MOO-ving in the Right Direction: Policies to Reduce Agricultural Methane Emissions in British Columbia

by

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Abstract

British Columbia's (BC) agricultural sector produces greenhouse gases which contribute to climate change, with methane being the primary source of agricultural greenhouse gas emissions in BC. BC's agricultural methane emissions remain largely unregulated. The policy problem this study seeks to address is the complex set of barriers to mitigating methane emissions in BC. A jurisdictional scan guided by a literature review and case studies is conducted to develop an understanding of the underlying problems with the mitigation efforts such as the lack of accurate methane emissions measurement technologies, clear enforcement mechanisms and the ongoing dynamics of the agricultural sector in BC. A multi-criteria analysis is used to explore and assess potential policy options that seek to address these barriers. This study recommends a policy bundle consisting of an Agricultural Methane Emissions Reduction Research and Development Program and an Agricultural Methane Reduction Offset Protocol and Subsidies.

Keywords: agricultural methane emissions; greenhouse gas emissions; livestock emissions; policy analysis; climate change.

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Table of Contents

List of Tables

List of Figures

List of Acronyms

AAFC	Agriculture and Agri-Food Canada
ACS	Agricultural Climate Solutions
ACTP	Agricultural Clean Technology Program
AD	Anaerobic Digestion
AFF	British Columbia Ministry of Agriculture, Food and Fisheries
AFFC	Agriculture and Agri-Food Canada
APF	Agricultural Policy Framework
BC	British Columbia
BCCAF	BC Climate Agri-Solutions Fund
BMP	Beneficial Management Practices
CAFO	Concentrated Animal Feeding Operations
CAP	Canadian Agricultural Partnership
CARB	California Air Resources Board
CBCAIP	Canada-BC Agri-Innovation Program
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	CO2 equivalent
COP	Conference of the Parties
DDRDP	Dairy Digester Research and Development Program
ECCC	Environment and Climate Change Canada
EFP	Environmental Farm Plan
EU	European Union
GHG	Greenhouse Gas
GMI	Global Methane Initiative
GMP	Global Methane Pledge
GoC	Government of Canada
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
MCA	Multi-Criteria Analysis

MERiL	Methane Emissions Reduction in Livestock
MMT CO_2e	Million Metric Tons of Carbon Dioxide Equivalent
Mt	Megaton
NDC	Nationally Determined Contributions
NIR	National Inventory Report
NZAGRC	New Zealand Agricultural Greenhouse Gas Research Centre
O&G	Oil and Gas
OECD	Organization for Economic Co-operation and Development
RNG	Renewable Natural Gas
SAS	Sustainable Agricultural Strategy
SCAP	Sustainable Canadian Agricultural Partnership
SLCP	Short-Lived Climate Pollutants
TIER	Technology Innovation and Emissions Reduction
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America

Executive Summary

Methane (CH_4) is a powerful greenhouse gas (GHG) with a global warming potential over 80 times more powerful that carbon dioxide in a 20-year time frame. CH_4 lasts in the atmosphere for roughly 12 years. For this reason, CH_4 mitigation provides a way to reduce global warming in the short term, while helping reach broader climate goals.

Agriculture is the biggest source of human-caused CH_4 emissions in the world. These emissions are primarily from livestock, namely cattle. There are two main types of agricultural CH_4 emissions: enteric and manure emissions. Enteric emissions are a result of the digestive process of livestock and manure emissions are a result of manure management practices.

In British Columbia (BC), 20% of total CH_4 emissions are from the agriculture sector. However, currently, there are no policies or regulations targeting these emissions. This is due to numerous barriers to adoption of CH_4 mitigation strategies. Such barriers are faced both on the farm scale and sectoral policy level. These barriers include measurement challenges, financial, political, and regulatory barriers.

This study seeks to address the following policy questions: 1) What are the barriers and challenges to targeting agricultural CH_4 emissions in BC? 2) What programs or strategies are already in place? 3) What are possible mitigation strategies that could be adopted by the province? 4) What are other jurisdictions doing to mitigate their own livestock CH_4 emissions?

The methodologies used in the research include a jurisdictional scan guided by a literature review, case studies from other jurisdictions, and a multi-criteria analysis. Two policies are recommended as a policy bundle: the Agricultural CH_4 Emissions Reduction Research and Development Program and an Agricultural Methane Reduction Offset Protocol and Subsidies. The key criterion used to evaluate these policy options is the effectiveness of a policy in reducing barriers to adoption of CH_4 mitigation strategies. Other criteria include administrative ease, cost to government, equity, and stakeholder acceptance. The recommended policies have the potential to establish a better framework for addressing and mitigating agricultural CH_4 emissions in BC. The recommendations are followed by a brief discussion of implementation considerations.

As this is an area of ongoing research, the suggested policy bundle will need to be adapted based on new findings from the literature.

Chapter 1.

Introduction

Methane (CH_4) is the second most prominent greenhouse gas (GHG) after carbon dioxide (CO_2) and has a global warming potential (GWP) 87 times greater than CO_2 over a 20-year period while remaining in the atmosphere for about only 12 years (Baray et al., 2021).[1] Due to its short lifespan, climate experts believe that cuts in CH_4 emissions would have almost immediate benefits in reducing global warming, would help the world stay under a 1.5ºC temperature increase, and would allow society more time to transition to net-zero emissions (Institute for Agriculture and Trade Policy, 2019). With these findings, CH_4 emissions have been at the forefront of recent climate discussions, particularly since taking the spotlight at the 2021 United Nations Climate Change Conference of Parties (COP26) where the United States and the European Union (EU) announced the Global Methane Pledge—an initiative to reduce CH_4 emissions by at least 30% below 2020 levels by 2030.

Agriculture contributes an estimated 40% of global CH_4 emissions and is projected to rise with rising food production (Searchinger et al., 2021). Most of these emissions (70%) come from livestock through enteric fermentation, and a smaller share from manure management (8%) (Searchinger et al., 2021).[2] Enteric fermentation is a digestive process of ruminant animals[3] whereby CH_4 is produced and emitted through belching and exhalation; the amount of enteric CH_4 an animal produces is dependent on its type and size, on the amount and composition of its feed, and on feed management practices, as illustrated in Figure 1.1 (United States Environmental Protection Agency, 1998). While responsible for a large share of CH_4 emissions, the agricultural sector is also one of the sectors most vulnerable to the risks of climate change (e.g., increased heat stress on livestock; increased pests; drought and flooding and their effect on crops, etc.) (Cheng et al., 2022).

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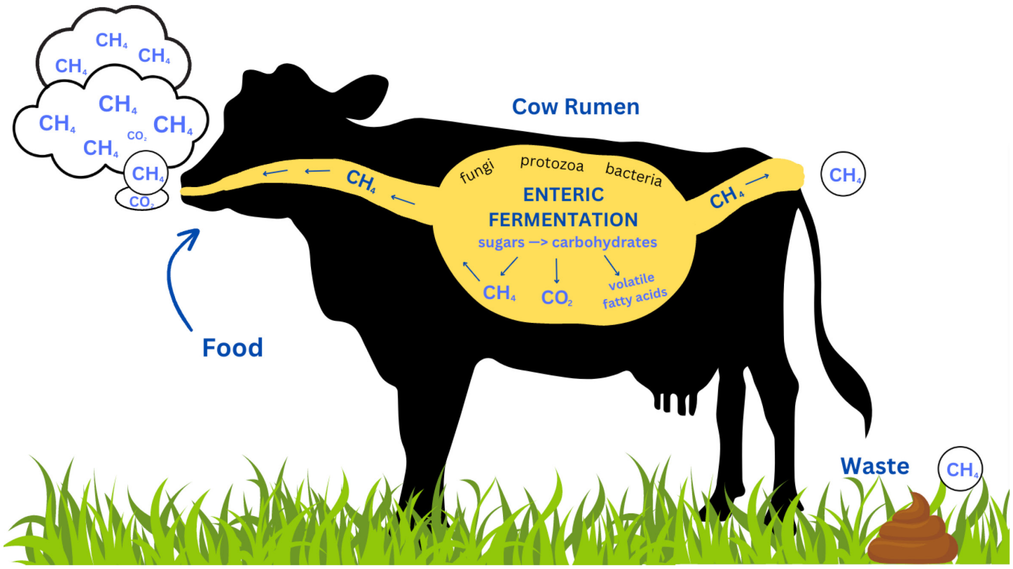
[1] As opposed to CO_2's atmospheric lifespan which can be thousands of years.

[2] Rice production makes up 15% of emissions. However, as rice is not produced in Canada, emissions from rice production and other sources of agricultural CH_4 emissions are beyond the scope of this paper.

[3] Ruminant animals are those with a rumen—a multichambered stomach that can digest tough plants and grains. The main types of ruminants kept as livestock in Canada are cattle, sheep, goats and bison, with cattle being the most common.

Figure 1.1　Process of Enteric Fermentation in Cattle



Source: Author's illustration using data from Let's Talk Science, 2019.

Internationally, progress on addressing agricultural GHG emissions (CH_4 and others) has been uneven across countries and has mostly relied on voluntary initiatives such as beneficiary-pays approaches[4], green finance, and modest target setting (OECD, 2019). These strategies have not been found to achieve as much as if concrete targets, policies, and/or regulations in place (Searchinger, 2021).

