linares and Labandeira, 2010). This is considered an inefficient use of funds because it will not bring about further emission reductions.

Policy effectiveness refers to the ability of a policy to bring about the desired GHG abatement. Compulsory policies such as carbon pricing or regulations are considered to be effective because if designed well they can force changes in technology and fuel consumption, either through a mandate or pricing incentives.

However, even a compulsory policy can be ineffective if it is not stringent enough. For example, in 2009 B.C.'s carbon tax only increased gasoline prices by 2.4 cents per litre. However, gasoline prices had recently increased by 50 cents per litre due to spikes in global oil prices (Jaccard, 2012). In this case, the carbon price effect on technology choice and behaviour may well have been lost in the noise of major gasoline price fluctuations in the period 2008 to 2012. Although the B.C. carbon tax has been extensively analyzed and deemed successful at abating emissions, the tax was still relatively low at this point, therefore dampening some of its effectiveness.

A third criterion for assessing climate policies is administrative feasibility. A policy is considered to be administratively complex if its implementation requires a significant increase in private or public administrative costs, such as an increase in bureaucracy. For example, a cap-and-trade program is considered more administratively complex than a carbon tax because it requires the establishment of a market for permit trading and brokers to administer this market. On the other hand, revenue from a carbon tax, at least on emissions from regular fuels, can be collected through a region’s established taxation system, and often does not require much bureaucratic expansion (Smulders and Vollebergh, 2001).

The fourth and final criterion I consider is political acceptability. This refers to the perception different segments of the voting public have of any given policy. If voters perceive the policy as justified and fair it is more likely to garner support and not be terminated by public opposition. For example, research suggests that carbon taxes are less politically favourable in comparison to any other type of climate policy. A study that surveyed citizens of B.C., investigated what climate policies the public was aware of (Rhodes *et al.,* 2014). The study found that British Columbians did not know most of the climate policies in place at the time of the survey. When the participants were able to recall a policy, the most frequently cited was the provincial carbon tax. However, it was also the most opposed. Both the increased awareness and opposition for the carbon tax is believed to be caused by increased salience of the explicit price relative to other policies (Harrison, 2012; Olson, 1965). In fact, when participants of the survey administered by Rhodes *et al.*, (2014) were told about other climate policies in place at the time of the survey — such as regulations, subsidies, and information campaigns — these policies were predominantly supported.

However, even though carbon pricing is more explicit, other policies still have a cost that is often less obvious to the public. Some researchers measure the implicit price of a regulation as the level of carbon pricing needed to bring about the same amount of GHG abatement. These prices can also be quite high although they are concealed. For example, research estimates that B.C.'s Clean Electricity Standard has an implicit price of $148 per tCO2e (Rhodes and Jaccard, 2013), yet this standard received greater public support relative to the carbon tax—despite an estimated higher cost. This implies that public perception affects the political acceptability of a climate policy, and is likely an important consideration for policy-makers.

2.4. Political challenge of implementing climate policy

Research suggests that effective climate policy is politically difficult to implement. Public opposition is often linked to the inherent cost imposed by stringent climate policy (Simpson *et al.,* 2007). However, there are many policies, such as government expenditure on health and education, that increase costs to society yet are predominantly supported. Below I address some additional factors that likely affect public perception and make climate policy implementation challenging. These factors may be useful for considering trade-offs between climate policy designs. Moreover, these factors are relevant to this study as they provided substantial rational to the mixture of climate policies I chose to simulate for my analysis.

First, although it is not possible for scientists to predict exactly the magnitude or timing of climate change, they do predict that it will affect future generations more significantly than current ones. However, energy and climate researchers argue that the type of change necessary to bring about a low carbon shift will need to happen soon. This early shift is recommended because huge costs to society can be prevented if low-emission technology acquisition happens slowly over time to approximate natural technology turnover. Therefore, most of the costs from climate change mitigation will be experienced in the present and the greatest benefits in the future. This circumstance creates a gap between the incentive to act and the reward from implementing climate policy.

Second, often it is difficult to recognize the effects of climate policy since it can take several years, even decades, for an energy transition to occur (Hulme, 2009;

Marshall, 2014). Furthermore, the influence of climate policy on technology acquisition, retirement, and retrofit choices can be diffuse and widespread throughout an economy. This may make it difficult for a voter to differentiate between the effect of a climate policy, and what is being caused by other economic and political factors —or technology advancements independent of climate policy. For example, the past Conservative federal government claimed that greenhouse gas emissions had decreased in Canada due to climate policy. Critics argued that this was not caused by Canadian climate policy, but instead by the economic recession which slowed consumption, and therefore greenhouse gas emitting activity (Maclean's, 2015). This type of discussion can raise much confusion since it is difficult to unravel the many factors responsible for activities and emissions in an economy.

Third, perception can be more important than reality. Studies find that many individuals believe policy will affect them negatively, even when the policy has a net-benefit to society and has been designed to mitigate distributional effects. For example, a survey suggested that 70% of British Columbians believed the provincial carbon tax caused them to incur a net financial loss, despite the fact revenue was being returned in the form of income and corporate tax breaks (Harrison, 2013). Research found that only 20% of the public were at a net loss under the tax, and most of these losses were concentrated in the upper income brackets. It appears the public's appreciation of income and corporate tax breaks did not outweigh their disdain of having to pay the carbon tax. Psychologists attribute this perception to the human tendency to experience losses more greatly than gains (Kahneman, 2015).

Fourth, an invested minority can have a disproportionate sway on the implementation of a policy (Olson, 1965). Even if a climate policy has a net-benefit to society, if the benefits are diffused across many individuals and the costs are concentrated on a few, the policy is less likely to be politically viable. This is because those who face concentrated costs will have more of an incentive to lobby or protest against the policy than the great majority who are receiving much smaller benefits per person.

The above factors are believed to contribute to the reluctance of politicians to initiate policy (Simpson *et al.,* 2007). However, in the last couple of decades there has been an increase in public awareness with regards to the existence and threat of climate change. Since governments may feel some public pressure to address the issue, even those politicians which do not believe climate change mitigation should be prioritized, may be incentivized to take some action. This presents a problem for policy-makers who may want to balance the pressure to act on climate change with implementing a policy favourable to the voting public.

Balancing these often contradictory influences may result in sacrifices with respect to some of the criteria. For example, if a politician expects public backlash from policy implementation, one strategy is to sacrifice some of the effectiveness or economic efficiency of a policy in exchange for greater political acceptability. Then, once a policy has been established, along with the corresponding legislature and bureaucratic framework, it might be easier to increase its stringency if conditions for stronger policy become more favourable in the future. For example, if other countries begin to implement stringent policies, this will likely decrease the competitive disadvantage experienced by a jurisdiction which applied climate policy early. This may change the perception of firms and individuals who were previously concerned that their business would be damaged or jobs would be lost.

Considering the political difficulty of implementing climate policy, it may be beneficial for policy-makers to assess whether it is reasonable to sacrifice policy effectiveness or efficiency to improve perception of the voting public. Since studies suggest that compulsory climate policies are the most effective at reducing GHG emissions, a substantial component of this analysis is assessing the two main categories of compulsory policy: carbon pricing and regulations. In the following chapter, I describe some of the potential sacrifices to effectiveness and efficiency a politician makes when choosing to implement one over the other.

2.5. Designing compulsory policy

Both regulations and carbon pricing are types of compulsory policies that can be used together or as substitutes to effectively reduce emissions. However, carbon pricing is likely to be more economically efficient than regulations (Canada's Ecofiscal Commission, 2014). This suggests that carbon pricing —which includes carbon taxes and cap-and-trade programs —may be a more favourable option than regulations.

However, the economic efficiency advantages of carbon pricing are often demonstrated by comparison to the most rigid forms of regulation. These are command-and-control policies that mandate a specific action or technology adoption. Instead, governments could implement flexible, market-based regulations, which are more economically efficient than command-and-control regulations (Goulder and Parry, 2008). These types of policies are less prescriptive and will usually allow market forces to determine how a mandate is met. This variety in regulations implies that economic efficiency losses of regulations may be exaggerated when compared to carbon pricing.

Another feature of carbon pricing is that revenue collected from taxation or the auction of permits in a cap-and-trade program can be used for a variety of purposes. These include income and corporate tax breaks, lump sum payments to reduce distributional effects, or funding for government subsidy programs. In particular, advocates for carbon pricing often reference the potential boost to GDP from cutting income and corporate taxes. However, not all carbon pricing is designed to include this feature. In fact, B.C. is the only jurisdiction in North America that cuts income and corporate taxes with carbon pricing revenue. There is no assurance that once a carbon price has been implemented it will be designed in this form. Even though the federal government announced that its backstop carbon price will be federally revenue neutral, it does not mean that the provinces will use the revenue for productivity enhancing tax cuts.

Moreover, carbon pricing and regulations can both be designed to achieve other similar benefits. For example, both types of compulsory policies can be designed to protect emissions-intensive and trade-exposed (EITE) sectors of the economy (Parker and Blodgett, 2008). Under a taxation program, certain sectors can receive revenue as compensation. Under a cap-and-trade program, permits can be awarded free of charge to more vulnerable sectors. A similar approach can be used when applying flexible regulations. Certain sectors can receive more lenient mandates or receive government funding as compensation. Lastly, under both regulations and carbon pricing, trade measures such as GHG-related tariffs can be imposed on imports to protect domestic industries.

Both types of compulsory policies can also be designed to reduce distributional effects among regions and income groups. Under a carbon price, revenue can be returned in the form of lump sum payments to reduce the regressive nature of these policies (Büchs, et al, 2011). Under a regulation, sectors or demographics can receive differential policy stringency, or government funding as compensation.

Keeping in mind the above points, it may be possible to design a package of flexible regulations that are effective at reducing GHGs, while also mitigating distributional impacts, protecting trade exposed and emissions-intensive industries, and approximating the efficiency of carbon pricing. This is not to say that regulations are the perfect solution to implementing successful climate policy. Under different circumstance carbon pricing may be more appropriate. However, it may be valuable to consider the trade-offs and similarities between the two types of policies, instead of over stating the benefits of one or the other.

Chapter 3.

Methods

In this chapter, I summarize the methodology I used for this project. Specifically, I describe the hybrid energy-economy model called CIMS. This model incorporates some of the benefits of both top-down and bottom-up models. Therefore, in section 3.1, I review top-down models, in section 3.2, I review bottom-up models, and, lastly, in section 3.3, I describe what a hybrid model is, and what features of top-down and bottom-up models are included in the hybrid model CIMS.

In this chapter, I also describe how CIMS is maintained, and populated with data, parameters, and exogenous drivers (section 3.4). I also include an outline of the specific updates made to CIMS for this study (section 3.5). Lastly, in section 3.6, I describe the macroeconomic functions I used for the simulations in this study, and some of the features of CIMS that influence how the results should be interpreted.

3.1. Top-down models

A top-down model is one that evaluates an economy using broad scale indicators, such as GDP, investments, expenditures, employment, and trade. These models base their key parameters on historical market data. Therefore, they are thought to be more behaviourally realistic at the micro-economic level in terms of how they simulate the decisions firms and individuals make when purchasing and using technology.

However, top-down models are somewhat inappropriate for assessing technology specific policies since they are not disaggregated by the individual technologies that consume or produce energy in an economy. Instead these models are only able to approximate emissions and energy consumption from economic activity.

The strength of a top-down model is its ability to capture macroeconomic effects from policy changes. These models are often able to capture price feedbacks, structural changes, and rebound effects (Bergman, 2005; Bohringer, 1998). An example of the rebound effect is when increased energy efficiency is expected to decrease energy consumption by a specific amount. However, due to the decline in operating cost, the technology is used more than before. This offsets some of the expected reduction in energy consumption (Owen, 2010). Models that fail to capture this effect would overestimate the energy and emission reductions from policies mandating greater energy efficiency.

Finally, a top-down model, such as a computable general equilibrium model (CGE), is useful for simulating different government revenue uses. This makes CGE models ideal for assessing the economic and equity effects of alternative uses of revenue collected from carbon pricing. For example, revenue may be returned in the form of lump sum transfers, income and corporate tax breaks, or as funding for government projects. This funnelling of revenue into different parts of the economy can cause GDP changes and structural effects which only a model with macroeconomic feedbacks can capture.

3.2. Bottom-up models

Bottom-up models, in contrast, are characterized by their technological and energy end-use disaggregation. They usually include a database of technologies that consume and/or produce energy in an economy (Loschel, 2002). They are particularly useful for modeling technology specific policies, such as niche-market regulations which mandate a specific market share for certain low-emission technologies, or a building code which sets a standard for specific insulation levels.

However, these models are criticized for their lack of behavioural realism, particularly their inability to factor in the heterogeneity of consumers (Jaffe *et al*., 1999). Thus, for example, in producing estimates of energy and GHG reduction costs, some bottom up models only consider the explicit financial costs of two competing technologies, implicitly assuming that these are perfect substitutes for all consumers and firms (Murphy and Jaccard, 2011; McKinsey and Company, 2009).

In reality, firms and individuals have different perspectives and preferences that influence their use and purchase of technologies. And they may face different financial costs when making these decisions. Ignoring this reality can lead to simulations in which a bottom-up model predicts low costs for GHG abatement because it implicitly assumes that everyone would adopt low- to zero-emission technologies as soon as they become financially affordable. These simulations usually do not include other factors that may slow market penetration of the newer technologies, including different perceptions of intangible costs and risks (Murphy and Jaccard, 2007).

3.3. Hybrid energy-economy models

The CIMS model I used in this study is known as a hybrid energy-economy model in that it attempts to incorporate the positive attributes of conventional top-down and bottom-up models. CIMS does this by combining three factors which are not typically seen in the same model: behavioural realism, technological explicitness, and partial macroeconomic feedbacks (Jaccard, 2009).

The Canadian version of CIMS is divided into individual provinces, except for the maritime provinces, which are treated as one region. Within each CIMS provincial model, individual sectors of the economy demand and/or supply energy services. Within these sectors, there are technologies competing for market share to produce different forms of energy or to satisfy the energy end-uses of consumers (Rivers and Jaccard, 2005). These technologies compete for market share based on a number of factors, the most conventional being financial costs. However, CIMS is not a simple financial cost minimization model that presents all individuals and firms as identical cost minimisers. Instead, CIMS also incorporates intangible costs, which represent all costs that are not explicitly monetary — including perceived risk, lack of awareness, status implications, and lack of supporting infrastructure (Bataille *et al.*, 2007).