In 2020, the agricultural sector was responsible for 20% of British Columbia's (BC) CH_4's emissions.[5] As with global CH_4 emissions, BC's largest source of agricultural CH_4 emissions is from livestock, particularly cattle. As such, this analysis focuses on livestock cattle emissions as they make up the largest source. The province does not have any regulations or policies in place for agricultural CH_4 emissions reductions, despite the sector's significant contribution to CH_4 emissions in BC. This research addresses this policy gap. While they present a significant opportunity for climate action, agricultural emissions have been targeted by few policies as they present many challenges. This study seeks to answer the following questions: What are the barriers and challenges to targeting agricultural CH_4 emissions in BC? What programs or

[4] More on these approaches can be found in the Appendix

[5] In 2020, BC's CH_4 emissions amounted to 8.5 Mt CO_2e and agriculture's emissions were 1.7 Mt CO_2e (Government of British Columbia, 2022).

strategies are already in place? What are possible mitigation strategies that could be adopted by the province? What are other jurisdictions doing to mitigate their own livestock CH_4 emissions?

Chapter 2 provides an overview of national and provincial CH_4 emissions, including sources and trends. Chapter 3 provides an overview of the methodologies used in this study, which include a scan of existing policy options, programs, and research and development initiatives across the world, and a multi-criteria analysis to evaluate these policy options and determine the most effective bundle for BC. Chapter 4 outlines the barriers and challenges to the adoption of CH_4 mitigation policies. Chapter 5 reports current policy goals relevant to CH_4 emissions on the international, federal, and provincial landscapes. Chapter 6 analyzes policies in other jurisdictions to inform policy options for BC. Chapter 7 provides a multi-criteria analysis framework to evaluate policy options for BC and is followed by descriptions of each option in Chapter 8. The last chapter presents the evaluation of the policy options and provides the recommended bundle and implementation considerations.

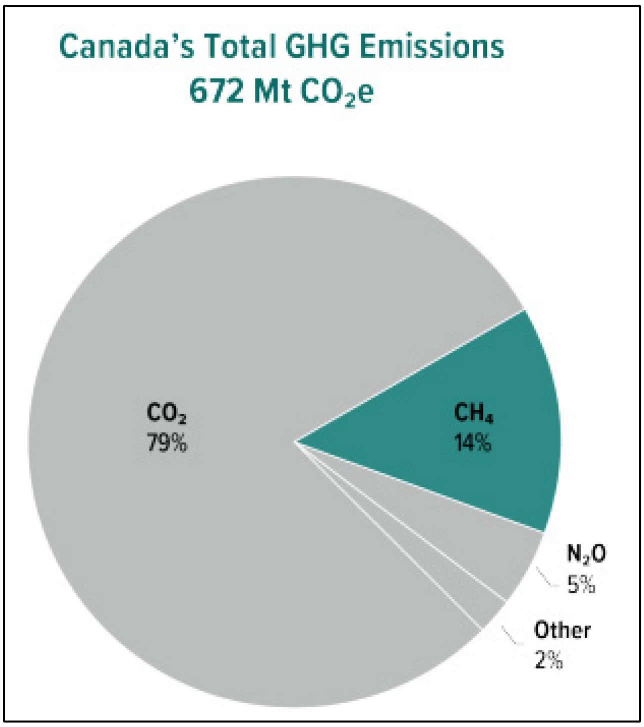
Chapter 2.

Background

2.1. Canada's Methane Emissions

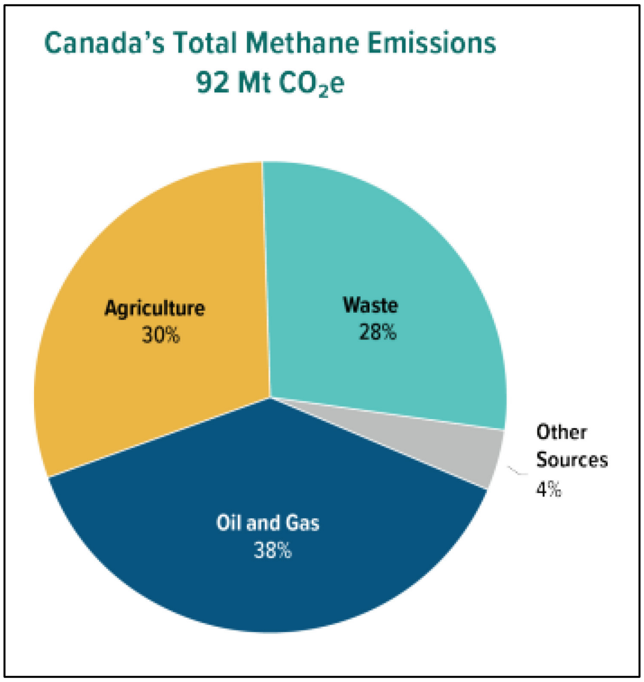
In 2020, Canada's methane (CH_4) emissions were 92 Mt CO_2 equivalent (CO_2e), making up 14% of total national GHG emissions (ECCC, 2022b). Canada's anthropogenic (human created) CH_4 emissions come from a variety of different economic sectors; however, the vast majority (over 95%) of Canada's anthropogenic CH_4 emissions are from the oil and gas (38%), agriculture (30%), and waste (28%) sectors (ECCC, 2022b).

Figure 2.1 Canada's Total 2020 GHG Emissions



Source: ECCC, 2022b

Figure 2.2 Canada's Total 2020 Methane Emissions by Source



Source: ECCC, 2022b

In 1990, CH_4 emissions were roughly equivalent to those in 2020, but steadily increased and peaked in 2006 at 126 Mt CO_2e (ECCC, 2002; ECCC, 2022b). This increase of 38% in emissions was mostly due to increased natural gas production leading to more fugitive oil and gas (O&G) emissions (24Mt); increased agricultural emissions (8.9 Mt) and increased waste emissions (3.7 Mt) (ECCC, 2022b; Scarpelli et al., 2022; Brandt et al., 2016). Since 2006, CH_4 emissions have gradually declined, mainly due to the O&G sector's improved leakage detection and natural gas conservation; an initial decline in cattle populations—which has since stabilized—and a decrease in waste emissions through decreased wood landfills, and capture and recovery of landfill gases (ECCC, 2019; Lu et al., 2021). Between 2019 and 2020, CH_4 emissions dropped significantly from 109 Mt to 92 Mt[6]. This decrease is a result of two factors: the federal and provincial (Alberta, BC, and Saskatchewan) efforts to reduce CH_4 emissions from the oil and gas (O&G) industry and the COVID-19 pandemic which resulted in a general decrease of GHG emissions across all sectors and jurisdictions.

[6] Lowest recorded emissions, on par with 1990 (ECCC, 2022b).

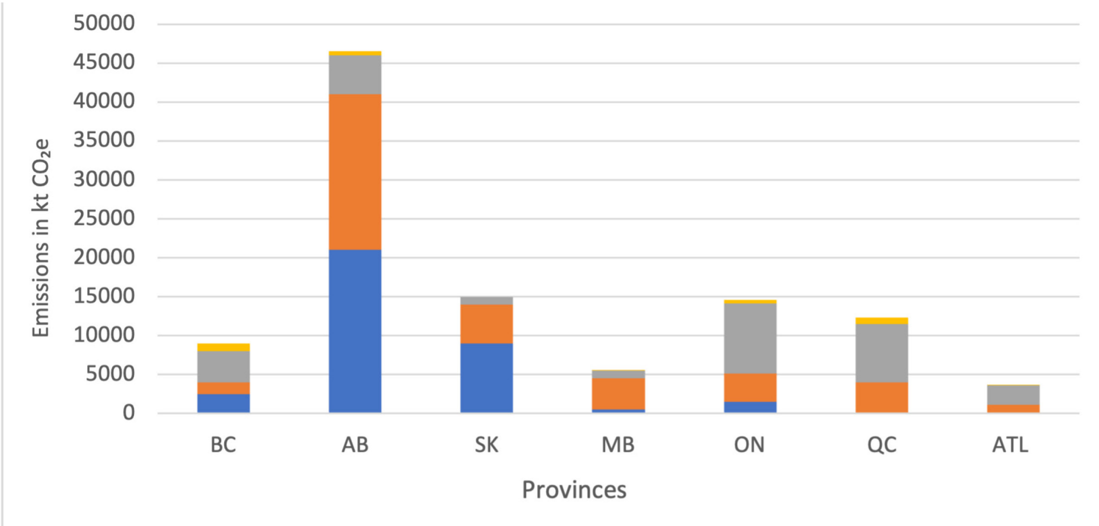
2.2. Provincial CH_4 Emissions

Provincially, Alberta's CH_4 emissions are the highest in the country, emitting double than of any other province. This is explained by having most of the national O&G production, as well as around 40% of Canada's cattle population (Dobson et al., 2022). Second in provincial CH_4 emissions is Saskatchewan, which is home to Canada's second-largest oil production and cattle population (Dobson et al., 2022). Both provinces' O&G and agricultural CH_4 emissions make up over 85% of their total provincial CH_4 emissions, with the remainder coming from the waste sector (Dobson et al., 2022). Ontario and Quebec have the third and fourth highest emissions, respectively, with the majority of their CH_4 emissions originating from agriculture and waste (Dobson et al., 2022). Interestingly, despite Ontario's very low oil production, 10% of the province's CH_4 emissions are from the O&G sector due to a large amount of fugitive emissions from pipelines (Dobson et al., 2022).