The model also accounts for the heterogeneity of firms and individuals. They often have different perceptions and preferences, and may even face different financial costs. This measure of heterogeneity describes how sensitive individuals and firms are to changes in price. Finally, these financial and intangible costs, when occurring in future periods, may be discounted at different rates to account for the distinct time preferences for different types of decision makers (large industry, small industry, consumers) (Bataille *et al.*, 2007).

Furthermore, costs and preferences are not treated as static over time. CIMS has two functions that incorporate these dynamics: declining capital cost and declining intangible cost. The declining capital cost function reflects learning-by-doing and economies-of-scale that reduce the capital costs of new technologies as they penetrate the market. This reduction is accomplished by linking capital cost to cumulative production in the model. The declining intangible cost function reflects changing preferences and consumer perceptions as new technologies penetrate the market. It does this by linking intangible costs to market share in a given period of the model. The parameters for these two functions are derived from empirical research (Bataille *et al.*, 2007).

Lastly, CIMS is a partial equilibrium model. This means that unlike a top-down model, such as a computable general equilibrium model, CIMS does not simulate structural changes caused by climate policy for the economy as a whole. Instead it is only capable of balancing the supply and demand for energy services. This means that GHG abatement is achieved in the model simulation by switching technologies or fuels. However, it does not capture the full emission reductions which stem from climate policy influencing further changes in factors such as: sectoral output, total income, trade, and employment.

3.4. Data, parameters, and exogenous drivers in CIMS

The Energy and Materials Research Group at Simon Fraser University and the off-campus consulting firm maintain CIMS. Although some of the data and exogenous drivers in CIMS are routinely updated, some data, exogenous drivers, and parameters are compiled over several years and involve efforts from many individuals. In this section, I describe how the current information in CIMS has been acquired or estimated.

The information in CIMS can be broken into three main categories: technological data that represent the cost, market shares, operating, and maintenance characteristics of technologies; behavioural parameters that represent how firms and individuals make decisions about technology acquisition; and exogenous drivers, such as economic growth or globally determined energy prices, that influence the trajectory of GHG emissions in the model.

In terms of technological data, they are either based on real-world engineering characteristics of current technologies, or assumptions on future and emerging technologies. For technologies currently on the market, data are often easily accessible from trade journals, manufacturers, retailers, agencies, and governments. In contrast, finding market share and operating data for technologies in operation for several years is more difficult since these technologies are usually unmonitored and may fail to keep their original characteristics. Possible exceptions are industrial technologies where facilities are required to monitor and report on equipment. Lastly, data for capital costs and operating characteristics of emerging technologies are the most difficult to estimate. One method to represent the changing costs and characteristics of emerging technologies is to base estimates on empirical evidence derived from historical trends. Another method is to rely on expert judgement (Jaccard, 2009).

In the case of simulating technology choices of firms and households, key parameters are estimated using a revealed or stated preference method. In the former, analysts quantify historical decisions made by firms and individuals under different contexts. In the latter, researchers survey individuals or firms to ask what technologies they would prefer under different circumstances, such as different costs or performance characteristics. These data are then used to statistically estimate key model parameters that determine technology acquisition, retirement, and retrofitting decisions (Jaccard, 2009).

Lastly, exogenous drivers are often retrieved from governments, researchers, or agencies, that publish forecasts for key economic drivers such as fuel prices, GDP, and population. Additionally, GHG emission forecasts are retrieved from similar sources, and are used to calibrate CIMS to ensure that sectors in the model produce reasonable emissions overtime in the absence of new policies.

3.5. Changes made to CIMS for this study

3.5.1. Updated exogenous drivers

Some data and exogenous drivers in CIMS are updated regularly, whereas, some of the data, exogenous drivers, and parameters have been compiled slowly over time. For example, the historical data in CIMS are usually not updated unless a major revision is made by the organization that published it. However, some exogenous drivers are made available annually, such as fuel prices and production forecasts, and can be updated in line with available publications. I (and collaborating researcher Tiffany Vass) made the following updates to CIMS for the purposes of this study:

- We based production forecasts for the oil, gas, and mining sectors on the reference case from the National Energy Board's (NEB) *Canada's Energy Futures 2016* report (NEB, 2016). The one exception is the activity level in the natural gas sector for the provincial study, which I obtained from the Canadian Association of Petroleum Producers (CAPP, 2015).

- We updated fuel price forecasts for conventional fuels, such as refined petroleum products and natural gas, using forecasts from the *Energy Futures 2016* report (NEB, 2016).

- Since biomass price forecasts vary greatly depending on the source, we took an average estimate from the International Renewable Energy Agency (2012) and the US National Renewable Energy Laboratory (2016).

- We calibrated GHG emissions in CIMS to historical emissions using the Canadian National Inventory Report (Environment Canada, 2015).

3.5.2. Adding biomethane as a fuel

For this study, I introduce biomethane as a fuel option in CIMS. Biomethane is often referred to as renewable natural gas since it is processed to closely match the quality of conventional natural gas. This is unlike biogas, which is cheaper to produce, but is also less processed and not of sufficient quality to be blended with natural gas during transportation or combustion. In contrast, biomethane has the advantage of being blendable with natural gas, and therefore, under a carbon constrained world is likely to be a direct competitor with natural gas. For this reason, I allow industrial boilers and co-generators to consume biomethane starting in 2015 to produce heat and power.

Since natural gas boilers are indiscriminate between burning biomethane or natural gas, I allow a competition between natural gas and biomethane as fuel input to industrial boilers. I adjusted the model so that boilers do not demand natural gas directly as a fuel. Instead boilers demand “methane fuel services”. Methane fuel services is a separate node which simulates a competition between natural gas and biomethane.

The combustion of biomethane does not contribute to GHG emissions as represented by the model. Even though burning biomethane produces emissions, these can be considered part of the natural carbon cycle unlike fossil fuels. Furthermore, biomethane is not actually being produced within a sector in CIMS. Without simulating biomethane production we are not factoring in the cost of investing and operating methane capture technology at waste and sewage plants, and processing facilities. However, I assume that these costs are reflected by the prices being paid by consumers.

Fortis BC quotes the average biomethane price paid by consumers as $14.41 in 2016$/GJ (or $11.93 in 2005$/GJ) (Fortis BC, 2016). Finding prices for biomethane is quite difficult and I couldn’t find an available forecast for how prices may change. Instead I took the price for natural gas in the same year and calculated the percentage difference with biomethane. I then created a biomethane price forecast (Table 1) by anchoring it to the NEB natural gas price forecast and kept the percentage difference the same until 2050 (NEB, 2016). It should be noted that the NEB historical and forecast prices represent retail prices to consumers, including transportation, delivery, and various taxes.

Table 1. Prices for natural gas and biomethane used in the CIMS model

Year	Natural gas prices in 2005$/GJ (historical and forecast based on NEB)	Biomethane prices in 2005$/GJ
2005	8.22	16.90
2010	5.68	11.67
2015	5.81	11.93
2020	6.48	13.31
2025	6.53	13.42
2030	6.54	13.44
2035	6.56	13.47
2040	6.58	13.53
2045	6.58	13.53
2050	6.58	13.53

3.6. Macroeconomic functions in CIMS

CIMS can produce some of the economy-wide feedbacks that one would expect from a policy that changes production costs and retail prices via regulations or emissions pricing. In this section, I describe some key feedbacks in CIMS and my rationale for either enabling them or disabling them in this study.

Table 2 below lists the various macroeconomic functions in the CIMS model. The first is energy supply-demand, which when enabled allows the model to find an equilibrium between the energy supplied by energy producing sectors and the energy demanded by all sectors in the model. Therefore, this function can capture changes in the production and price of fuels in the Canadian economy under different domestic climate policy signals. As can be seen in Table 2, I enabled the energy supply-demand function. However, for the purposes of this study it is inappropriate to allow the price and production of all fuels produced in Canada to be affected by domestic climate policy. Since prices for fuels such as coal, natural gas, refined petroleum products, and crude oil are determined by global markets, these prices are set exogenously.

I also assume that production of these fuels (coal, natural gas, refined petroleum products, and crude oil) will not be affected by any of the climate policies I simulate in this study because if demand decreases any excess production can be exported. Therefore, I set production exogenously. However, for electricity and biofuels I assume that most domestic production is consumed domestically, and therefore, Canada is not a price taker for these markets. I assume that the price and production of electricity and biofuels are affected by changes in demand brought on by domestic climate policies. Thus, I set them to be endogenously determined.

Table 2. Settings for macroeconomic functions used in the CIMS model

Function	Setting
Energy Supply-Demand	Enabled
Energy Production and Pricing:	
Coal	Exogenous
Natural Gas	Exogenous
Electricity	Endogenous
Biofuels	Endogenous
Refined Petroleum Products	Exogenous
Crude Oil	Exogenous
Revenue Recycling	Enabled
Foresight	Average
Macro-economic feedbacks	Enabled
Energy Trade	Disabled

Next, Table 2 lists the revenue recycling function, which I enabled for the simulations in this study. The revenue recycling function determines whether revenue from carbon pricing is returned to the sector and province from which it was originally collected. Since this function is enabled, when CIMS is calculating average technology costs it does not include the added cost from carbon pricing. Furthermore, by turning on this function I assume that leakage effects between regions are minimized.

Abatement decisions in response to carbon pricing are affected by a function in CIMS called the foresight function that anticipates future trends in prices, including expectations for carbon pricing. I set this function to average (Table 2), which means that economic agents calculate technology costs with the average expected carbon price over a technology's lifespan. Were I to set the function to current, the model would simulate decision-makers who calculate the costs of their technology and energy options using only the energy prices at the time of their decision. I set the function to average because a rising carbon tax would likely be well-advertised by government, thus leading to decisions by households and firms that to some extent include anticipation of future fossil fuel price increases caused by climate policies.

However, enabling the foresight function means that although two scenarios could have the exact same carbon price in one period, if one scenario has an increasing carbon price trajectory, the effect on GHG emissions in that particular period would be somewhat greater. This is important to know when interpreting the results since I do not imply that any one carbon price is sufficient to bring about a certain reduction in GHG emissions. Instead I imply that the context within which the carbon price is applied, including the pricing trajectory, can significantly impact the course of GHG emissions abatement.

CIMS has two macro-economic components. One is the energy trade function, which consists of elasticities that adjust the relative shares of Canadian energy products and foreign energy products in domestic and export markets. I disabled this function for the simulations in this study (Table 2) because I assume that Canada will protect its emissions-intensive, trade-exposed (EITE) energy sectors. Furthermore, oil (in the case of the national study), and natural gas (in the case of the provincial study) are subject to sensitivity analysis which consist of very specific fuel output trajectories as part of scenario setting. Thus, it would be inappropriate to enable the energy trade function because it would conflict with this scenario setting. Since measuring the response of international fuel competitiveness to climate policy is not an objective in this study, I did not model Canada's global energy trade.

The other macro-economic component in the CIMS model is a macro-economic feedback function on the output of industrial sectors. As can be seen in Table 2, this function has been enabled for the simulations in this study. This function consists of elasticities on the manufacturing of non-energy commodities that adjust domestic output based on changes in the cost of production and the effect of this on the international competitiveness of Canadian industry. In other words, this function causes structural change in the Canadian economy in response to the production cost changes caused by domestic climate policies. Additionally, output in domestic industrial sectors is linked to changes in the transportation, residential, and commercial sectors by elasticities in another function. I enabled this function to represent some of the macro-economic feedbacks that occur within the Canadian economy. However, not all factors affecting the magnitude and direction of structural change were explored in my project, such as coverage and stringency of foreign climate policy.

It should be noted that CIMS is only a partial-equilibrium model and is not capable of representing the full macro-economic feedbacks from climate policies. Experience linking CIMS to models with full-equilibrium capabilities, such as a computable general equilibrium model, shows that the carbon prices suggested by CIMS alone are too high. Therefore, the prices I quote in the results section have been judgmentally adjusted downward by 25%, consistent with the approach taken in Jaccard *et al.* (2016). I summarize these adjustments in Appendix A.

Chapter 4.

National simulation assumptions

As noted in the introduction, in this section of the report I describe an analysis I did in collaboration with Tiffany Vass, where we explored a flexible regulations approach and a carbon pricing approach to achieve Canada's 2030 national emissions target, with continued reductions to 2050.

This analysis resulted in a report entitled "Is Win-Win Possible? Can Canada's Government Achieve It's Paris Commitment... and Get Re-Elected?", which was released in September 2016. This report was co-authored with our thesis supervisor, Dr. Mark Jaccard. Because this analysis was done prior to the announcement of the national backstop carbon price, the national coal phase-out, and the clean fuel standard, none of these were included in the following simulations.

4.1. Sensitivity analysis: oil sands in Alberta

Oil Sands production in Alberta is dependent on the global oil price. However, the model used in this study is not connected to a global oil supply-demand model. Since global oil prices are known to fluctuate greatly and the future price is equally uncertain, I represent two distinct oil price forecasts to provide a range of possible outcomes for each of the scenarios simulated.

shows the exogenous oil price assumptions retrieved from the NEB for each of the forecasts (NEB, 2016). For the high oil price trajectory, the global price is assumed to increase to $80/bbl in 2020, reaching $100/bbl by 2040, and remaining constant until 2050. The low oil price is assumed to remain constant at $50/bbl until 2050.

Table 3 below shows the exogenous oil price assumptions retrieved from the NEB for each of the forecasts (NEB, 2016). For the high oil price trajectory, the global price is assumed to increase to $80/bbl in 2020, reaching $100/bbl by 2040, and remaining constant until 2050. The low oil price is assumed to remain constant at $50/bbl until 2050.

Table 3. Endogenous oil price and output forecasts used in the CIMS model

	Oil Price Trajectory	Oil Sands Output
High Price	Rises to $80/bbl in 2020 and reaches $100/bbl in 2040, where it is held constant up to 2050	Rises to 6 mbd by 2030 and stays constant until 2050
Low Price	Stays constant at $50/bbl until 2050	Stays constant at 2.5 mbd up to 2050

Table 3 also summarizes the exogenous output made for the high and low oil price forecasts. The low oil price forecast holds oil sands output at its 2015 level of 2.5 mbd, which remains constant to 2050. The high oil price output is set judgmentally to provide a reasonable contrast with the low-price forecast. This output is set to rise from current levels to 6 mbd by 2030, staying constant after that to 2050.

Given that oils sands output is represented exogenously, the model is unable to capture output feedbacks caused by changes in the cost of production. This is a limitation of this study because climate policies such as the ones simulated in these scenarios can be expected to change the cost of production of oil sands oil. It can be assumed that if cost feedbacks from climate policy were captured by the model, GHG emissions would fall further, due to decreases in oil sands output caused by increases in its production cost. Of course, the magnitude of this decline would depend on the stringency of climate policy in other oil producing countries, but since oil sands has among the highest production emissions, strong global climate policies in Canada and elsewhere would certainly have a downward effect on oil sands output.