BC's CH_4 emissions are the fifth highest, with waste being its largest contributor, despite the province having the second largest natural gas production in the country, providing over 30% of Canada's natural gas supply (Canada Energy Regulator, 2021). BC's fugitive emissions from natural gas make up around 5.9% of its total CH_4 emissions and only 7% of total national O&G CH_4 emissions (Dobson et al., 2022). While Alberta's natural gas production is about double BC's, it accounts for 77% of fugitive CH_4 emissions from natural gas, and Saskatchewan which produces less than 2% of natural gas, accounts for 5% of fugitive CH_4 emissions from natural gas (Dobson et al., 2022). This is explained by both BC's lower use of pneumatic devices which emit high levels of CH_4, and that fugitive emissions from pipelines starting in Alberta used for transporting natural gas to eastern Canada and the United States are responsible for a large share of these emissions (Dobson et al., 2022; Robinson et al., 2020).

Manitoba and the Atlantic provinces have the lowest levels of CH_4 emissions—almost 60% of Manitoba's CH_4 emissions are from agriculture, while the Atlantic provinces' largest source of emissions is the waste sector, followed by agriculture. Methane emissions in the territories are about 4% of the lowest provinces' CH_4 emissions (Atlantic), making their emissions essentially negligible (Dobson et al., 2022).

Figure 2.3 Canadian CH_4 Emissions by Province and Economic Sector

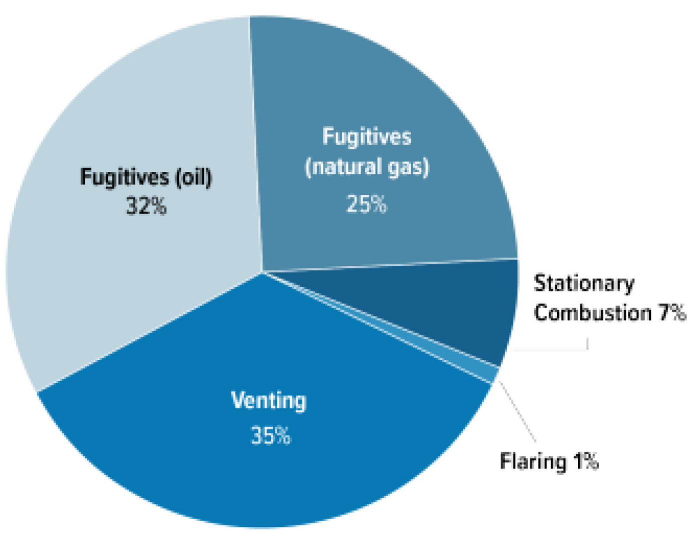


Source: Author's calculations using data from ECCC, 2022b and Dobson et al., 2022.

2.3. Sectoral Emissions

2.3.1. Oil and Gas

Figure 2.4 Sources of Canadian O&G CH_4 Emissions



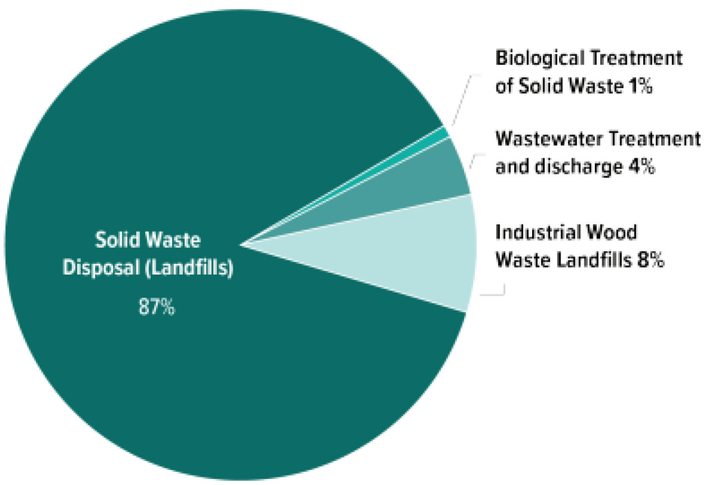
Source: ECCC, 2022b

The O&G sector is Canada's largest source of GHG emissions and the largest emitter of CH_4 emissions in Canada (responsible for about 38% of CH_4 emissions in

2020) (ECCC, 2022e). Various activities in the O&G industry emit CH_4[7]; however, the major sources are activities during upstream production[8] and the largest source is unintentional fugitive emissions (ECCC, 2022e). Fugitive emissions are the waste or loss in the fuel production process, storage or transport, and includes CH_4 emissions during O&G drilling and refining, as well as natural gas leakage from pipelines (ECCC, 2022e; Scarpelli et al., 2022). While O&G is the largest source of CH_4 emissions, various studies indicate there has been an underestimation of emissions from O&G production, meaning the numbers are larger than those reported in the National Inventory Report of Canada (Atherton et al., 2017; Baray et al., 2021; Chan et al., 2020; Deng et al., 2021; Johnson et al., 2017; Lu et al., 2021; Tyner & Johnson, 2021; Scarpelli et al., 2022).

2.3.2. Waste

Figure 2.5 Sources of Canadian Waste Sector CH_4 Emissions



Source: ECCC, 2022b

In 2020, the waste sector was responsible for around 28% of Canada's CH_4 emissions, with the majority of these being from municipal solid waste landfills and industrial wood waste at sawmills and pulp/paper mills (ECCC, 2022b). The landfill CH_4 generated today is the result of decades of landfilling of biodegradable waste, which

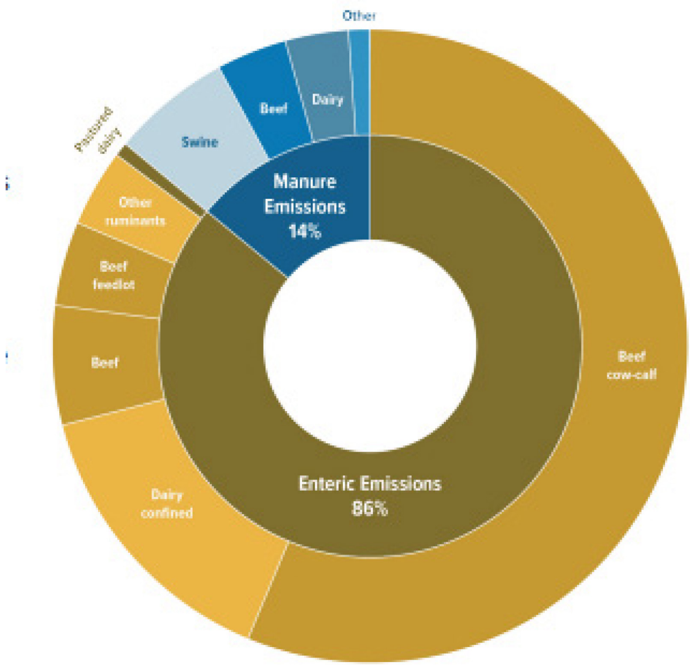
[7] These include drilling, gas gathering, production, field processing, refining, transmission, and transportation, among others (ECCC, 2022b).

[8] Such as such as intentional releases from venting and flaring; stationary combustion (ECCC, 2022b).

makes up over 60% of landfill waste in Canada (ECCC, 2022a). Canadian waste sector emissions have largely stayed constant for the last 20 years, indicating there have not been significant mitigation efforts to reduce emissions as they've only managed to keep pace with population growth.

2.3.3. Agriculture

Figure 2.6 Sources of Canadian Agricultural CH_4 Emissions



Source: ECCC, 2022b

The agricultural sector is the focus of the analysis in this study. In 2020, Canada's agricultural CH_4 emissions were 27,608 kt CO_2e. The vast majority[9] of these emissions are from enteric fermentation (86%) and manure management (14%) (ECC, 2022b). Livestock — specifically, cattle — is the largest single source of CH_4 emissions.

Nearly 96% of Canada's enteric CH_4 emissions in 2020 came from cattle (ECCC, 2022e). Enteric CH_4 emission rates differ by cattle breed; with dairy cows producing

[9] The remaining methane emissions from agriculture (41 kt CO2e/0.1 %). are from incomplete combustion of agricultural crop residues burning (ECCC, 2022b).

more CH_4 as they require more feed to meet the energy requirements of lactation.[10] Canada's total CH_4 emissions from enteric fermentation peaked at 30,821 kt CO_2e in 2005 and have declined by 23% since then, mainly due to the decreasing size of the national cattle population (ECCC, 2022e). However, between 1990 and 2020, enteric CH_4 emitted per cow have increased because of gains in milk production rates for dairy cows and average non-dairy cow weight increases as market preferences changed (Dobson et al., 2022).