Climate policy within Canada is unlikely to affect the global oil price. However, if Canadian climate policies affect the prices of refined petroleum products in Canada, the model will simulate reduced domestic demand. A lower oil price suggests that individuals and firms will consume more refined petroleum products for a given stringency of climate policy, and therefore, GHG emissions from end-users can be expected to increase. On the other hand, a higher oil price will result in less consumption of refined petroleum products, and therefore, GHG emissions from end-users can be expected to decrease.

4.2. Simulation scenarios

We modeled three policy scenarios for the national simulation. These include a business-as-usual (BAU) scenario, a carbon pricing scenario, and a flexible regulations scenario. The detailed design and rational for simulating each scenario is described below. It should be noted that for each of the three scenarios, both oil price forecasts are applied to assess how sensitive the results are to changes in global oil price.

4.2.1. Business-as-usual scenario

The BAU scenario represents ongoing effects from current and committed federal and provincial climate policies in Canada from 2005 to 2050. The stringencies of the policies in the BAU are consistent with announced or legislated policies as of September 2016. This scenario serves as a contrast for the other scenarios simulated in this study that explore potential increases in climate policy stringency relative to BAU.

We modeled the following federal policies for the BAU scenario:

Federal policies

- Light and heavy-duty vehicle emission standards on transportation sectors.
- Performance standard on coal-fired electricity plants that regulate plants to shutdown or introduce carbon capture and storage.
- Methane regulations on oil and gas mandating a reduction of national methane emissions by 45% below 2012 levels by 2025.
- National renewable fuel standard mandating 5% renewable fuel by volume in gasoline pools and 2% renewable fuel by volume in diesel pools.
- Federal budget commitments targeting low-emission technologies and infrastructure. These budget commitments were modeled as subsidies in the following sectors: oil and gas, buildings, vehicles, electricity, and public transit infrastructure.

Provincial policies

The following section describes the BAU policies simulated for each of the Canadian provinces. It should be noted that we chose not to give a provincial climate plan incremental credit for announcing a policy that the federal government earlier promised to implement, and for which the federal government has regulatory authority. Thus, for example, Canadian provincial governments cannot take credit for implementing emissions pricing if they are doing this only to ensure collection of revenues in a policy and at a carbon price level to which the federal government already committed.

We modeled the following provincial policies for the BAU scenario:

British Columbia

- Clean electricity standard requiring 93% of electricity to be derived from clean sources.
- B.C. building code that sets standards for the energy efficiency of buildings and associated equipment.
- Landfill gas regulation which sets standards on methane emissions.
- B.C. carbon tax.
- Provincial renewable fuel standard.
- Low carbon fuel standard mandating reductions in average lifecycle carbon intensity of transportation fuels.

Alberta

- Coal phase-out by 2030 and subsequent replacement of two-thirds of electrical coal capacity with renewable sources.
- Specified gas emitters regulation which requires industrial facilities to meet an emissions intensity standard, and pay for each unit of GHG emissions above this benchmark.
- A performance standard on oil sands under the high oil price to ensure emissions do not increase past the 100 Mt cap imposed by the province. However, this performance standard was unnecessary under the low oil price forecast since emissions stay under the 100 Mt cap without policy.
- Carbon levy on combustion emissions for non-industrial sectors, reaching $30 per tCO2e by 2018.

- Alberta's building code that sets standards for energy efficiency of buildings and associated equipment.
- Landfill gas regulation which sets standards on methane emissions.
- Provincial renewable fuel standard.

Saskatchewan

- Electricity policy mandating that 50% of capacity be met from renewable sources.
- Boundary Dam retrofit to include carbon capture and storage.
- Provincial landfill gas regulation which sets standards on methane emissions.
- Provincial renewable fuel standard.

Manitoba

- Electricity regulation mandating a coal phase-out by 2010.
- Provincial landfill gas regulation which sets standards on methane emissions.
- Provincial renewable fuel standard.

Ontario

- Ontario's cap-and-trade program.
- Electricity policy mandating a coal phase-out by 2014.
- Feed-in tariff for renewable electricity generation.
- Landfill gas regulation which sets standards on methane emissions.
- Provincial renewable fuel standard.

Quebec

- Quebec's carbon tax starting at $3/tCO2e in 2007, replaced in 2013 with the cap-and-trade program.
- Vehicle regulation which prescribes that 15.5% of sales be zero-emission vehicles by 2025.
- Provincial landfill gas regulation which sets standards on methane emissions.

Atlantic

- Emissions cap on electrical generation, reaching a 4.5 Mt reduction by 2030.
- Renewable portfolio standard mandating a minimum of 40% renewable electricity generation by 2020.
- Provincial landfill gas regulation which sets standards on methane emissions.

4.2.2. Carbon price scenario

For this scenario, in addition to BAU policies, different Canada wide carbon price trajectories were tested to assess how stringent a carbon price is needed to reach the federal 2030 GHG target. This was done for both the high and low oil price forecasts. The price was designed to cover both combustion and process emissions to target a broad base of emissions. It is important to note that this price is not in addition to provincial carbon taxes — instead prices were modeled such that the highest carbon price for any given year becomes binding and others no longer apply.

4.2.3. Flexible regulations scenario

The flexible regulations scenario includes a package of policies designed to reduce emissions to reach Canada's 2030 GHG target. We simulated this scenario to provide an example of how GHG emissions can be reduced substantially without relying heavily on a carbon price. Both the carbon price and regulatory scenario are simulated to explore some of the trade-offs between either approach, without suggesting that one policy type is superior to the other.

This study proposes that policymakers could consider implementing a flexible regulation rather than a command-and-control regulation. Although a regulation is usually less efficient than carbon pricing, a flexible-regulation attempts to approximate the efficiency of carbon pricing policies. Flexible regulations increase their efficiency by allowing regulated entities to meet a desired outcome as a group through market-based mechanisms (Kling, 1994). For example, California's niche market vehicle regulation is flexible in that it requires a group of manufacturers to sell a specified percentage of low- to zero-emission vehicles in total. Some manufacturers can compensate for their lack of individual compliance by buying permits from other manufacturers who find it easier to produce and sell low- to zero-emission vehicles in excess of their compliance requirement. Moreover, niche-market regulations (and other flexible regulations) are agnostic with regards to what technologies are used to meet a desired outcome. This allows the market to determine shares of technology adoption, instead of relying on policy-makers or experts to predict what technology will be the most viable. In contrast, a command-and-control regulation requires regulated entities to meet a desired outcome individually. Command-and-control regulations are therefore less efficient than flexible regulations because they do not meet the equi-marginal principle (Lázaro-Touza, 2008).

For this study, we designed the package of flexible regulations to be sector-specific, these sectors include: industry, oil sands, electricity, personal transportation, and freight transportation. Along with this package of policies, we simulated a moderate carbon price. The price starts at $25/tCO2e in 2021, rises to $40/tCO2e in 2030, and reaches $100/tCO2e by 2050. This price trajectory was not a result of modeling, or an example of what an ideal carbon price should be. Instead it was chosen and set exogenously, to explore how a moderate carbon price can work along with flexible regulations.

The following describes the flexible regulations applied on a national scale by sector:

Personal transportation

For the personal transportation sector, we modeled a partial zero-emissions vehicle (PZEV) standard, requiring manufacturers to sell a minimum percentage of PZEVs in total. This minimum percentage was modeled as 5% in 2020, 35% in 2025, 70% in 2030, and 100% in 2040. We also modeled a low carbon fuel standard (LCFS) requiring low-emission fuels (i.e. ethanol, biodiesel, or electricity) to consist of an increasing percentage of conventional transportation fuel sales. This requirement was set to start at 10% in 2025, 40% in 2030, and 90% in 2040.

Freight transportation

We simulated vehicle emissions standards that tightened the stringency of current federal standards by allowing only high efficiency and low- to zero-emission freight vehicles to compete for market share after 2020. We also modeled a low carbon fuel standard, set to increase renewable content in diesel over time starting at 20% in 2025, 40% in 2030, and 80% in 2040. This regulation is flexible in that it can be satisfied through a variety of fuel options that have lower carbon intensity than diesel, such as: biodiesel, hydrogenation-derived renewable diesel, natural gas, hydrogen, and electricity.

Buses and rail

We implemented a flexible regulation for new rail and buses that, from 2020 on, allowed any technology-fuel combination except ones burning only fossil fuel products. This regulation is flexible in that we did not specify what technologies and fuels will replace conventional bus and rail, and instead it allows market forces to determine the most viable options.

Electricity

For the electricity sector, we modeled a coal phase-out by 2030. Although this is a fairly rigid policy, it was coupled with a flexible low- to zero-emissions standard. This standard prescribes that an increasing percentage of electricity be derived from low- to zero-emission sources. For provinces with little availability of cheap hydro sources we modeled 90% zero-emission electricity generation by 2030. These provinces include: Alberta, Saskatchewan, Ontario, Nova Scotia, and New Brunswick. For provinces that do have hydro sources available, we modeled 100% zero-emission electricity generation by 2030. These provinces include: B.C., Manitoba, Quebec, and Newfoundland. Lastly, both utilities and industrial co-generation are included in the standard to prevent industrial facilities from being incentivized to produce cheaper emissions-intensive electricity.

Industrial sectors

For industry, we modeled sector-specific performance standards which set decreasing emissions intensity standards starting in 2020. Under this policy, facilities would be given permits for each unit of GHGs emitted up to an emissions intensity benchmark. To emit past the standard, a facility would need to pay a fee per unit of emissions, or buy permits from other facilities that can reduce emissions below the benchmark. The performance standard is flexible because facilities do not have to meet the benchmark individually. Instead an industry sector only needs to meet the standard in total.

We designed these performance standards to be less stringent for industries that are both emissions-intensive and trade-exposed (EITE), to reduce the risk that facilities would become uncompetitive internationally or simply relocate to a jurisdiction outside of Canada with no climate policy (i.e. carbon leakage). These EITE sectors include: petroleum refining, natural gas extraction, chemical products, and petroleum production. However, to meet the 2030 federal target, it was necessary to apply more stringent performance standards on industries less likely to be vulnerable to leakage. These non-EITE sectors include: industrial minerals, mining, metal smelting, other manufacturing, pulp and paper, coal mining, biodiesel, and ethanol. Lastly, because the flexible regulations applied to transportation sectors will incentivize greater demand for biofuels, we set performance standards on biodiesel and ethanol production to achieve near-zero emissions by 2030.

Oil sands

When designing this package of flexible regulations, we considered what is politically feasible under alternative contexts. For instance, the oil sands are a significant part of the Canadian economy, yet its operations are very emissions-intensive and trade-exposed. For this reason, the oil sands received special consideration. Unlike other industrial sectors we did not model a stringent national performance standard on the oil sands.

Under the low oil price forecast, we assume that stringent policy in oil sands is politically difficult to achieve. In fact, the current provincial cap is not binding under the low oil price forecast. Consequently, we found it unnecessary to increase the stringency of policies on the sector up to 2030.

Further constraining oil sands emissions under the high price forecast would be politically more feasible. However, we found it was unnecessary to lower emissions past the Alberta government’s current 100 MT cap to meet the 2030 target. Although reducing emissions in the oil sands would allow for more lenient policies in other sectors, leniency on the oil sands sector is likely to increase the political acceptability of this package of regulations.

After 2030, the federal government may lower the 100 Mt cap, especially to contribute to the 2050 national target set at 65% below 2006 levels. Therefore, we ramped up the performance standard past 2030 to drive deeper de-carbonization up to 2050.

Chapter 5.

National results and discussion

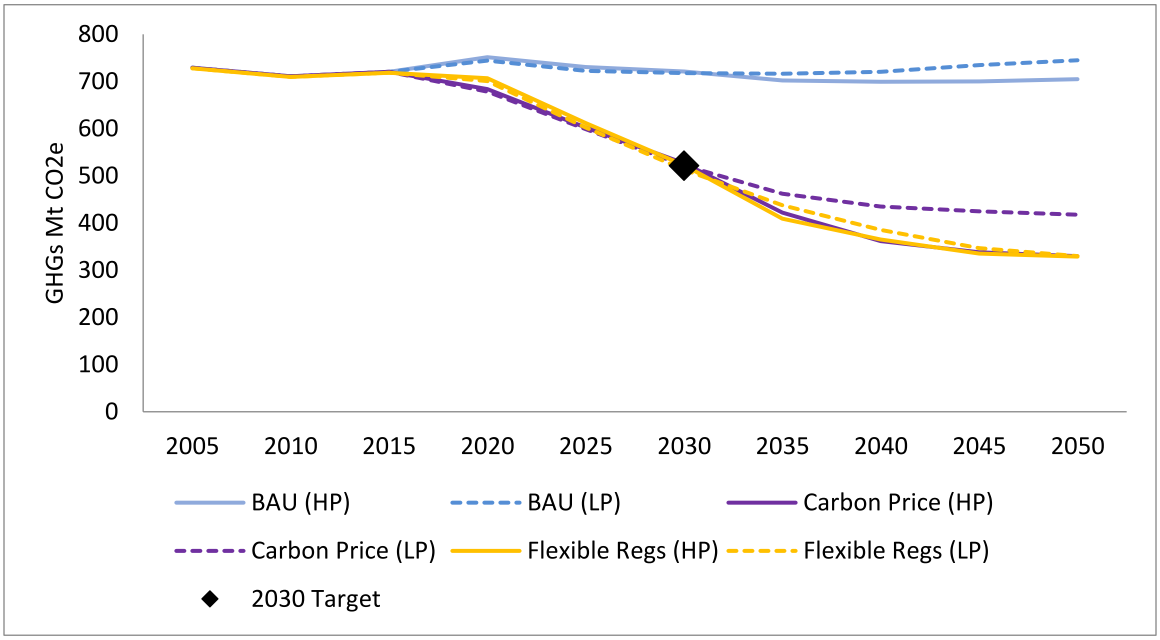
5.1. Results by scenario

Out of the three simulation scenarios, only the carbon price and flexible regulations scenarios meet the 2030 national target. In the following subsections, I review the GHG emissions trajectories for each of the 3 scenarios, and discuss how results were affected by the oil price forecasts.

5.1.1. Business-as-usual scenario

Figure 1 shows the emissions trajectory for all three scenarios from 2005 to 2050. As can be seen, the BAU scenario (represented by the blue line) misses the 2030 target by roughly 200 Mt, for both the low and high oil price forecasts. Although the BAU emissions trajectory has moderate dips and rises, it remains relatively constant from 2005 to 2050. However, Canada's population is projected to keep growing up to 2050 and beyond (Statistics Canada, 2015). This suggests that BAU policies are effective at reducing some GHG emissions in the long-run since it is likely that without policy, emissions would continue to grow along with population.

Figure 1. National GHG emissions trajectory from 2005-2050, by scenario and oil price forecast



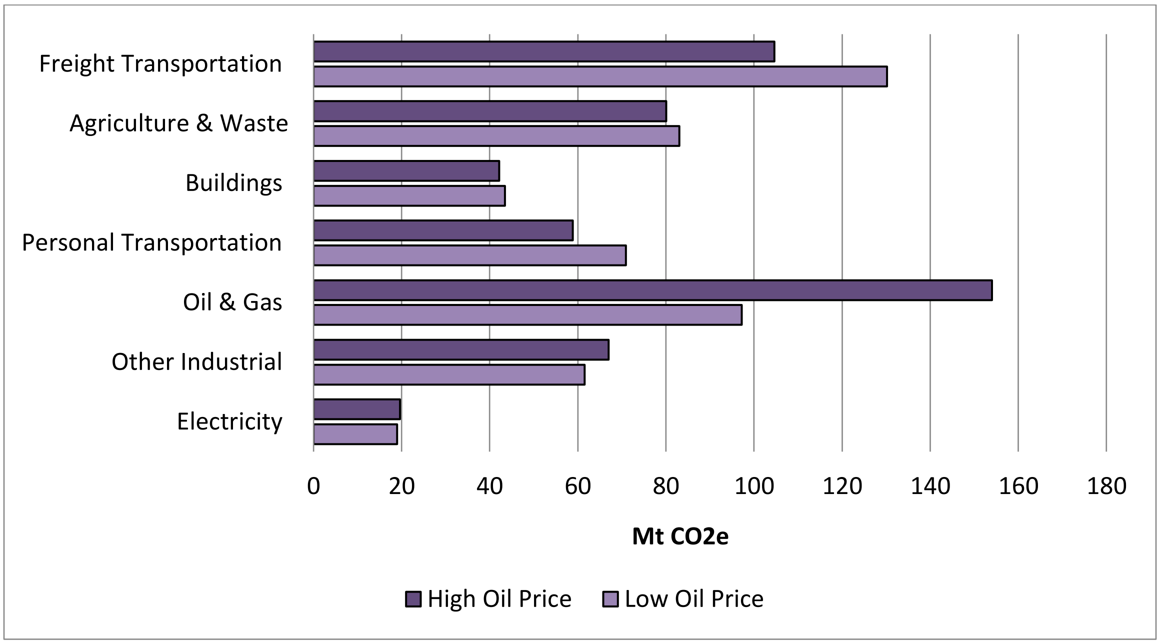
5.1.2. Carbon price scenario

Figure 1 shows the emissions trajectory for the carbon price scenario in purple. We designed this scenario to meet the 2030 target under both the high and low oil price forecasts by testing different carbon price trajectories. The results suggest that Canada's national carbon price must increase significantly from current levels to meet the 2030 target. We found that a carbon price starting at $30 in 2017 (2016$) would need to reach $190 under the high oil price, and $200 under the low oil price.

Under the low oil price, the carbon price is higher because of increased domestic consumption of petroleum products, and therefore, Canadian end-use emissions are greater. However, the difference in the required carbon price between the two forecasts is not substantial. This is because high oil prices incentivize increased production and emissions in the oil sands, offsetting some of the difference between the two forecasts in terms of end-use emissions in all other sectors.

Figure 2 shows a 2030 snapshot of sectoral emissions under the carbon price scenario for both the high and low oil price forecasts. Notably, emissions under the high oil price forecast are substantially higher in the oil and gas sector relative to those under the low oil price forecast. However, emissions are significantly lower under the high oil price forecast in the freight and personal transportation sectors. This is to be expected since these sectors are the most dependent on petroleum based fuels, such as gasoline, diesel, and heavy fuel oil, and thus their consumption level is the most affected by high oil prices.

Figure 2. National GHG emissions in 2030 under the carbon price scenario, by sector and oil price forecast



Some sectors show little difference in emissions between oil price forecasts. This is because those sectors are less dependent on petroleum fuels. For example, Figure 2 shows minimal differences between GHG emissions in the electricity sector under high and low oil prices. This is reasonable since electricity in Canada relies most heavily on natural gas, coal, and hydro energy sources.

5.1.3. Flexible regulations scenario

The flexible regulations scenario is also designed to meet the 2030 target (Figure 1). However, the results suggest that two levels of stringency are needed under the different oil price forecasts. Because oil prices affect GHG emission levels, as discussed in the carbon price scenario results, different approaches are necessary to meet the federal target.

A more stringent performance standard on industry was set under the low oil price forecast. In practice, stringency is increased by reducing the allowed carbon intensity. However, in CIMS to stimulate an increase in the stringency of the performance standard, I increased the permit price that facilities pay. This reflects a decreasing intensity because a more stringent performance standard incentivizes greater demand for permits, and therefore, permit prices are higher.

Table 4 summarizes the resulting permit prices ($2016 CAD) for the different sectors under the performance standard. These sectors include: emissions-intensive and trade-exposed (EITE) industries, and industries that do not fall under the EITE category. As can be seen, the results suggest that the low oil price forecast requires a higher permit price (i.e. lower carbon intensity benchmark). Under the high oil price forecast a lower permit price (i.e. higher carbon intensity benchmark) is sufficient.

Table 4. Permit prices under the national industrial performance standard in 2030 ($2016 CAD)

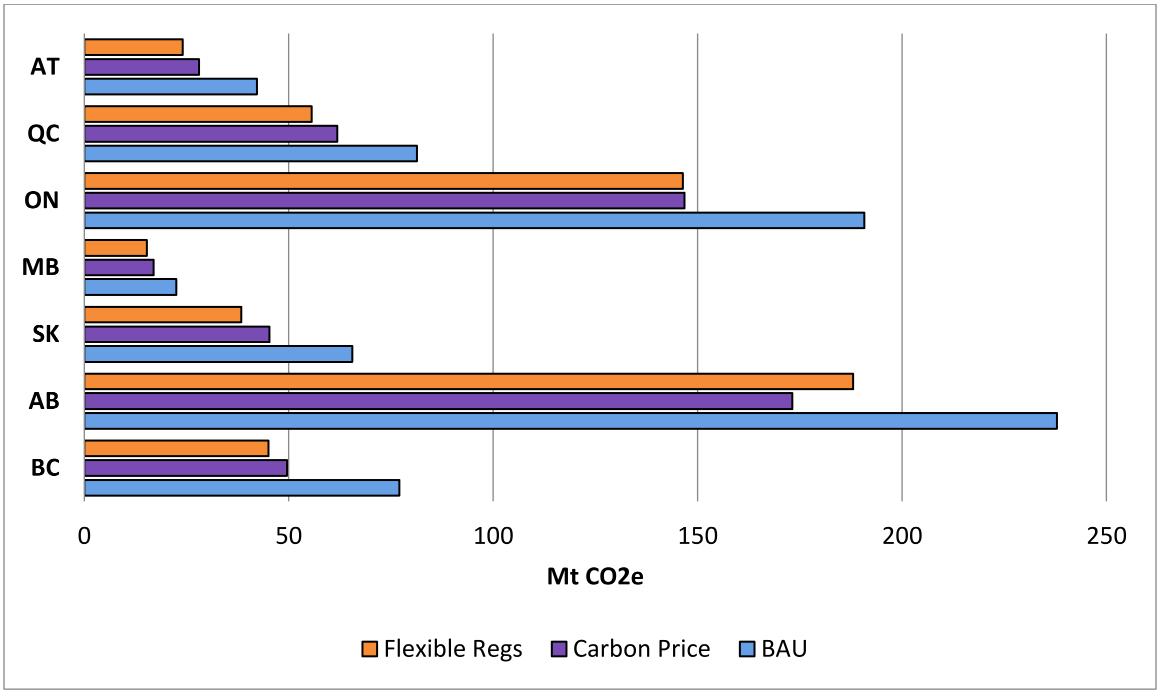
	Low Oil Price	High Oil Price
EITE Sectors	$120	$105
Non-EITE Sectors	$205	$190

Table 4 also shows that the permit price modeled for the industrial EITE sectors is substantially lower relative to the industrial non-EITE sectors. This is not a modeling result, instead these performance standards were designed to protect EITE sectors, and therefore, a more lenient carbon intensity benchmark is applied.

5.2. Provincial results

Figure 3 shows emissions in 2030 for each province under the low oil price. I do not include a figure showing emissions under the high oil price since trends were similar. As can be expected, GHG emissions under the BAU scenario are significantly greater for all provinces, relative to the carbon price and flexible regulations scenarios.

Figure 3. National GHG emissions in 2030 under the low oil price forecast, by province



Although both the regulatory and pricing scenarios meet the 2030 target by design, Figure 3 shows that GHG emissions in each province are not the same between these two scenarios. This is because, unlike the regulatory scenario, the carbon price is applied equally across all sectors and provinces.

The carbon price scenario serves as an example of a singular pursuit of economic efficiency because it was designed to give the same price signal to all firms and individuals across Canada. The results suggest that to maximize efficiency, provinces do not need to reduce GHG emissions by the same proportion, due to regional differences in cost of abatement. For example, under the low oil price, the model estimates that relative to the BAU scenario Alberta need only reduce emissions by 21% (this can be seen in Figure 3). In contrast, the Atlantic reduces emissions by 43%. This means that within the Atlantic there is a higher proportion of inexpensive abatement options relative to the proportion available within Alberta.

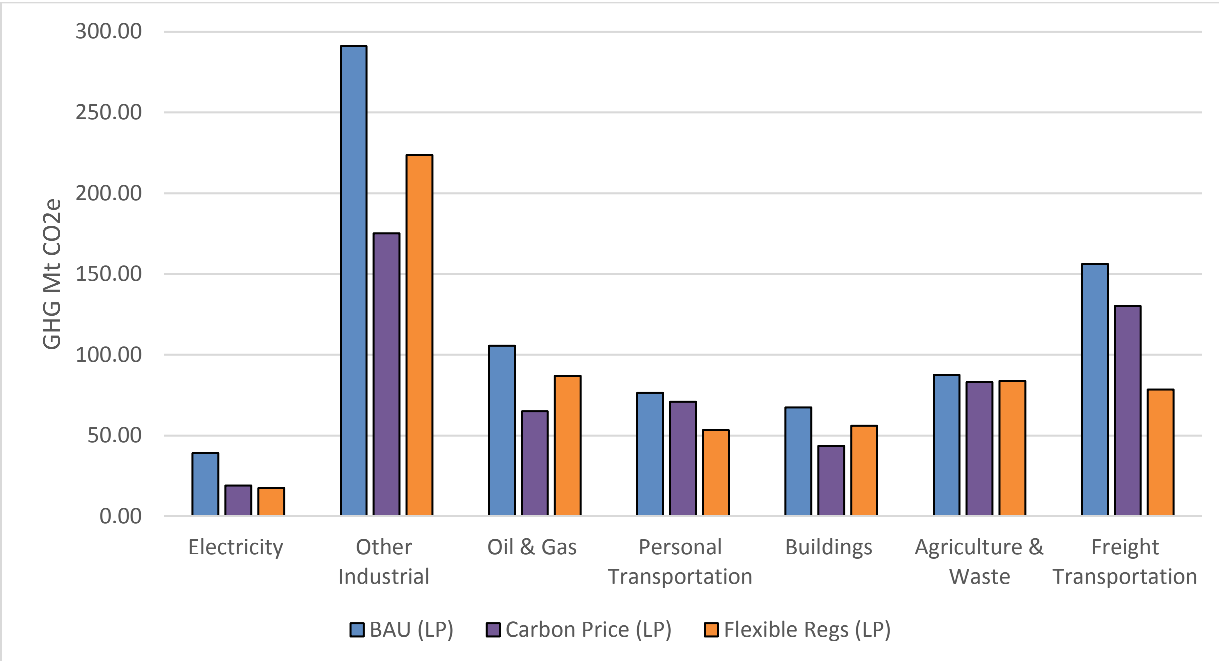
Since the carbon price scenario represents an economically efficient outcome, any inter-provincial deviation in GHG emission reduction under the regulatory scenario suggests a loss of efficiency. As can be seen in Figure 3, emission reductions were greater under the flexible regulations scenario relative to the carbon price scenario in Quebec, Ontario, Manitoba, Saskatchewan, B.C, and Atlantic. However, although emissions are not exactly the same under the carbon price and flexible regulations scenario, they are relatively close, suggesting that abatement costs are similar between the two.

Lastly, Figure 3 shows that the province with the greatest difference in emissions between the two scenarios is Alberta. Under the flexible regulations scenario, emissions are much higher relative to the carbon price scenario. Therefore, the greatest efficiency loss under the regulatory scenario is in Alberta. The likely cause is that the oil sands were protected under the flexible regulations scenario while, under the carbon price scenario, Alberta's oil sands received the same price signal as any other sector or province in the country.

5.3. Sector results

Although both the flexible regulations and carbon price scenarios meet the 2030 target by design, these scenarios do not affect sectoral emissions equally. Figure 4 shows emissions by sector in 2030 under the low oil price forecast for each scenario. The results suggest that the biggest emission differences between the two scenarios are found in industrial sectors, buildings, transportation, and oil and gas. In contrast, the agriculture and waste sectors, and the electricity sectors are very similar in terms of GHG emissions. This implies that these sectors face similar cost signals under both scenarios.

Figure 4. National GHG emissions in 2030 under the low oil price forecast, by scenario and sector



As can be seen in Figure 4 transportation sectors experience greater emissions reduction under the flexible regulations in comparison to the carbon price scenario. This is because the package of regulations applied to freight and personal transportation mandate the adoption of low- to zero-emission vehicles, as well as greater consumption of low carbon energy. A carbon price would have to be particularly stringent to induce such strong fuel switching away from fossil fuel-derived refined petroleum products. Although the carbon price scenario induces some fuel switching, it predominantly incentivizes adoption of more efficient conventional vehicles.

Commercial and residential buildings experienced less GHG emission abatement under the flexible regulations scenario in comparison to the carbon price scenario (see Figure 4). This is because under the flexible regulations scenario we did not impose any additional regulations on buildings relative to BAU. However, there are still some emission reductions because of the moderate carbon price imposed along with the flexible regulations.

5.4. Trade-offs between policy options

Within the Canadian economy, there are a variety of commercially available low-to zero-emission technologies that could dramatically reduce GHG emissions. However, due to higher financial costs when the global warming, ocean acidification and other damages from GHG emissions are not charged or regulated, these are usually not adopted. As noted, this study presents two policy options for increasing the adoption of these low carbon technologies, including a carbon pricing scenario and a flexible regulations scenario.