The other significant share of agricultural CH_4 emissions is from the decomposition of livestock manure under anaerobic conditions.[11] Anaerobic conditions are more likely to occur in operations where many animals are confined, and manure is stored in large piles. Manure management practices that expose manure to more oxygen—such as dry storage and quick field spreading for fertilizing—generate less CH_4, than those that do not (Dobson et al., 2022).[12] For dairy cows, Canada experienced a shift from solid to liquid manure-management systems between 1990 and 2020, resulting in a 208% increase in per-animal manure CH_4 emissions (Dobson et al., 2022).[13] Climate conditions and weather can also affect CH_4 production, as warmer temperatures and rainfall increase methanogenic activity.

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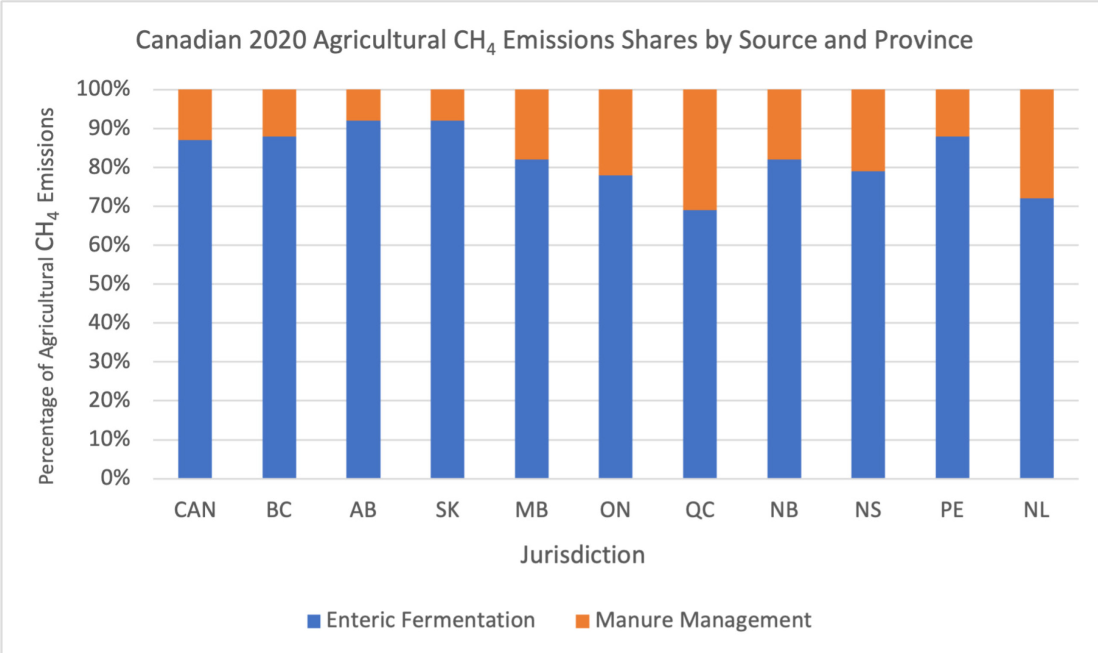
[10] In general, higher energy requirements translates to more feed consumption, more enteric fermentation activity and more methane production.

[11] Conditions where oxygen is not present, and bacteria generates methane.

[12] Such as wet storage of manure in tanks or lagoons, and long, infrequent spreading.

[13] Due to the large population of non-dairy cattle, however, this group is still a marginally larger source of methane emissions.

Figure 2.7 Canadian 2020 Agricultural CH_4 Emissions Shares by Source and Province

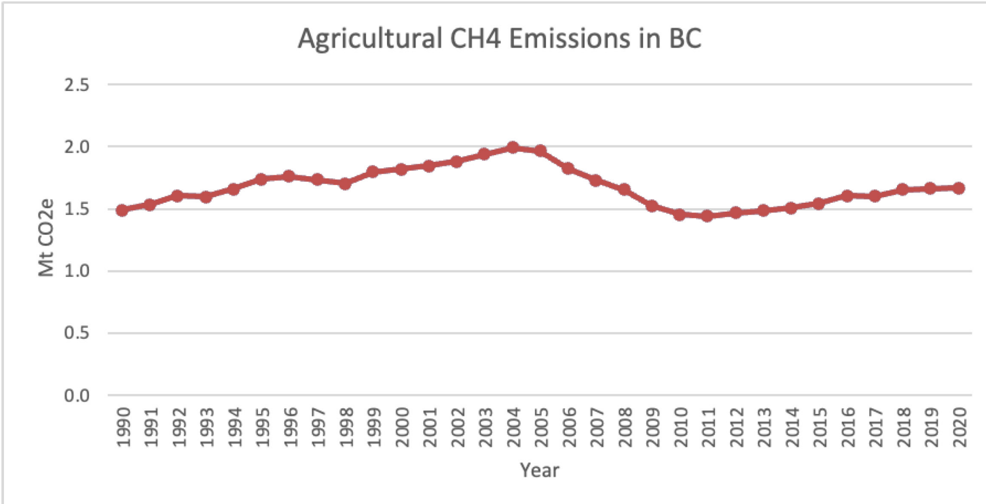


Source: Author's calculations from information in Dobson et al, 2022.

2.4. British Columbia's Agricultural Emissions

In BC, agriculture made up 20% of total CH_4 emissions (1.7 Mt CO_2e) in 2020 (Government of British Columbia, 2021). Of these emissions, 88% are attributed to enteric fermentation while 12% are from manure management (Government of British Columbia, 2021). Since 1990, the province's agricultural CH_4 emissions gradually increased and peaked at 2 Mt CO_2e (33% increase since 1990) in 2004 (Government of British Columbia, 2022). After 2004, emissions stayed constant for a couple of years before gradually decreasing to their lowest recorded levels in 2011 (1.4 Mt CO_2e), after which they increased again. Emissions have stayed constant at 1.7 Mt CO_2 since 2018, which is a 13% increase from 1990 levels. (Government of British Columbia, 2022). It is worth noting that BC has about 5% of the national beef herd and its agricultural CH_4 emissions make up roughly 7% of national agricultural CH_4 emissions (Government of British Columbia, 2022).

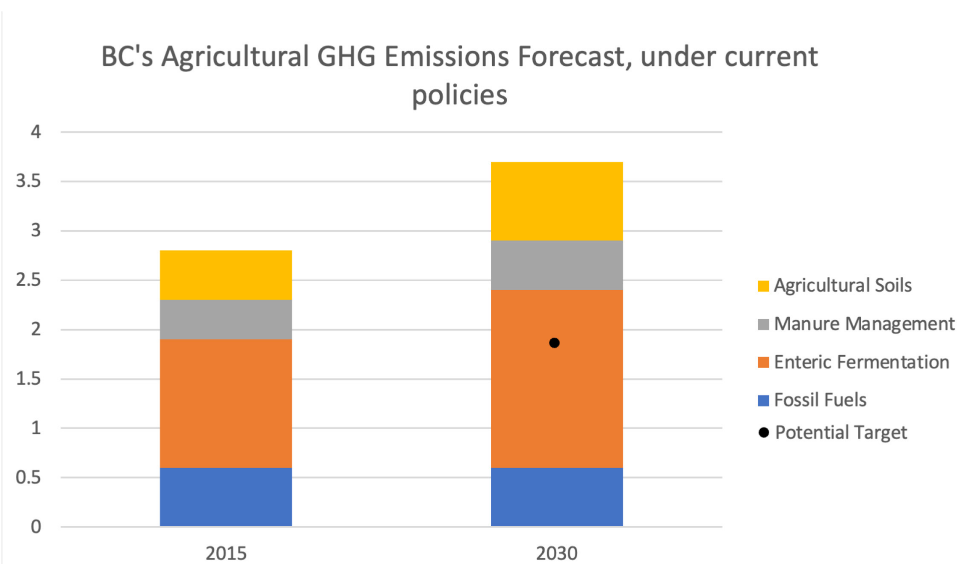
Figure 2.8 Agricultural CH_4 Emissions in BC (1990-2020)



Source: Author's calculations using Government of British Columbia (2022).

However, due to economic and demographic growth in the province, agricultural output is likely to continue to expand. Without mitigation strategies, this will most likely result in an increase of CH_4 emissions (Navius Research, 2021). As it is explained in Chapter 5, BC does not currently have any policies targeting agricultural CH_4 emissions. If the province were to extend its 40% GHG reductions target to the agriculture sector, Figure 2.9 demonstrates the gap between projected emissions and potential targets set without the implementation of any targeted policies.

Figure 2.9 BC's Agricultural GHG Emissions Forecast, under current policies



Source: Author's calculations using Navius Research, 2021

Chapter 3.

Methodology

This study employs a jurisdictional scan guided by a review of the literature and a multi-criteria analysis (MCA) to evaluate the proposed policy options.

3.1. Jurisdictional Scan

The jurisdictional scan identifies efforts undertaken by different levels of government in the United States, Canada, and internationally to implement strategies for the mitigation of agricultural methane emissions. California is chosen as one of the jurisdictions included in this study as it is often compared to BC in terms of geography and is considered a leader in GHG mitigation efforts in the United States. Alberta is another jurisdiction included in this study due to the policy options it presents that could be feasibly implemented in BC. Lastly, New Zealand and Australia are included as they present comparable examples of policy frameworks to Canada in terms of GHG mitigation efforts

3.2. Multi-Criteria Analysis

In order to determine the most effective policy bundle for reducing agricultural CH_4 emissions in BC, an MCA is conducted. Six criteria are identified to evaluate the policy options: policy effectiveness; administrative ease, equity; cost, and stakeholder acceptance. Each policy option is rated as either good, moderate, or poor for each criterion, with a maximum possible score of 18 for each policy option.