Although carbon pricing is generally thought to be the most efficient form of climate policy — and is certainly flexible and market-based — it may not always be the most appropriate option. Carbon pricing tends to face public opposition due to the perception that the policy is causing adverse costly effects for individuals and businesses, with difficult-to-detect long-run benefits. Some researchers suggest that sector-specific regulations may be more politically viable because they are likely to be clearer about the benefits they are targeting (Haley, 2016). For example, a coal phase-out, such as the one modeled in this study, is explicit about eliminating an emissions-intensive fossil fuel, but not explicit about how much this policy is going to cost consumers of electricity. Although well designed carbon pricing tends to be cheaper for society relative to a sector-specific regulation, politicians may become convinced that an exclusive reliance on carbon pricing to achieve emission targets will be politically impossible. In that case, they may be willing to consider alternatives to pure emissions pricing, such as flexible regulations and perhaps even command-and-control regulations in some cases.

Additionally, while a carbon price incentivizes the cheapest GHG emissions reductions first, this might not necessarily be the best outcome because these early GHG reducing actions may not be compatible with the more expensive long run shifts predicted under deep decarbonisation (Roberts, 2016; Haley, 2016). For example, one policy explored under the flexible regulation scenario was a PZEV mandate. Our results suggested that relative to the carbon price scenario, the PZEV mandate incentivizes greater fuel switching away from conventional fossil fuels towards electricity and biofuel options. This is because a carbon price is likely to incentivize increasing efficiency of conventional vehicles first. A substantially higher carbon price is necessary to start phasing out fossil fuels in transportation and establishing the supporting infrastructure needed for other fuel sources. Therefore, by using a flexible regulation that targets the introduction of low- to zero-emission vehicles, further investments can be made that support these new technologies rather than increasing the efficiency of conventional technologies first.

It is also important to note that pricing and regulations do not have to be substitutes. Both policy forms can be used together, similarly to how they were modeled in the flexible regulations scenario. This is important because the results from this study suggest that relying primarily on a carbon price to meet the federal target will require a price as high as \$190-\$200 per tCO_2e. These prices are likely to be politically difficult to implement. Instead a moderate price could be implemented along with flexible regulations. The flexible regulations can serve as an avenue to lower the barriers preventing the adoption of low carbon technologies, without the use of an explicit, quickly rising carbon price. This may increase the eventual acceptability of gradually higher carbon prices with more accessible abatement options, increased public awareness, decreased perception of risk, or increased demand allowing for cheaper large-scale production of low carbon technologies.

Chapter 6.

B.C. simulation assumptions

In this section I explore designs for integrating BC climate policy within a Canadian target and policy framework. I especially focus on policy designs that would gradually harmonize initiatives by all regions and all levels of government to a similar marginal cost of emission reduction.

Simulating B.C. required choosing a target for 2030 since the last B.C. government, led by Premier Christy Clark, avoided setting one. While B.C. does have a provincial 2050 target, I chose not to use it since the objective of this study is to assess how B.C. could contribute to the national target. Instead, I based both B.C.'s 2030 and 2050 targets on its likely cost-effective share of emissions reductions under the national targets for those years.

6.1. Choosing a GHG emission reduction target for B.C.

At the 2015 Paris Climate Conference, Canada agreed to reduce GHG emissions 30% below 2005 levels by 2030 (UNFCCC, 2015). In the Copenhagen Accord in 2009, the federal government established a 2050 target, agreeing to reduce GHG emissions 65% below 2006 levels by 2050 (Copenhagen Accord, 2009). However, because the agreements at both Paris and Copenhagen were to meet national targets, not all provinces will necessarily need to reduce emissions by the same proportion.

Because of the heterogeneity of each province's energy system and resulting GHG emissions, the cost of reducing GHGs is also heterogeneous. Overall costs can best be minimized when the last unit of GHG that B.C. abates is equally as costly as the last unit abated by all the other provinces. Therefore, acknowledging this heterogeneity — rather than forcing each region to reduce emissions by the same proportion—is likely to increase the overall efficiency of meeting the national target.

The CIMS model I used in this analysis considers the heterogeneity between regions and between sectors in these regions. Although CIMS is not capable of perfectly capturing heterogeneity in the Canadian market, it is informed by robust empirical studies and technological data to represent these differences. When we modeled a national carbon price in CIMS, our results met the Paris and Copenhagen targets by design (see Chapter 4 and Chapter 5). However, we did not prescribe by how much each province should reduce its emissions. The results from the national study suggest that under a cost-minimization objective, provinces would reduce emissions by different proportions due to regional heterogeneity. Within this objective, the results suggest that B.C.'s target should be to reduce its emissions 25% below 2005 levels by 2030.

Unlike the national study, which focuses on the 2030 target, I chose to expand the provincial study to include the 2050 federal target as well. To set a 2050 target for B.C. within the federal context, results were obtained from Tiffany Vass who modeled the 2050 national target for a separate study (Vass, 2016). The results imply that under a target that reduces national GHG emissions 65% by 2050, the cost-minimizing GHG emissions reduction in B.C. over the same period should reduce emissions 60%.

6.2. Sensitivity analysis: liquefied natural gas in B.C.

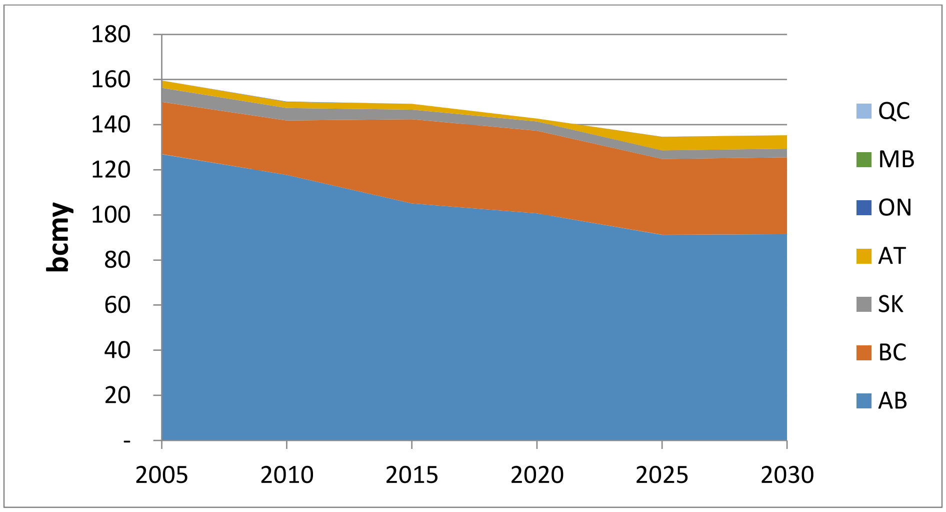
In 2012, the government of B.C. released a report outlining a strategy for producing and exporting liquefied natural gas (LNG) (B.C. Ministry of Energy and Mines, 2012). This report detailed the provincial government's goal under Premier Christy Clark to build three LNG plants on the BC coast by 2020. According to the reports, building these export-oriented LNG plants would more than double natural gas production in B.C. However, in 2017 (at the time of writing) it is uncertain whether any LNG plants will be built in the province.

To account for the uncertainty of future natural gas production, I simulate two scenarios with different natural gas production forecasts. These forecasts are based on analysis by the Canadian Association of Petroleum Producers (2015) and represent natural gas production with no No-LNG exports, and expanded natural gas production with LNG exports.

6.2.1. No-LNG forecast

The first forecast assumes that there will be no LNG plants built in B.C. Under these conditions, CAPP predicts that natural gas production in B.C. will see a slight decrease from today's level. Production will drop by 9% from 37.38 billion cubic meters per year (bcm/y) in 2015, to 34.06 bcm/y in 2030. This trend can be seen in Figure 5, which shows provincial natural gas production as forecasted by CAPP, alongside historical data.

Figure 5. No-LNG natural gas production trajectory from 2005-2030



It should be noted that CAPP's data were published showing eastern and western Canada's natural gas production, as opposed to actual provincial production. To disaggregate these data by province, I used historical trends from the National Energy Board (NEB, 2016).

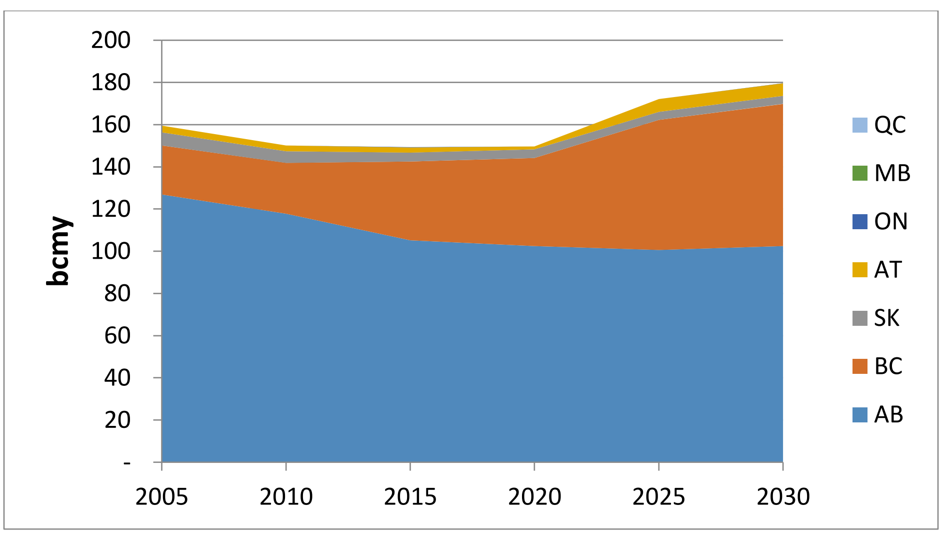
CAPP's forecast that B.C.'s natural gas production will decrease without LNG development seems reasonable. Currently, most natural gas production from the province is consumed in Canada or exported to the United States. However, technological advancements are allowing the United States to tap into abundant sources of unconventional natural gas (notably shale gas) that were previously too difficult and costly to access. Due to these advancements, the U.S. Energy Information Administration predicts that the United States will soon be a net exporter of natural gas (EIA, 2016). Since B.C.'s main trading partner will have its supply of natural gas increase domestically, it is unlikely that provincial production will grow unless another market is accessed.

6.2.2. LNG forecast

The second forecast represents natural gas production in B.C. if five LNG export trains were in operation in the province by 2023. Each train would be capable of exporting 7.23 billion cubic meters of LNG per year (bcm/y) (CAPP, 2015). This capacity could satisfy the government's goal of building three LNG plants, since it is common for an LNG plant to have one or two trains in operation.

Under these conditions, CAPP predicts that natural gas production in B.C. will grow substantially (CAPP, 2015). LNG plants would allow B.C., and other Canadian provinces, to ship natural gas to Asia. I assumed that 75% of the natural gas being shipped to Asia would be extracted from B.C., and the remaining 25% from Alberta. As can be seen in Figure 6, B.C.'s natural gas production starts to increase in 2018 as export trains become active. Production grows by 44% from 37.38 bcm/y in 2015 to 67.29 bcm/y in 2030.

Figure 6. LNG natural gas production trajectory from 2005-2030



6.3. Simulation scenarios

6.3.1. Business-as-usual scenario

The business-as-usual (BAU) scenario represents federal and provincial climate policies with an effect on B.C. emissions, excluding those announced in the 2016 provincial Climate Leadership Plan. The stringency of these BAU policies is consistent with announced or legislated policies, and assumes that they will remain until 2050. The BAU scenario serves as a contrast for the other scenarios in this study that explore potential increases in climate policy stringency. The following federal and provincial policies were modeled in our analysis.

Federal

I include several federal policies in the BAU simulation, these include the:

- Federal carbon tax starting at $10/tCO2e in 2018, increasing to $50/tCO2e in 2022. However, since I leave the tax level constant after 2022 its effect declines over time with inflation.
- Light and heavy-duty vehicle emission standards in the transportation sectors.
- Methane regulations for oil and gas, mandating a reduction of national methane emissions by 45% below 2012 levels by 2025.
- Renewable fuel standard mandating the blending of biofuels with gasoline and diesel pools.
- Federal budget commitments targeting low-emission technologies and infrastructure. These budget commitments were modeled as subsidies in the following sectors: oil and gas, buildings, vehicles, electricity, and public transit infrastructure.

Provincial

I also include the following B.C. specific policies in the BAU: the clean electricity standard that requires 93% of electricity to be derived from clean sources; the B.C. building code that sets standards for energy efficiency of buildings and associated equipment; the landfill gas regulation which sets standards on methane emissions; the

B.C. carbon tax and its eventual replacement with the federal carbon backstop price; and lastly, the renewable and low carbon fuel standards.

6.3.2. B.C.'s Climate Leadership Plan scenario

In 2016, the past government of B.C. released a Climate Leadership Plan (CLP), which I model in addition to BAU policies (Government of B.C., 2016). For this scenario, I assume that the B.C. government post-2017 sustains commitments from the CLP of the B.C. government of 2011-2017.

Although the CLP outlines many objectives that could aid in the reduction of GHG emissions, several of these lack details on the actual mechanisms that would be implemented to achieve them. I therefore focus on modeling CLP emission reduction objectives that are tied to an announced and clearly stated policy. Only in these cases can I assess the potential effectiveness and efficiency of these intended plans. Additionally, these simulations do not include GHG emission reduction policies from forestry practices since CIMS does not include GHG emissions from changes in land-use and changes in forest management practices. I therefore do not include the annual 12 Mt reduction anticipated by the Clark government of B.C by 2050 as a result of the forestry focused CLP policies.

The following policies from B.C.'s 2016 Climate Leadership Plan were modeled in the analysis:

Step Code

B.C.'s Step Code is a policy that outlines a set of performance standards for new building shells. The Step Code begins with the current B.C. building code and outlines an incremental path towards a net-zero-ready standard. A net-zero-ready building is one that is so efficient that in theory all energy consumption could be offset by on-site production of renewable energy, presumably from PV and/or solar thermal. Specifically, under the Step Code a net-zero-ready building is defined to have a thermal demand intensity of 15 kWh/m^2/year (Stretch Code Implementation Working Group, 2016).

Currently, adherence to the Step Code is voluntary. However, to promote municipal adoption, monetary incentives will be offered. Nevertheless, if the current B.C.

government follows through with the plans from the recent Clark government, the Step Code will be mandatory in 2032[1].

To model the Step Code in CIMS, I forced all new market share after 2032 for residential and commercial buildings to have thermal demand intensities of net-zero-ready buildings. No subsidies were modeled because projects that follow the Step Code during the non-compulsory phase of the program are likely to be free-riders, and because the past and current B.C. government have yet to release any specific details on what these monetary incentives will be.