3.3. Limitations

This study seeks to provide mitigation strategies for agricultural CH_4 emissions in BC, however, this has been a topic that has only recently entered the public eye. New research on the topic is released very frequently due to the urgency created by the climate change problem and the pledges to limit global emissions in the Paris Agreement.

One limitation of this study is the lack of interviews with relevant stakeholders such as provincial and federal government representatives (e.g., AFF, AAFC, ECCC); non-government organizations; Indigenous experts; and farmers.

This research also lacks a thorough analysis of the potential impacts of CH_4 mitigation policies on First Nations communities, which is significant as they have been stewards of the land colonially known as “British Columbia” since time immemorial. Hence, future research on agricultural CH_4 emissions should include Indigenous voices and perspectives.

Additionally, this analysis is limited with factors within the project scope. A thorough analysis of economic and distributional impacts of the policy options evaluated in this study would improve our understanding of the potential consequences of these policies.

Chapter 4.

Barriers to the Adoption of Agricultural CH_4 Emissions Mitigation Strategies and Policies

While agricultural CH_4 emissions make up a large portion of global, national, and provincial CH_4 emissions, they have not been prioritized as an area for mitigation to help reach climate goals. This can be attributed to the multiple barriers to the adoption of mitigation strategies. These barriers are present both at the farm-level and at the policy-setting level. Overcoming these barriers increases the likelihood that a policy would successfully achieve its purpose, or at least ensure that new barriers are not created (Wreford et al., 2017). Additionally, if farmers are unable to identify their own benefits for changing their practices, they are unlikely to want to adopt mitigation measures without regulations (Wreford et al., 2017). Barriers identified in this section guide the choice of CH_4 mitigation policy options explained in Chapter 8.

4.1. Measurement Challenges

Across sectors, CH_4 emissions have been hugely underestimated.[14] Notably, there has been significant development in technologies for identifying and quantifying CH_4 emissions in the fossil fuel industry over the last decade (Nisbet et al., 2020). While this is necessary, there is little research on the inaccuracy of agricultural CH_4 emissions (Baray et al., 2021; Chan et al., 2020; Dobson et al., 2022; Johnson et al., 2017; Scarpelli et al., 2021).[15] As agricultural CH_4 emissions vary based on site-specific environmental conditions[16] and on differing farm management practices[17], this makes it very difficult to accurately estimate emissions because gathering data from each farm

[14] Before accounting for any errors due to measurement challenges Canada's baseline CH_4 emissions are likely underestimated by almost 40% (Dobson et al., 2022)

[15] Estimated discrepancies in O&G sector emissions range between 25-50% to over 200% (Dobson et al., 2022).

[16] Such as temperature, moisture, and oxygen availability.

[17] Feed, manure management, etc.

would be logistically and financially unfeasible (Barnard et al., 2021).[18]. This leads to inaccurate emissions data which in turn creates false baselines for policy action (Herrero et al., 2011).[19] Due to measurement challenges, there are also consequent difficulties with the complex reporting, monitoring and verification these emissions require (Fouli et al., 2021). So, while measurement poses a barrier for policy and target setting, it is also a barrier to adoption of mitigation strategies for producers, in the case of policies requiring cooperation from farmers with reporting their emissions. Thus, as Dobson et al. (2022) assert, due to inaccurate and insufficient measurements and data, CH_4 emissions in Canada are under-regulated.

4.2. Financial Barriers

Financial barriers are another significant barrier to mitigating agricultural CH_4 emissions. At the farm level, these financial barriers include the lack of perceived financial benefits, the high cost of adopting new technologies or practices, hidden and transaction costs, and limited access to credit (Wreford et al., 2017). Measures that do not guarantee financial benefits are unlikely to be adopted, and some climate-friendly measures are associated with high adoption costs at the farm level (Wreford et al, 2017). Hidden transaction costs could explain the non-adoption of seemingly profitable measures, and limited access to credit may slow down adoption (Wreford et al., 2017). To encourage adoption of CH_4 mitigation strategies, it is crucial to demonstrate or create financial benefits (Wreford et al, 2017).

On the policy side, there are high costs with establishing these policies especially as it pertains to monitoring, reporting, and verification (MRV). Some estimates have suggested that reducing agricultural CH_4 emissions would entail prices in the hundreds of dollars per ton of CO_2e abated (DeAngelo et al., 2006). However, other research suggests that agricultural GHG mitigation potential has been found to be cost-effective

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[18] In Canada, agricultural emissions from enteric fermentation and manure management are estimated through a top-down method utilizing IPCC Tier 2 methodologies populated with country-specific parameters collected through an expert consultation (ECCC, 2022; Norgaard et al., 2021). The resulting estimates have an uncertainty factor of 22%, which is a significant variation for such a large source of emissions (Dobson et al., 2022).

[19] For agricultural emissions, Canada follows UNFCCC reporting guidelines for converting CH_4 to CO_2e using a GWP of 25[19], however, the most recent IPCC report recommends converting CH_4 to CO_2e with a GWP of 29.8, which would increase Canada's reported estimated GHG emissions by 2.6% (Dobson et al., 2022).

and competitive with non-agricultural options– such as energy or transportation– in achieving long-term climate objectives (Smith et al., 2007). The question is who should pay.[20] Because CH_4 mitigation adds a cost to farm operations, if the mitigation strategies don't improve animal performance in a meaningful way, other incentives will be required to encourage adoption.

4.3. Societal, Cultural, and Political Barriers

On the policy side, targeting agricultural emissions is politically challenging due to the critical role agriculture plays in the lives and livelihoods of people, as it is estimated that globally, one in four people are farmers (Ahmed et al., 2020). Agriculture is crucial to the achievement of nutritional goals, rural development and poverty alleviation in many developing countries– 65% of low-income working adults make a living through agriculture (Reisinger et al., 2021). North Americans are the highest consumers of meat and dairy products globally and the indirect sway of voters who consume meat and dairy overwhelmingly has rendered policymakers reluctant to challenge the status quo and find solutions to tackle the issue at hand (Crenson, 1971). There is thus a lot at risk when proposing policies that would potentially alter the conditions of billions of people, and possible mitigation policies need to consider the implications of their implementation on all those dependent on these systems.

In Canada, another factor for the lack of progress on agricultural CH_4 mitigation is the bilateral trade relationship with the United States. Since 1989, there has been a free-trade agreement (FTA) for most agricultural products between Canada and the USA. Due to Canada's reliance on the United States as its largest export market, Canada's agricultural policy has been shaped by concerns regarding competitiveness with American agriculture and protecting key industries (Fisher, 2022). More than half of Canadian beef is exported, primarily to the United States and as such, the federal government is careful to maintain the competitiveness of the livestock industries by hesitating to place burdens on agricultural producers that are price-takers on international markets (Fisher, 2022).

[20] The Appendix explains the difference between beneficiary-pays and polluter-pays policies.

At the farm level, the decision-making of farmers is affected by various social and cultural factors, such as a strong attachment to occupation, workplace, land, and animals, as well as the sense of identity and status it provides (Davies, 2022; Wreford et al., 2017). Farmers' beliefs about climate change have a modest impact on whether they adopt climate-friendly measures, but the literature suggests that personal experience with climate change or extreme weather events may have a significant effect on the adoption of climate-friendly agricultural practices (Wreford et al., 2017). Cultural capital also plays a role, with farmers reluctant to take steps that may result in lower yields, threatening their perception of being a 'good farmer' (Wreford et al., 2017). Further, emotional or cultural attachments to land can both enhance and act as a barrier to adoption of mitigation strategies. Lastly, insufficient information and awareness is also a barrier which limits mitigation action. Farmers may lack knowledge about potential climate-friendly measures and how to implement them, and the way in which information about climate change is communicated is crucial (Davies, 2022; Wreford et al., 2017).

4.4. Leakage

Additionally, there is the risk of emissions leakage in the case that adopted mitigation policies leading to a decrease in production in one area, result in another region's increase in production to offset the production loss and creating transboundary CH_4 emissions elsewhere (OECD, 2019). For this reason, when evaluating possible policies for agricultural CH_4 emission abatement, it is important to analyze the net benefits that the policy will have on overall emissions.

4.5. Regulatory Barriers

Regulatory approvals can delay the adoption of new technologies that offer GHG emissions reduction in livestock (AAFC, 2022b). Barriers arise within the context of agricultural CH_4 mitigation because strategies that are implemented, must not have a negative impact on the animal or consumer's health. For example, with new chemical feed additives which inhibit CH_4 production, there are safety concerns about how these additives will impact the animal's performance, health, and any humans eating the resulting animal products. Regulatory barriers often involve lengthy processes as the necessary bureaucracy has to be in order before a novel technique can be implemented.