Industrial natural gas boiler regulation

By 2020 the Clark government established intent to set new efficiency requirements for gas fired boilers used in industrial sectors. These requirements will be compulsory for new and replacement boilers, but will not affect existing stock. After 2020, I set new market share to zero for standard gas boilers, allowing only "high" efficiency boilers to compete in the model and acquire new market share.

Organic waste diversion

The CLP outlines a plan to divert 90% of organic waste from landfills by 2030. This was modeled in CIMS by adjusting B.C.'s forecasted volume of waste to reflect a 30% reduction of organic waste in 2017, ramping up to 90% by 2030.

Low carbon fuel standard

B.C. already has a low carbon fuel standard mandating a 10% reduction in carbon intensity by 2020 relative to 2010 levels. The CLP establishes a plan to further decrease carbon intensity by 15% by 2030 relative to 2010 levels. This was modeled in CIMS by increasing the average renewable content in both gasoline and diesel to 15% by 2030.

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[1] One could argue that I should not recognize this as a legitimate component of the B.C. government's climate plan. The reason is that the norm in climate policy modeling is to give governments credit for policies they have already implemented, are in the process of implementing, or – the most tenuous – have promised to implement before facing re-election. In the case of the step code, the B.C. government is promising to implement a policy that will only be applied to the construction of new buildings if it sustains this promise through four straight elections victories. As it turns out, the government was defeated in 2017.

Electrification of natural gas extraction and processing

Currently, there are areas in B.C. where natural gas extraction and processing rely primarily on combustion of fossil fuels. The biggest barrier for switching to electricity is the lack of electric infrastructure in some of these more isolated areas. For this reason, the past government of B.C. under Premier Christy Clark had plans to electrify the Montney Basin, a region with significant natural gas extraction. According to the CLP, electrification will abate 4 Mt of CO2e. However, prior to the release of the CLP, electrification projects were already taking place in the Montney Basin, and these were predicted to reduce emissions 1.6 Mt. For that reason, I only model an additional 2.4 Mt reduction to reflect the CLP. This was done in CIMS by allowing greater adoption of electric technologies in the natural gas sector, resulting in a reduction of 2.4 Mt of CO2e by 2030.

Methane regulation in the natural gas sector

In the CLP, the previous B.C. government committed to reducing leaked and vented methane emissions from natural gas extraction and processing by setting requirements for current and future infrastructure. The methane emission target for current infrastructure is a 45% reduction by 2025. This policy was modeled in CIMS by forcing existing technologies to retrofit to include leak detection and repair until a 45% reduction was achieved. Methane emission targets for future infrastructure are not yet clear, but leak detection and repair technology will eventually become mandatory. However, since the federal government announced a similar methane regulation prior to the provincial one, and we included its effect in our national modeling, it is likely that B.C.'s methane regulation will have minimal effects.

Clean electricity standard

For many years B.C. has had a clean electricity standard mandating 93% of electricity production to be zero-emissions. The CLP made an amendment to this regulation calling for almost 100% of electricity to be sourced from renewable or clean energy. This means that electricity can come from either renewable energy, fossil fuel combustion paired with carbon capture and storage (CCS), or, for the purposes of reliability, small amounts of natural gas without CCS. I modeled this standard in CIMS by allowing a very small amount of peak electricity to be sourced from single-cycle gas turbines.

Regulations for natural gas space and water heating

In this analysis, I modeled new standards outlined by the CLP for space and water heating in residential and commercial buildings. These standards require natural gas furnaces and boilers installed after 2020 to be 90% efficient, and natural gas space water heaters installed after 2025 to have an efficiency rating of factor 84.

6.3.3. Carbon price scenario

For this scenario, in addition to BAU and CLP policies I tested different emissions price trajectories, significantly greater than B.C.'s current carbon tax, to assess how stringent of an emissions price would be needed for the province to reach the 2030 GHG target. This was done for both the No-LNG and LNG natural gas production forecasts. However, unlike the B.C. carbon tax, which only covers combustion emissions, I designed this emissions price to cover both combustion and process emissions to target a broader base of emissions. It is important to note that these emissions prices are not in addition to the B.C. carbon tax or the federal carbon tax — this scenario was modeled to replace other current carbon pricing schemes since the emissions price reaches levels that render the others no longer binding.

6.3.4. Flexible regulations scenario

Similar to the national study, I simulate a package of flexible market-based regulations for the provincial study. However, unlike the national study, which focused on the 2030 target, this package of flexible regulations explores potential ways to meet both the 2030 and 2050 targets. Furthermore, just like the national study, this package of flexible regulations was paired with a moderate carbon price. However, because of the national backstop price this carbon price rises more quickly, from $50 in 2022 to $100 in 2050. In contrast, the national study was modeled before the announcement of the national backstop price and starts at $25/tCO2e in 2021, rises to $40/tCO2e in 2030, and reaches $100/tCO2e by 2050. Below is a list of the flexible regulations included in both the national and provincial studies. For greater detail please see section 4.2.3 where I describe how these were modeled:

Personal transportation:

- Partial zero emissions vehicle standard
- Low carbon fuel standard

Freight transportation:

- Vehicle emissions standards
- Low carbon fuel standard
- Fossil fuel ban for new rail and buses after 2030-2035

Industrial sectors:

- Moderately stringent performance standard on the following sectors: petroleum refining, chemical products, and petroleum production.
- Stringent performance standard on the following sectors: industrial minerals, mining, metal smelting, other manufacturing, pulp and paper, coal mining, biodiesel, and ethanol.

Additional policies

For the national study, flexible regulations were applied only to industry, personal transportation, and freight transportation. For the provincial study, in addition to the policies described above, I also applied regulations to buildings (both commercial and residential) and to the production of liquefied natural gas. These additional policies are described below.

Liquefied natural gas

LNG can be produced by various technologies and fuels, the most common energy sources being natural gas or electricity. If LNG plants are developed in B.C., decisions must be made about what energy source is to be used (i.e. electricity or natural gas) and what corresponding technologies. Since less emissions-intensive LNG plants are the most expensive, I modeled a performance standard applied to the natural gas sector such that low-emission technologies become more competitive. It was important to apply this performance standard immediately since LNG technologies have a 30-year lifespan.

Buildings

As noted, B.C. plans to mandate a net-zero-ready building code by 2032, which is not useful in terms of meeting the 2030 target. Therefore, I modeled the Step Code as compulsory in 2025.

Chapter 7.

B.C. results and discussion

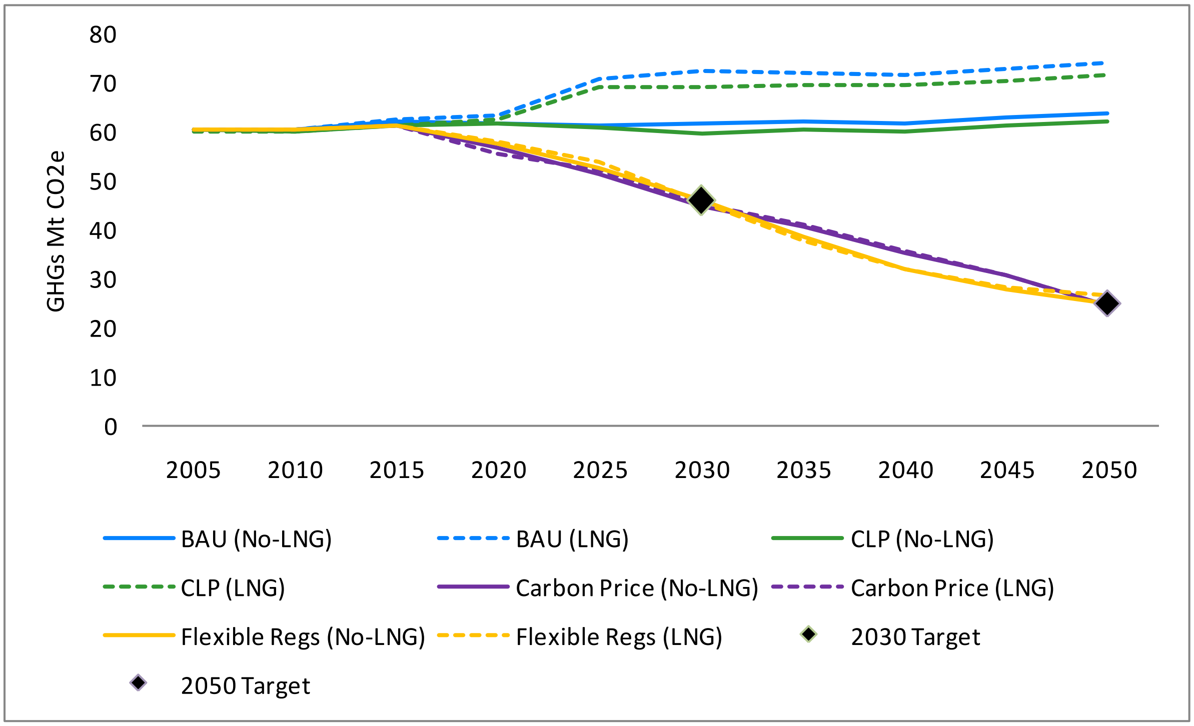
7.1. Results by scenario

Of the four scenarios, only the carbon price and flexible regulations scenarios reduce emissions sufficiently to meet the 2030 and 2050 targets.

7.1.1. Business-as-usual scenario

This study finds that although the current policies under BAU may reduce some emissions, dramatically greater abatement is necessary to reach the 2030 and 2050 targets. As can be seen in Figure 7, the BAU scenario emissions — represented by the blue lines — were far above the 2030 and 2050 targets for both the LNG and No-LNG natural gas production forecasts. Although my study predicts that emissions under the BAU scenario will increase from 2005 levels, this does not mean that BAU policies are not contributing to some GHG emission reductions. Emissions could be increasing overall due to political and economic decisions such as the building of an LNG plant, or from growth in GDP and population.

Figure 7. B.C.'s GHG emissions trajectory from 2005-2050, by scenario and LNG forecast



7.1.2. B.C.'s climate leadership plan scenario

Although the policies modeled as B.C.'s Climate Leadership Plan (CLP) reduce emissions somewhat relative to the BAU scenario, my results suggest they are not nearly sufficient to meet the 2030 or 2050 targets. As can be seen in Figure 7, I predict that CLP policies — represented by the green lines —reduce emissions 2-3 Mt further than the BAU scenario under the LNG and No-LNG forecasts by 2030 and 2050. This is due to a lack of stringent policy able to offset the emissions of a growing population and economy. For more detail on the effects of specific policies from the CLP refer to section 7.2.1.

7.1.3. Carbon price scenario

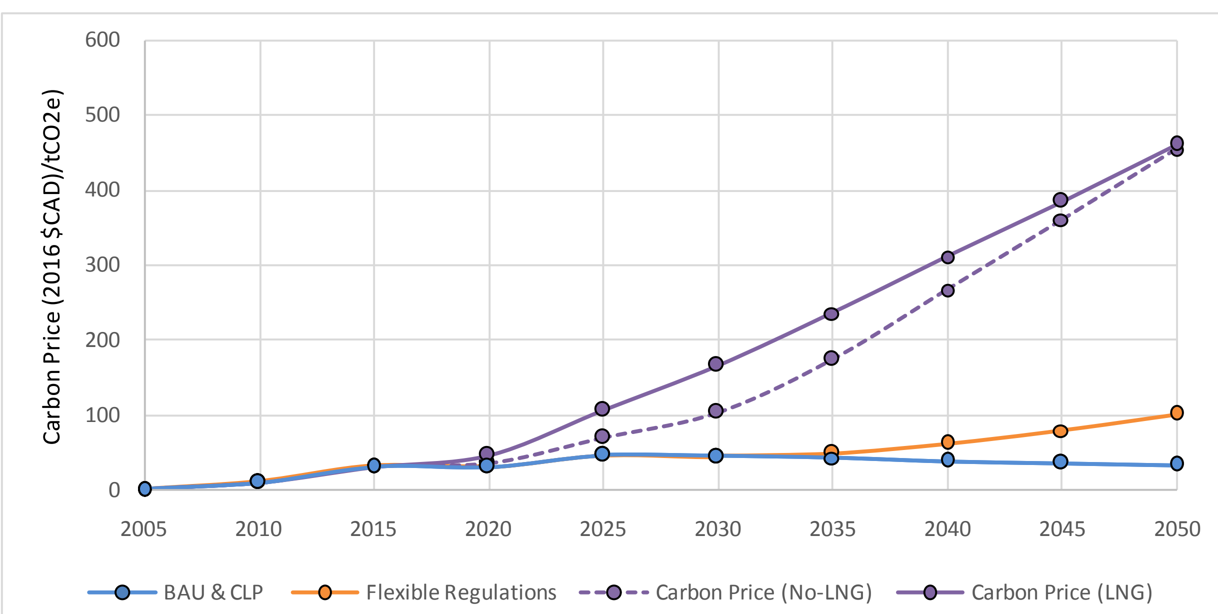
The results of this study suggest that if B.C. were to rely on carbon pricing to close the gap between forecasted emissions and its likely necessary contribution to the federal targets, the price would have to be ramped up steeply from the current trajectory. Under the No-LNG forecast, prices increase from today's carbon tax to reach

$120/tCO2e (2016 $CAD) by 2030, and $490/tCO2e by 2050. Under the LNG forecast, the carbon price increases to $190/tCO2e by 2030, and $490/tCO2e by 2050.

It should be noted that CIMS has a function that anticipates future carbon price increases, which affect emissions in previous time periods. This means that if the price trajectory modeled in CIMS was frozen in 2030 the price may not be sufficient to meet the 2030 target, since individuals and firms would not be anticipating any further emissions price increases when making purchase decisions. This function does not affect the 2050 target since the model only simulates up to 2050.

Figure 8 represents the emissions price trajectories for all scenarios in this study. Each point on the graph represents the average price for a 5-year period (i.e. 2026-2030 not 2030). This figure does not, however, show the full cost effects that would be incurred by other climate policies simulated for these scenarios, such as flexible regulations. Future studies could try to address the cost of regulations in comparison to carbon pricing. This is an important question that I have not addressed in my study. For example, a study comparing a national clean fuel standard with carbon pricing suggests that fuel prices, mobility shares, and vehicle shares are similar for the same level of emissions reductions under either policy. This suggests similar cost effects (Vass and Jaccard, 2017).