4.6. Equity Considerations

Policies targeting the agricultural sector will have different impacts on different types of producers. Farm size and the nature of farm operations will impact how the policy affects each producer (e.g., livestock grazing vs Confined Animal Feeding Operations (CAFO)). Different climate and soil conditions may favour producers in one area of the province vs another for certain policies. Therefore, policymakers also need to consider the distributional effects of mitigation strategies.

Notably, BC has the highest number of Indigenous agricultural farm operators (Statistics Canada, 2019). Especially due to this fact, thoughtful consultation and engagement must be undertaken in order to implement policies that adequately incorporate Indigenous values and interests.

Urgent calls for climate action from the BC First Nations Climate Strategy and Action Plan (2022) include urging decision-makers to support First Nations to reduce their own GHG emissions through:

- support in developing environmentally sustainable and low carbon economic development projects and opportunities;
- support for implementing nature-based solutions and eliminating barriers for Nations to pursue land-based carbon offsets;
- support for assessing, quantifying, and reducing their GHG emissions to inform decision-making, develop offset and/or mitigation measures, and explore economic investments.

Chapter 5.

Current Policy Goals Relevant to Methane Emissions

This chapter outlines existing policies which may directly or indirectly have implications for agricultural CH_4 mitigation. These are divided by international, federal, and provincial efforts.

5.1. International Policies

The Paris Agreement is signed by 196 Parties under the United Nations Framework Convention on Climate Change (UNFCCC). Its primary goal is to limit global warming to below 2°C, preferably 1.5°C, compared to pre-industrial levels. Under this agreement, countries submit Nationally Determined Contributions (NDCs) outlining actions to reduce GHG emissions (UNFCC, 2016). The Intergovernmental Panel On Climate Change (IPCC) (2014) has reported CH_4 is the second (behind CO_2) most important anthropogenic contributor to present-day radiative forcing[21], and thus one of the main gases to target. Because the Paris Agreement does not set any specific targets for the agricultural sector CH_4 emissions, these are subject to each country's discretion. For this reason, only 38% of agricultural emissions are covered by NDCs under the Paris Agreement (Ahmed et al., 2020). Despite not being explicitly mentioned in the Agreement, the literature makes it clear that failure to include agricultural GHG emissions would make it impossible to limit warming by 1.5°C even if CO_2 emissions from other sectors were to decrease dramatically (Cain et al., 2021; Frank et al., 2019; Leahy et al., 2020; Lynch et al., 2021; Nisbet et al., 2020; Reisinger et al., 2021).

Another initiative is the Global Methane Pledge (GMP) which was announced at COP26 in 2021, with the aim of reducing CH_4 emissions by 30% below 2020 levels by 2030 (GMP, 2021). Over 100 countries, representing over 50% of global anthropogenic CH_4 emissions, signed the GMP, which explicitly includes the agricultural sector. The Pledge also supports existing global CH_4 emission reduction initiatives, such as the Global Methane Initiative (GMI) and the Climate and Clean Air Coalition.

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[21] Radiative forcing refers to the difference in energy entering the Earth's atmosphere from the energy leaving it. This can force changes in the Earth's climate (Forster et al., 2021).

Lastly, the International Methane Emissions Observatory (IMEO) was launched at the G20 Summit and is aimed at joining data and research with action, reporting, and implementation (UNEP, 2021). This will provide the means to prioritize actions and monitor commitments made by nations in the GMP (UNEP, 2021).[22] The IMEO currently focuses on fossil fuel emissions from the energy sector, with plans to expand to other major CH_4-emitting sectors, like agriculture.

5.2. Canadian Federal Methane Policies

Canada has expanded its climate policies to include CH_4 mitigation and is recently shifting its policy attention to sector-specific action. Importantly, sectoral policies related to CH_4 emissions are developed both federally and provincially, as economic activities are regulated by provinces, while the environment (and emissions) have shared federal and provincial jurisdiction (Dobson et al., 2022).[23] Primarily, action has been focused on the O&G sector as it is the largest contributor of CH_4 emissions (Dobson et al., 2022).[24]

5.2.1. Faster and Further: Canada's Methane Strategy

In 2022, the federal government released "Faster and Further: A Methane Reduction Strategy for Canada," which outlines the government's plan to reduce CH_4 emissions across various sectors to achieve its climate goals. The strategy builds on the previous 2018 Methane Reduction Strategy and includes more ambitious targets, new regulations, and expanded support for research and innovation. This strategy sets a

[22] The IMEO (UNEP, 2021) will collect and integrate diverse CH_4 emissions data to establish a global public record of empirically verified CH_4 emissions at an "unprecedented level of accuracy and granularity." By making this data available, the IMEO aims for a significant reduction of CH_4 emissions through strategic mitigation actions.

[23] Canada uses a cooperative federalism approach to regulating CH_4 emissions: federal regulations make up a minimum standard and provinces can develop their own policies. When granted equivalency, provincial policies stand in place of the federal ones. However, granting equivalency is not the same as true equivalency in regulations. This creates significant differences in policy action in the case of CH_4, specially in what is permissible and penalized in different jurisdictions (Dobson et al., 2022).

[24] Current federal regulations require the O&G sector to reduce CH_4 emissions by 40-45% below 2012 levels by 2025. Canada's 2030 Emissions Reduction Plan sets out a roadmap for Canada to reach an emissions reduction target of 40-45% below 2005 levels by 2030 and net-zero emissions by 2050. They identify tackling CH_4 emissions as one of the lowest cost opportunities to make important progress in the short-term on Canada's climate goals. The government has also committed to develop measures to further reduce methane emissions from the oil and gas sector to at least 75% of 2012 levels by 2030 (ECCC, 2022).

national goal of reducing CH_4 emissions by 75% below 2012 levels by 2030 (ECCC, 2022b). To achieve this goal, the strategy identifies the key sectors of O&G, agriculture, and municipal waste—which make up about 96% of total Canadian anthropogenic CH_4 emissions.

With regards to the agricultural sector, the strategy acknowledges the difficulties in estimating and quantifying CH_4 emissions for the sector including accounting for the diversity of production practices[25] across the almost 200,000 farms across the country (ECCC, 2022b). The strategy outlines possible mitigation actions for the sector and recognizes that some farmers across the country have already begun to voluntarily implement these practices (ECCC, 2022b).[26] The strategy also announces the expansion of support for the Environmental Farm Plan (EFP) Program and the Beneficial Management Practices (BMP) Program, which assist farmers in identifying and implementing CH_4 reduction measures on their farms (ECCC, 2022b).

While it is significant that the federal CH_4 mitigation strategy recognizes the importance of mitigation action in the agricultural sector, it does not provide a tangible strategy for the necessary reductions nor proposes any mandatory sectoral regulations. The measures outlined continue to be voluntary programs, meaning there is no guarantee that any or all farmers will adopt recommended practices– thus limiting potential reductions in emissions. Additionally, there aren't any clearly defined goals or timelines for the sector's mitigation.

5.2.2. Federal Initiatives Relevant to Agricultural Methane Emissions Reductions

As mentioned earlier, CH_4 emissions from agriculture make up the largest source of unregulated GHG emissions in Canada (Dobson et al., 2022). While the federal government under Prime Minister Justin Trudeau has made significant climate policy progress through the enactment of the Pan-Canadian Framework on Clean Growth and Climate Change and the Clean Fuel Standard, these policies have largely excluded

[25] Such as regional climatic conditions and varying soil types.

[26] Through strategies such as feed additives, manure management approaches, anaerobic digestion and more.

agriculture, and ECCC projects an increase in the sector's emissions through 2030 (Fisher, 2023).

Agriculture and Agri-Food Canada (AAFC) is the federal department responsible for federal regulation of agriculture, including policies on production, processing and marketing of food, farm, and agri-based products (Davies, 2022). AAFC works with provinces and territories to develop and deliver policies and programs. The majority of Canada's federal agricultural policy is delivered through a five-year Agricultural Policy Framework (APF). The current APF (2018-2023) is called the Canadian Agricultural Partnership (CAP) and the next APF beginning in April 2023 is the Sustainable Canadian Agricultural Partnership (SCAP) (AAFC, 2021a).

While emissions pricing has been implemented in other sectors, currently, Alberta and Quebec are the only jurisdictions with offset protocols[27] for agriculture, wherein participating farmers may earn tradable emissions credits for specific practice improvements resulting in GHG reductions (AAFC, 2020; Dobson et al., 2022; Fisher, 2022). Dobson et al. (2022) highlight that these protocols indirectly regulate 39% of Canada's CH_4 emissions; however, this only reflects the potential coverage and not the actual coverage. To illustrate, while manure accounts for 31% of Quebec's agricultural CH_4 emissions, there are no projects targeting manure emissions in its offset registry (Ministère de l'Environnement et de la Lutte contre les changements climatiques n.d.).

The federal government is currently developing an offset protocol for Livestock Feed Management with protocols for Livestock Manure Management and Anaerobic Digestion planned for subsequent development (ECCC, n.d.). There is also the potential for indirect coverage through federal and provincial clean fuel standards, which require renewable fuel blending for transportation—eligible feedstocks for these include animal waste (Dobson et al., 2022). This creates a possibility for CH_4 abatement where fuel-providers purchase captured CH_4 to meet their blending requirement (Dobson et al., 2022). As federal and provincial emissions pricing systems currently exempt biomass

[27] Alberta's system currently includes three protocols relevant to CH_4 whereby farmers earn credits for emissions reductions from breeding cattle for more efficient feed conversion rates and creating biogas from manure (Dobson et al., 2022). Quebec's only protocol for agricultural CH_4 is capture and destruction of methane from covered manure storage facilities (Government of Québec, 2011).

combustion emissions, this may act as an incentive for on-farm fuel switching via an anaerobic digester (Dobson et al., 2022).