Figure 8. B.C.'s carbon price trajectory from 2005-2050, by scenario and LNG forecast



As can be seen by the purple lines in Figure 8 — which represent the carbon price scenario —relying on emissions pricing to meet the federal targets requires a substantially higher price relative to the current trajectory seen in the BAU and CLP scenarios. As suggested by the contrast between the price trajectory under the No-LNG and LNG natural gas production forecasts, it is costlier to achieve the 2030 target with LNG development, relative to a future with no LNG in B.C. However, since the LNG forecast in CIMS accounts for an increase in natural gas extraction only up to 2030 (production is kept constant from 2030 to 2050) the price reaches the same magnitude under both forecasts by 2050. This suggests that if the 2030 GHG target is met, albeit at different prices for either scenario, a similar carbon pricing trajectory may be required to meet the 2050 target with or without the introduction of LNG.

With the 2050 target, my work suggests that a more modest target of 60% reduction for B.C., relative to 65% for all of Canada, may nonetheless be difficult to achieve. This can be seen by the costly trajectory in Figure 8. However, the price suggested by the CIMS model is likely higher than necessary because (1) I did not model all options for emissions reduction, such as, forest carbon sequestration, and (2) in the sectors I did model there will be lower-cost emerging technology options that cannot be predicted now with certainty. And while there is always uncertainty surrounding technology evolution, it is easier to make assumptions about breakthroughs before the 2030 target, than to make long-term predictions about the cost of abatement in the two final decades leading up to 2050.

Lastly, it must be noted that the downward trend seen in Figure 8 for the emissions price trajectory in the BAU and CLP scenarios can be attributed to inflation. The federal government announced a $50/tCO2e carbon tax by 2022. However, no further announcement has been made regarding how the price will change or be adjusted beyond that period. In this study, I model the federal carbon tax as frozen at $50/tCO2e after 2022, thus decreasing with inflation over time.

7.1.4. Flexible regulations scenario

Like the carbon price scenario, the flexible regulations scenario met the 2030 and 2050 targets by design (Figure 7). However, under this scenario I set the carbon price at a level I deemed more likely to achieve political acceptability. Because of this, most emissions reductions in this scenario result from the package of flexible regulations, not the carbon price. It should be noted that this moderate carbon price is not a result of modeling the flexible regulations scenario, instead the price was chosen to show how a moderate price could work along with a package of flexible regulations.

One result from this modeling was the permit price from the performance standard on industry. A summary of these prices ($2016 CAD) can be seen in Table 5. To meet the 2030 target, the results suggest that the carbon permit price of the performance standard would reach $30-$55/tCO2e under the No-LNG forecast. It should be noted that the lower bound permit price corresponds with the protected EITE industrial sectors, and the upper bound corresponds with unprotected non-EITE industrial sectors. Under the LNG forecast, the carbon permit price is estimated to reach $55-$85/tCO2e by 2030. A greater permit price reflects a decreasing intensity benchmark because a more stringent policy would result in greater demand for permits, and therefore permit prices would be expected to increase. Moreover, to reach the 2050 target, I estimate the permit price to increase dramatically. Under the No-LNG forecast the permit price would range from $250-$330/tCO2e depending on whether the sector was protected from leakage. Under the LNG forecast the price would be between $280-$420/tCO2e.

Table 5. Permit prices under the provincial industrial performance standard in 2030 and 2050 ($2016 CAD)

Year	Sector	No-LNG	LNG
2030	EITE Sector	$30	$55
	Non-EITE Sector	$55	$85
2050	EITE Sector	$250	$280
	Non-EITE Sector	$330	$420

Lastly, besides the performance standards on industry, two levels of stringency are needed for the other sector-specific regulations, which thus reflects the different response required to the different emission trajectories under the No-LNG and LNG production forecasts. Most of the policies modeled under the No-LNG forecast are the same as under the LNG forecast. However, the No-LNG forecast requires less stringent flexible regulations to meet the 2030 and 2050 targets. Therefore, I apply the following differences when modeling the flexible regulations under the No-LNG forecast, relative to the LNG forecast as described in Section 6.3.4:

- Performance standards on industry are 15% less stringent for all regulated sectors.
- No performance standard on LNG plants are modeled since this forecast predicts that no LNG plants will be developed in B.C.
- The Step Code is not mandatory until 2032, as was originally planned by B.C.'s CLP.
- The LCFS in the freight sector is set to limit market share of diesel in freight trucks. Fuel demand was satisfied by low-emission fuels on the following trajectory: 20% by 2035, 40% by 2040, 60% by 2045, and 80% by 2050.This contrasted with the LNG forecast, which required the following more stringent trajectory: 20% by 2025, 40% by 2030, and 80% by 2040.

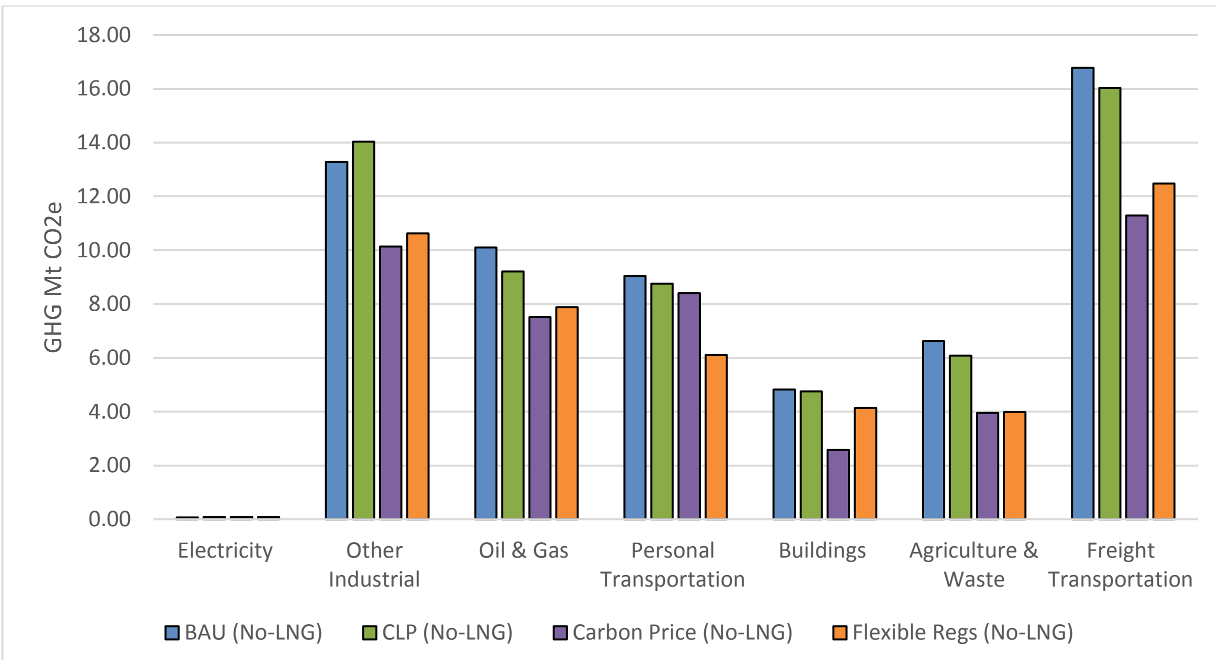
7.2. Sector results

7.2.1. Scenarios that did not meet the 2030 and 2050 targets

As was mentioned, neither the BAU or CLP policies meet the 2030 or 2050 targets. There is little difference in the total GHG emissions between the CLP and BAU scenarios given that the CLP has almost no effect on energy-related GHG emissions. However, one limitation of this study is that CIMS does not include GHG emissions from forestry. I therefore was not able to include forestry focused CLP policies, which could further reduce GHG emissions and sequester more CO2 from the atmosphere via higher forest biomass productivity.

As can be seen in Figure 9, by 2030 there are differences in sectoral GHG emissions between BAU (blue bar) and the CLP (green bar). Most of the GHG reductions that I modelled can be attributed to the following CLP policies: the low carbon fuel standard, organic waste diversion, and electrification of natural gas extraction and processing. The low carbon fuel standard is effective because it mandates further carbon intensity reductions by 2030. This is represented in Figure 9 under both the “personal transportation” and “freight transportation” sectors. The organic diversion regulation was also effective because I made the perhaps overly generous assumption that the 90% reduction of organic waste by 2030 target would be compulsory. The emission reductions from the organic diversion regulation are represented in Figure 9 as the difference between BAU and the CLP under the “agriculture & waste” sector. Lastly, my results showed that electrification of natural gas extraction was effective because I assumed that the electrification project will be carried out in full, despite the uncertainty as to whether funding has been committed. This is represented in Figure 9 under the “other industrial” sector.

Figure 9. B.C.'s GHG emissions in 2030 under the No-LNG forecast, by sector



Some of the policies I modeled from the CLP were not particularly effective at reducing emissions to meet the 2030 target. For example, the Step Code does not become compulsory until 2032. Thus, in Figure 9 there is no difference between the emissions under the BAU and CLP scenarios for the “buildings” sector.

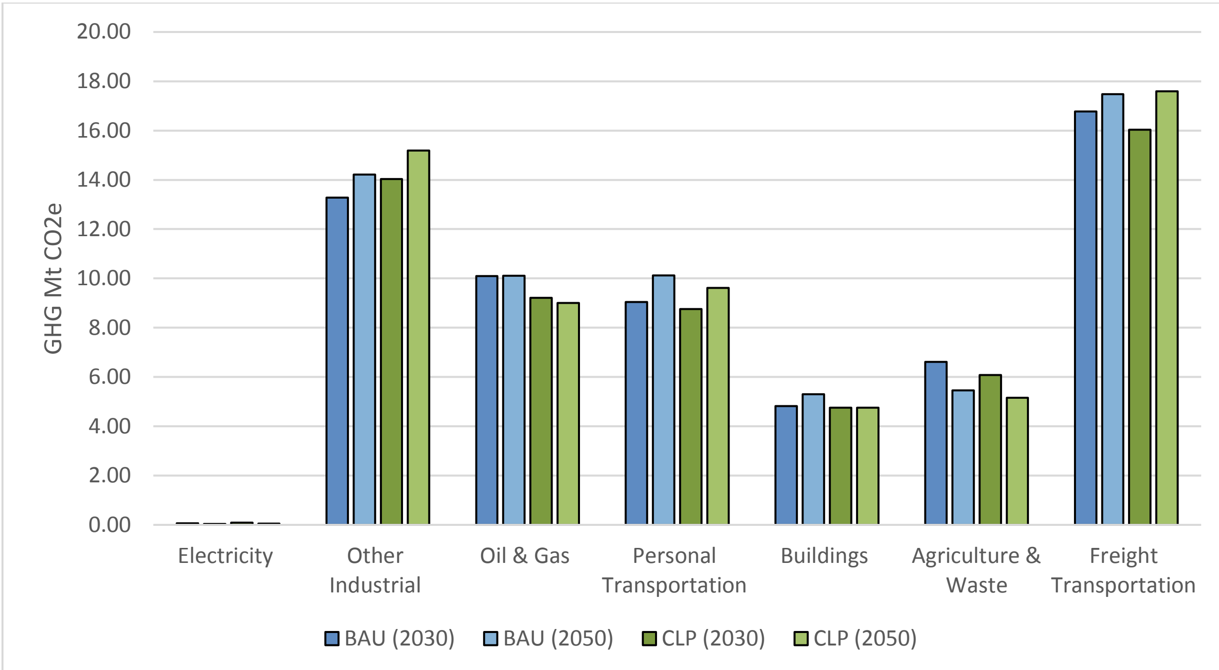
In addition, policies regulating higher efficiency for heating in buildings or boilers in industry had minimal effect by 2030. This was because many of the more efficient technologies represented in CIMS are predicted to become cheaper than less efficient alternatives by 2030. The market shares of these more efficient alternatives are predicted to increase independent of the CLP policies.

One policy from the CLP that had significant potential to reduce emissions was the methane regulation in the natural gas sector. This regulation mandates a reduction of leaked and vented methane emissions from natural extraction and processing by 45% below today's' rates by 2025. However, prior to the release of the CLP, the federal government released plans for a national methane regulation in the oil and gas sectors. The national regulation requires average methane emissions from oil and gas extraction to be 45% below 2012 levels by 2025. Although, the provincial regulation would be effective at reducing some emissions, our modeling indicates that the majority of methane reductions in B.C. should be attributed to the prior-announced federal methane policy.

Conversely, relative to the BAU scenario, the CLP scenario saw increased emissions from the ethanol and biodiesel production sectors. This can be seen in Figure 9 under the “other industrial” sector. This trend is the product of CLP policies either incentivizing or regulating greater biofuel consumption, which reduces end-use gasoline and diesel emissions but increases ethanol and biodiesel production emissions, especially in the absence of a policy to reduce these latter. Although the GHG increase from biofuel production sectors is small, this trend lessened some of the overall emissions reduction impact of the CLP policies.

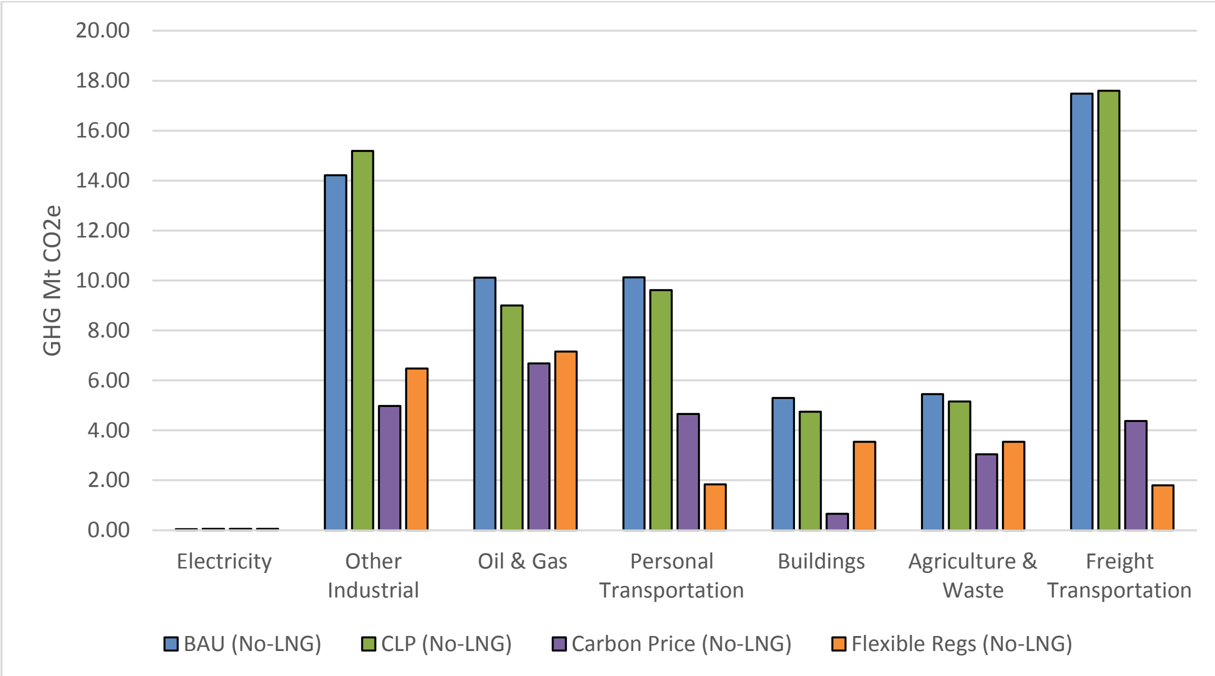
As was noted in section 7.1, overall GHG emissions increase from 2030 to 2050 for both the CLP and BAU scenarios. This is likely caused by lack of policies capable of offsetting increasing emissions from a growing population and economy. However, for some sectors GHG emissions move in a downward trend from 2030 to 2050. As can be seen in Figure 10 landfill regulations in the BAU and CLP scenarios reduce emissions in the "agriculture & waste" sector from 2030 to 2050. Additionally, in the CLP scenario electrification of natural gas production and processing brings down emissions from 2030 to 2050 in the "oil and gas" sector.