Environmental Farm Programs (EFPs)—voluntary plans that farmers complete to increase their environmental awareness and reduce agricultural operations' impact—are another mechanism that can support farm-level CH_4 mitigation. EFPs may address energy efficiency, livestock facility management, manure storage and handling, pasture management, soil management, and nutrient management (AFF, 2021c). They are available to farmers across the country and are typically administered through not-for-profit provincial farm organizations and funded through joint federal-provincial agreements under the Canadian Agricultural Partnership (Smith et al., 2020). Therefore, they represent a significant opportunity to establish widespread plans for farm-specific CH_4 emissions reductions. Through the Agricultural Climate Solutions (ACS) Program and the Agricultural Clean Technology Program (ACTP), the federal government also funds research projects that assess opportunities for farm-level GHG reductions (AAFC, 2021c, 2022a, 2022b). More information on the existing initiatives can be found on Table 5.1.

The federal government has also recently focused on a demand-side methane mitigation strategy by encouraging Canadians to eat less red meat and dairy through the updated 2019 Dietary Guidelines. These new guidelines clearly outline that Canadians should diversify their protein sources and transition away from animal sources of protein and toward plant-based sources (Health Canada, 2019). While this has led various environmental organizations to recognize the guidelines as an example of 'climate smart' nutrition guidelines, the OECD projects that red meat consumption in Canada will remain static without market interventions such as a meat consumption tax (Dyer et al., 2020; Fisher, 2022).

Table 5.1 Current Canadian Federal Agricultural CH_4 Initiatives

Program	What it is	Actions/Goals/Details
Canadian Agricultural Partnership (CAP)/ Sustainable Canadian Agricultural Partnership (SCAP)	AAFC's 5 year Agricultural Policy Framework (APF) to strengthen and grow Canada's agriculture sector. The current APF (2018-2023) is the Canadian Agricultural Partnership (CAP). The SCAP is the new APF, which will replace the CAP (ending March 31, 2023).	- The CAP has allocated $2 billion for cost-shared programs and activities by federal, provincial, and territorial governments (FPT) and $1 billion for federal activities and programs to strengthen the competitiveness, innovation, and resiliency of the agriculture, agri-food and agri-based products sector. - The SCAP will include a 3-5 Mt reduction in GHG emissions over its lifespan as one of its prioritiesFPT cost-shared funded programs to raise producers' awareness of environmental risks and support the adoption of BMPs, including those which reduce CH4 emissions. - It will include the AgriScience Clusters programs for R&D in collaboration with the sector, including the beef and dairy sectors, to provide innovative solutions for effective CH4 mitigation.

Agricultural Climate Solutions (ACS) Program	Multi-stream program under the $4 billion Natural Climate Solutions Fund (managed by NRCAN, ECCC, and AAFC) to help develop and implement farming practices to tackle climate change. Composed of the ACS Living Labs Program and the ACS On Farm Climate Action Fund.	- Agricultural Climate Solutions Living Labs will provide $185 million to accelerate co-development, testing, adoption, dissemination, and monitoring of technologies and practices that sequester carbon and/or mitigate GHG emissions.
		- On Farm Climate Action Fund (OFCAF)will provide $670 million to support immediate on-farm action to tackle climate change, through adopting BMPs that store carbon and reduce GHGs, specifically in the areas of:
		    - nitrogen management
		    - cover cropping
		    - rotational grazing practices

Agricultural Clean Technology Program (ACTP)	The ACTP is a 2 stream program that will provide $495.7 million to create an enabling environment for the development and adoption of clean technology.	The ACTP has 2 streams: 1. The Research and Innovation stream aims to support pre-market innovation in areas of precision agriculture; improved feed strategies (considering additives and manure treatment); on-farm energy efficiency; and green energy and bioeconomy including biofuels and biodigesters. According to Canada's Methane Strategy, this stream will be used to incentivize innovative CH4-reduction technologies. 2. The Adoption Stream aims to support the purchase and installation of commercially available clean technologies with priority for projects with demonstrated GHG emissions reductions.
Canada's Greenhouse Gas Offset Credit System	Managed by ECCC, Canada's GHG Offset System enables project proponents to generate federal offset credits for projects that reduce GHGs using a published federal GHG offset protocol.	- Offset credits can be sold and used for compliance by facilities covered in the federal Output Based Pricing System or sold and used by others who are looking to meet voluntary climate targets or commitments. - A protocol for Livestock Feed Management is being developed, which will credit CH4 reductions from livestock produced through enteric fermentation. - Protocols for Livestock Manure Management and Anaerobic Digestion are also planned for subsequent development.
Sustainable Agriculture Strategy (SAS) *(formerly referred to as Green Agriculture Plan)*	Long-term plan aimed to strengthen collaboration on climate action in the agriculture sector. It is currently under development and seeking feedback from relevant stakeholders.	The SAS will bring together action needed in the sector as identified through various public and stakeholder engagements. The main focus areas are: - Soil health - Adaptation and resilience - Water - Climate change mitigation - Biodiversity A strategy will collectively identify goals and actions from other ongoing initiatives as well– amongst them the Global Methane Pledge, as set out in Canada's Methane Strategy.
Other Federal measures	- Emissions Reduction Plan announced an investment of $100 million in transformative science to support fundamental and applied research, knowledge transfer, and the development of metrics. - AAFC continues to leverage its longstanding collaboration with the livestock sector to increase resiliency and sustainability, while maintaining the sector's economic prosperity and Canada's food supply.	

Source: AAFC, 2021a, 2022a, 2022c, 2022d, 2022e; ECCC, 2023

5.3. British Columbia's Policies

In addition to federal legislation, Canadian provinces implement their own climate policies. BC has established legislated targets to reduce greenhouse gas emissions by 40% below 2007 levels by 2030, 60% by 2040, and 80% by 2050, through the Climate Change Accountability Act (2007). Notably, these targets are only in place for four sectors: transportation, industry, oil and gas, and buildings and communities—with agriculture being exempt from following the legislated targets. Further, BC's Greenhouse Gas Industrial Reporting and Control Act enables entities to purchase offsets (Davies, 2022). BC has also developed BC's Roadmap to 2030 (2021) and its Climate Preparedness and Adaptation Strategy (CPAS) (2022), which includes relevant key actions pertaining to the agriculture sector. However, none of these or other existing policies target agricultural CH_4 emission reductions. The province's carbon tax also excludes the agricultural sector; however, a study by Rivers and Schaufele (2015) finds that there is no compelling evidence to support exempting the sector from the tax.

While there are no direct policies that target agricultural CH_4 emissions, the province's emissions pricing systems exempt biomass combustion emissions, which creates an incentive for on-farm fuel switching via an anaerobic digester (Dobson et al., 2022). Similarly, BC's offset market includes a protocol for fuel switching, which is another potential nudge (Government of British Columbia n.d.). Additionally, the province released a Greenhouse Gas Offset Protocol for Methane from Landfill Waste (Government of British Columbia, n.d.). This could indicate that the province might be receptive to or currently preparing a protocol for projects related to mitigating CH_4 emissions from agriculture.

As highlighted in the above section, there are federal initiatives in place which provide funding to the province for agricultural programs through the British Columbia Ministry of Agriculture Food and Fisheries (AFF). The Environmental Farm Plan (EPF), Canada-BC Agri-Innovation Program (CBCAIP), BC Climate Agri-Solutions Fund (BCCAF), and Climate Change Adaptation Program (CCAP) are delivered by Investment Agriculture Foundation (IAF) in BC. The CBCAIP provides cost-shared funding to producers for innovative projects that aim to enhance sustainability, productivity, and/or resiliency in key areas including: soil, water, and air quality improvement, and climate change adaptation, with funding available for research and development, pilots and demonstrations, and commercialization and adoption projects (AFF, 2021b). The BCCAF provides cost-shared funding to eligible producers and supports the training of certified crop advisors as well as information sharing throughout the sector. Its goal is to support farmers in adopting BMP that store carbon and reduce GHGs, specifically in areas of nitrogen management, cover cropping, and rotational grazing (AFF, 2021a). The BC EPF aims to help farmers reduce agriculture's impact on the environment while increasing efficiency, profitability, and environmental sustainability (AFF, 2021a). At no cost to producers, a trained EFP Planning Advisor helps farmers complete an agri-environmental risk assessment, after which an action plan is created to address the environmental issues identified (AFF, 2021c). After completing an EFP, participants can apply for funding through the BMP Program for projects that will increase a farm's agricultural sustainability. Projects eligible for funding relevant to agricultural CH_4 are included in Table 5.2.