Figure 10. B.C.'s GHG emissions in 2030 and 2050 under the No-LNG forecast for the BAU and CLP scenarios, by sector



As can be seen in Figure 11, which shows sectoral results for 2050, the difference in GHG emissions between BAU (blue bar) and the CLP (green bar) are similar to those observed in 2030. However, unlike in 2030, emissions in buildings are lower under the CLP relative to BAU. This is because the Step Code becomes mandatory after 2032. Additionally, GHG emissions in freight transport are no longer lower under the CLP, instead they are virtually parallel with the BAU. This was unexpected since under the CLP the low carbon fuel standard (LCFS) on diesel mandates a 15% reduction in carbon intensity, rather than the 10% which occurs in the BAU. The LCFS caused switching away from heavy-duty trucks, in response to increased diesel prices, towards rail transport. This was observed because when I modeled the LCFS in freight I only applied it to diesel consumed for truck motors, and not the fuel consumed by rail transport.

Figure 11. B.C.'s GHG emissions in 2050 under the No-LNG forecast, by sector



7.2.2. Scenarios that met the 2030 and 2050 target

GHG emissions decreased overall in the province from 2030 to 2050 under the carbon price and flexible regulations scenario. This trend was also observed at a sectoral level for: other industrial, oil & gas, personal transportation, buildings, agriculture & waste, and freight transportation — while electricity stayed relatively constant at a near-zero emissions level. Although both the carbon price and flexible regulations scenarios were designed to meet the provincial 2030 and 2050 targets, each scenario affected sectors differently. The biggest difference between the carbon price and flexible regulations scenarios were found in the building and transportation sectors.

Both the “personal transportation” and “freight transportation” sectors had further emissions reductions under the flexible regulation scenario than under the carbon price scenario, as shown by the difference between the purple and orange bars in Figure 9 and in Figure 11. This is because the flexible regulations targeted a greater adoption of low- to zero-emission vehicles (i.e. electric or hydrogen vehicles), rather than increased efficiency of conventional gasoline and diesel vehicles. In contrast, it would take a substantially higher emissions price than the one I simulated to induce such a dramatic fuel switching away from gasoline and diesel.

The “buildings” sector had greater emission reductions under the carbon price scenario (Figure 9 and Figure 11). Under the flexible regulation scenario, the main regulation affecting building emissions was the Step Code, which only applies to building shells. On the other hand, in addition to buildings shells, the emissions price targets all end-uses and therefore all technologies used in buildings, including hot water, appliances, and air conditioning.

It can also be seen in Figure 9 and Figure 11 that industrial emissions are higher under the flexible regulations scenario. This is because the performance standards in the flexible regulation scenario were designed to protect the most trade-exposed and emissions-intensive industries, and were therefore not applied with even stringency across all industrial sectors. On the other hand, the carbon price scenario set an even price signal across all industrial sectors, and was therefore more effective at reducing emissions, albeit with greater risks to the long-run economic health of some industries.

My approach to modelling an emissions price in industry should not be seen as implying that trade exposure should be overlooked when designing climate policy. While the carbon price scenario appears to be more effective, a policy that protects trade-exposed and emissions-intensive sectors, whether the policy is emissions pricing or regulations, may be more effective overall, and is likely to be more politically acceptable.

7.3. Implications for federal-provincial initiatives

For the provincial study, I modeled policy designs for integrating B.C. climate policy with the national targets and policy efforts. I focused on designing flexible regulations that could gradually align initiatives by all regions and all levels of government in Canada, by testing and adjusting policies as needed to achieve the goal of a similar nation-wide marginal cost of emissions reduction.

Flexible policies can be linked across regional markets, enabling a mix of cost-effective actions across the country that reflect regional differences in alternative energy and technology costs and benefits. If the flexible policy involves the trading of credits or allowances, and if these can be traded by actors in different regions of Canada, the effect should be to reduce total national GHG emissions in a cost-effective manner (Bodansky *et al.*, 2014). Also, the stringency levels of flexible regulations, even those without significant credit trading, can be adjusted over time so that the marginal costs of GHG abatement are roughly equal between all provinces.

However, it is difficult to link climate policies across jurisdictions if they are not aligned appropriately. This presents a challenge for Canada, given that our climate policies are currently seen as a patchwork due to a lack of coordination amongst provinces and the federal government (Cameron and McLeod, 2015). This patchwork reflects a series of gaps in terms of the sectors covered by policy, as well as differences in stringency amongst the policies that are in place. Therefore, to effectively and efficiently link policies between Canadian provinces, it is likely that the current suite of policies will have to be restructured and in some cases replaced.

Furthermore, aligning policies between regions is particularly important in terms of reducing GHG emissions. This is because GHG emissions will affect the climate regardless of the point of emanation. Thus, if policy stringency is disparate across a country, some GHG emissions can simply relocate to a jurisdiction with less stringent or no policy altogether. For example, the low carbon fuel standard I modeled in B.C. could result in fuel shuffling such that low intensity fuels are sold in regulated areas and higher intensity fuels are sent to unregulated areas. Fuel shuffling is a form of carbon leakage because instead of emissions actually being reduced, they've simply been relocated. If, however, the low carbon fuel study was applied federally, as modeled in the national portion of this study, this would result in a binding policy across the country, and such fuel shuffling would not occur within Canada.

Similar linking can be done using the flexible transportation or electricity policies explored in this study. However, it is important to note that there are other market-based policies besides those modeled in this report. These specific flexible policies only serve as possible examples of sector-specific regulations as an alternative approach to a high carbon price. Furthermore, I do not suggest that either carbon pricing or regulations are better than the other. Instead, my study provides information that may be helpful to policy makers as they consider the performance of different policies in terms of effectiveness, economic efficiency and political acceptability.

Chapter 8.

Conclusions

The objective of this study is to test alternative climate policy scenarios to provide useful information for decision-makers. This study is comprised of two parts: a national study that evaluates options for meeting Canada's 2030 GHG emissions target, and a provincial study which evaluates options for B.C. to contribute to both the federal 2030 and 2050 targets.

8.1. National study findings

The first component evaluates options for meeting a Canadian target. The following summarizes the findings suggested by this study:

1.) The ongoing effects of existing policies at the federal and provincial levels are not sufficient to meet the 2030 target. The model estimates that the target will be missed by roughly 200 Mt CO2e.

2.) Carbon price trajectories able to reduce GHG emissions such that the federal 2030 target is met, are estimated to reach $190-$200/tCO2e. However, the price is dependent on several uncertain factors. We conducted a sensitivity analysis on the global oil price which suggests that the carbon price should be at the high end of the range if the global oil price is low since this may incentivize greater domestic consumption of petroleum based fuels.

3.) The 2030 target could potentially be met through a package of sector-specific flexible regulations, with an explicit carbon price that only reaches $40/tCO2e. This package of flexible regulations could be designed to approximate the efficiency of a single nation-wide carbon price.

8.2. B.C. study findings

The second component focuses on B.C. as a case study, and evaluates the province's possible options to contribute to a broader national target. The following summarizes the findings suggested by this study:

1.) Not all provinces will necessarily have to reduce emissions by the same proportion to meet the 2030 and 2050 federal targets. This is because the targets apply to Canada as a whole. Results from modeling a nation-wide carbon price suggest that to meet the equi-marginal principle, B.C. would only have to reduce emissions 25% below 2005 levels to meet the 30% national 2030 target, and 60% below 2006 levels to meet the 65% national 2050 target.

2.) The ongoing effects of existing policies affecting B.C., excluding those policies announced in B.C.'s Climate Leadership Plan, were insufficient to reduce emissions by the proportions describe above.

3.) The additional GHG emission reductions from policies announced in B.C.'s Climate Leadership Plan were also insufficient to reduce emissions by the proportions described above.

4.) I estimate that carbon price trajectories with the potential to meet the 2030 target reach between $120-$190/tCO2e. This price depends on several uncertain factors. I conduct a sensitivity analysis on the development of LNG, which suggests that the carbon price should be at the high end of this range if LNG is developed since it is estimated to expand the extraction of natural gas in the province, and associated emissions.

5.) I estimate that a carbon price trajectory to meet the 2050 provincial GHG emission target would reach $490/tCO2e.

6.) My findings suggest that it is possible to use sector-specific flexible regulations at a provincial level, along with a moderate carbon price that reaches $40/tCO2e in 2030 and $100/tCO2e in 2050, to achieve B.C.’s cost-effective share of the 2030 and 2050 Canadian emission targets.

8.3. Limitations

My study has several limitations in part related to my assumptions about future conditions for external factors, technologies, energy forms and the decision-making perspectives of consumers and firms. My study only has two sensitivity analyses: high and low oil price forecasts, and the substantial development or not of LNG in British Columbia. It is consequently limited in its ability to evaluate what other factors are likely to affect the results from the model. One way for future studies to potentially address this uncertainty is to implement sensitivity analyses on more of the key assumptions.

Another limitation is that I did not quantify the losses in economic efficiency between the scenarios. Although flexible regulations are more efficient that a command-and-control regulation, I did not quantify by how much. And while I assume that the flexible regulations are not as efficient as carbon pricing, I do not quantify how large this gap is. Future research could analyze the cost of different policies on society, notably the economic efficiency difference between carbon pricing, flexible regulations, and command-and-control regulations. Research could also be applied in a much narrower sense, to analyze the costs of applying different types of flexible regulations to achieve a similar outcome. For example, if a government would like to regulate emissions from industrial boilers, is there a difference in the efficiency or logistics between applying a niche market regulation or a performance standard?

Furthermore, although, I present a set of potential flexible regulations that could be used to link climate policies between different regions, this study did not quantify the advantage of any particular province (i.e. British Columbia) linking a particular climate policy with another jurisdiction. Future research could determine what linkages are most advantageous or appropriate.

Lastly, in this study I do not propose that one type of flexible regulation or carbon pricing approach is superior to another. I simply present some potential trade-offs between different policy types so that policy-makers can better assess climate policy design. Further research could investigate what is appropriate under real-world dynamics and the particularities of different regions.

8.4. Final Comments

This study is particularly relevant to the current situation in Canada. It provides information to policy-makers about some of the potential paths Canada's climate policies could take on a national level, and on a provincial level using B.C. as a case study. Furthermore, this study addresses some questions policy-makers could have about how climate policy will interact with future conditions, particularly with regard to oil prices and oil sands output, and the development of liquefied natural gas in B.C.

I present some options for meeting the 2030 and 2050 targets using compulsory policies. I chose to explore policies that have the ability to link climate policies between regions in response to the intentions of the current federal government. However, there is no evidence that successful climate policy necessitates involvement between provinces or with the federal government. Some of the most successful climate policies in Canada have occurred within individual provinces rather than inter-regionally. Therefore, in this study I do not argue that one policy design or framework is fundamentally better than another. Instead I hope to have provided some insight on the trade-offs between different climate policy options both for Canada as a whole and for British Columbia as a region within the Canadian federation.

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Appendix A.

Carbon pricing adjustments

The carbon prices reported in this study can be represented in several ways. The model takes 2005$ CAD as an input. However, I chose to report these values in 2016$ CAD. These values were then adjusted to reflect macroeconomic feedbacks that are not likely captured by CIMS since the model is only partial-equilibrium. Macro-economic feedbacks from climate policies would cause structural changes in the economy — lowering production in the more emission intensive sectors. Experience with models, such as a computable general equilibrium model, that do have full-equilibrium capabilities, linked to CIMS suggests that the carbon prices suggested by CIMS alone are too high. Therefore, the prices quoted in the results section have been adjusted downward by 25%.

The following summarizes the carbon prices for both the national and provincial studies, under the carbon price and flexible regulations scenario.

National Study

Table 6. Carbon prices under the carbon price scenario in 2030, including macroeconomic adjustments (national study)

Oil Price	2005$	2016$	$2016 (macro adjustments)
Low	225	265	200
High	215	255	190

Table 7. Performance standard permit prices under the flexible regulation scenario in 2030, including macroeconomic adjustments (national study)

Oil Price	Sector	2005$	2016$	$2016 (macro adjustments)
EITE Sector	Low	135	160	120
	High	120	140	105
Non-EITE Sector	Low	230	270	205
	High	215	250	190

Provincial Study

Table 8. Carbon prices under the carbon price scenario, including macroeconomic adjustments (provincial study)

Year	LNG Forecast	2005$	2016$	$2016 (macro adjustments)
2030	No-LNG	130	155	120
	LNG	215	255	190
2050	No-LNG	555	655	490
	LNG	555	655	490

Table 9. Performance standard permit prices under the flexible regulation scenario, including macroeconomic adjustments (provincial study)

Sector	Year	LNG Forecast	2005$	2016$	$2016 (macro adjustments)
EITE Sector	2030	No-LNG	30	35	30
		LNG	60	75	55
	2050	No-LNG	270	335	250
		LNG	300	375	280
Non-EITE Sector	2030	No-LNG	60	75	55
		LNG	90	110	85
	2050	No-LNG	355	440	330
		LNG	450	560	420

Table 10. Performance standard permit prices on the natural gas sector under the flexible regulation scenario, including macroeconomic adjustments (provincial study)

Year	LNG Forecast	2005$	2016$	$2016 (macro adjustments)
2030	No-LNG	300	373	280
	LNG	300	373	280
2050	No-LNG	300	373	280
	LNG	300	373	280