Table 5.2 Eligible CH_4 Mitigation Practices within the BMP Program

Eligible BMP	Program Support
Anaerobic digestion	• Covered manure storage in combination with methane collection and renewable energy production from collected methane: 30% cost share – $30k cap – requires nutrient management plan; dairy or hog producers only
Cattle feed additive:	• Feed additives to ruminant feed that has a proven effect of reducing enteric fermentation trial: 30% cost share – $5k cap – maximum one year funding to trial; does not explicitly list 3NOP as eligible (lists proteins, seaweeds, dietary fats)
Manure composting	• Engineering or technical design work by a qualified professional (organic residuals – composting): 100% to $3k plus 80% to $10k cap · Composting of agricultural waste: 30% cost sharing – $25k cap
Rotational grazing (basic or intensive)	• Grazing management planning: 100% cost share – $1k cap • Fencing to manage grazing and improve riparian condition and function: 60% cost share – $30k cap; repairing existing fencing not eligible • Native range and restoration or establishment: 60% cost share – $30k cap • Grazing management in surrounding uplands: 60% cost share – $30k cap • Improved grazing systems – cross fencing to create biodiversity enhancements: 60% cost share – $30k cap • Alternative watering systems to manage livestock: 60% cost share – $30k cap • Other BMPs can also help facilitate changes required for the adoption of rotational grazing, such as relocation of facilities, improved stream crossings, etc.]

Source: AFF, 2021a

Importantly, the Opportunity Assessment of Agricultural Greenhouse Gas Reductions and Carbon Sinks project was conducted in 2021 to provide foundational knowledge for understanding potential pathways for reducing GHG emissions in BC's agricultural sector. The findings of this assessment led the researchers to recommend wide implementation of BMP by agricultural producers for GHG mitigation (Norgaard et al., 2021). They suggest including stakeholders in the initial stages of BMP evaluation as this would improve their success and help identify additional BMP for investigation (Norgaard et al., 2021). In the longer term, the authors suggest an expansion of the BMP database and further analysis of BMP are important next steps (Norgaard et al., 2021). Their analysis also highlights the need for piloting a wide range of BMP and incentive options to develop the data required for evidence-based decision-making (Norgaard et al., 2021). Such data is essential for the modelling and MRV approaches needed to establish accurate bottom-up emissions quantification and long-term analyses required to identify actions to meet future targets (Desjardins et al., 2018; Fouli et al., 2021; Smukler et al., 2021).

Table 5.3 BC's Voluntary Programs with Potential for Agricultural CH_4 Mitigation

Program	Description
Environmental Farm Plan Program (EFP)	Seeks to help farmers learn how to reduce agriculture's impact on the environment, while increasing efficiency, profitability, and environmental sustainability. At no cost to the farmer, a trained EFP Planning Advisor helps farmers complete an agri-environmental risk assessment, after which an action plan is created to address the environmental issues identified. One of the areas that the EFP program's BMPs address is a reduction of GHG emissions.
AgriInnovate/ Canada-BC Agri-Innovation Program (CBCAIP)	Program delivered by Investment Agriculture Foundation providing funding to producers and other entities for key areas of: - improvements in soil - water and air quality, - climate change adaptation. Funding for these key priority areas supports research and development, pilots and demonstrations, and commercialization and adoption projects.
EFP's Beneficial Management Practices (BMP) Program	The BC BMP is a program from BC Ministry of Agriculture, Food and Fisheries' (AFF) administered by the IAF which provides funding (maximum of $70k/farm) to increase a farm's agricultural sustainability. After implementing an EFP, participants can apply for funding for projects through the Beneficial Management Practices (BMP) Program. Projects eligible for funding include: - Waste management - Air quality control - Emissions control - Soil and riparian integrity - Water quality - On-farm materials storage Elibilible BMPs include Anaerobic Digestion, Cattle Feed Additives
BC Climate Agri-Solutions Fund (BCCAF)	Funded by AFFC and delivered by the IAF, the BCCAF provides cost-shared funding to eligible producers and supports the training of certified crop advisors and agrologists as well as information sharing throughout the agricultural community. Its goal is to support farmers in adopting BMPs that store carbon and reduce greenhouse gases, specifically in the areas of: 1. Nitrogen Management 2. Cover Cropping 3. Rotational Grazing All farms in BC that can implement a prescribed BMP and have the ability to cover 30% of their project costs are eligible to apply for BCCAF funding for a maximum of $75,000.
Climate Change Adaptation Program (CCAP)	The Investment Agriculture Foundation (IAF) delivers the Climate Change Adaptation Program on behalf of the BC Ministry of Agriculture, Food and Fisheries. The CCAP is led by industry with the goal of helping producers successfully adapt to the impacts of climate change through its two sub-programs – the Regional Adaptation Program and the Farm Adaptation Innovator Program. The Farm Adaptation Innovator Program (FAIP) delivers funding for farm-level, applied research projects that help producers adapt to the impacts of climate change. Projects bring together researchers, farmers, agricultural organizations, educational institutions, technical experts and others.
Clean BC: Roadmap to 2030	CleanBC's Roadmap to 2030 is the BC government's strategic climate action plan. Although limited regarding the agricultural sector, key actions under BC's roadmap pertaining to the sector include supporting GHG efficient practices, enhancing agricultural carbon sequestration, and seizing the potential of regenerative agriculture. The strategy highlights supporting increased on-farm efficiencies and fuel switching, and anaerobic digesters for biogas production
BC Agricultural GHG STUDY	The *Opportunity Assessment of Agricultural Greenhouse Gas Reductions and Carbon Sinks* project was conducted in 2021 to provide foundational knowledge for understanding potential pathways for reducing net greenhouse gas (GHG) emissions in B.C.'s agriculture sector. This study has three parts: 1. Assessment of GHG emission sources and carbon sinks, 2. Multi-criteria assessment of beneficial management practices to reduce emissions, and 3. Assessment of potential GHG models for B.C. agriculture

Sources: AFF, 2021a; 2021b; 2021c; Norgaard et al., 2020

Chapter 6.

Jurisdictional Scan

The case studies in this chapter inform viable policy options for BC. California is chosen due to its similarity to British Columbia in terms of geography and its reputation as being a leader in GHG mitigation strategies in the United States. Alberta is included in this scan as the province shares jurisdictional capabilities and a border with BC, thus approaches may be easily replicated. Finally, New Zealand and Australia are included for their comparable institutional frameworks to Canada and are leading countries in mitigating CH_4 emissions from agriculture.

6.1. Alberta

Alberta-- home to Canada's largest beef industry and approximately 40% of Canadian cattle-- has an established agricultural carbon offset program that includes agricultural GHGs such as CH_4. The program was originally established in 2007 through an amendment of the Climate Change and Emissions Management Act and the passage of the Specified Gas Emitters Regulation Act (Fisher, 2022). The program was designed to help large, industrial emitters reduce their GHG intensities by requiring regulated entities to voluntarily reduce their emissions, pay fees on emissions over a threshold quantity, or buy carbon offsets (Lokuge & Anders, 2022). This established a market for the agricultural sector to change its practices to earn carbon credits.

Under Alberta's current Technology Innovation and Emissions Reduction (TIER) system, biogas production and CH_4-suppressing cattle feed qualify for carbon offsets. In addition to agricultural carbon offsets, Emissions Reduction Alberta has used carbon pricing revenue from the Climate Change and Emissions Management Fund to fund a variety of pilot programs designed to reduce agricultural CH_4 emissions (Fisher, 2022). These pilots have included projects such as feeding red algae to cattle and whole herd genetic management systems (Government of Alberta, n.d.). Alberta currently has three approved protocols related to CH_4: two biogas projects and three cattle-feed projects in its offset market, with annual emissions reductions of approximately 157 kt CO_2e, equivalent to 1.6 % of Alberta's and 0.6% of Canada's agricultural CH_4 emissions (Dobson et al., 2022).

While Alberta's agricultural carbon offset protocols have been durable and influential, both in North America and globally, there is no evidence that provincial agricultural CH_4 emissions have decreased as a result of this policy (Dobson et al., 2022; Fisher, 2022; Lokuge & Anders, 2022).[28] Additionally, participation from agricultural producers is low (Dobson et al., 2022; Lokuge & Anders, 2022). This sheds light on the fact that while voluntary agricultural carbon offsets may sound like a promising market-based solution to policymakers, they may have little impact on GHG mitigation without the right incentives for producers.

6.2. California

California is a major agricultural producer, responsible for around 13% of the country's total agricultural output, as well as being the largest milk-producing state, providing 20% of the country's milk (Olmstead & Rhode, 2017). CH_4 makes up around 9% of California's GHG emissions, and livestock is responsible for 55% of these emissions (California Air Resources Board, 2022). As such, it is the state responsible for the most GHG emissions from livestock agriculture. In 2014, the California legislature passed S.B. 605 which required the California Air Resources Board (CARB) to create a comprehensive plan to reduce Short-Lived Climate Pollutants (SLCPs) including CH_4. In response, CARB developed the Proposed Short-Lived Pollutant Reduction Strategy in 2016 with the target of reducing statewide CH_4 emissions by 40% (Fisher, 2022). This goal was codified through S.B. 1383, becoming a landmark piece of legislation that established the most aggressive agricultural CH_4 reduction targets codified into United States law[29]. The senate bill included tasking the CARB with developing a regulatory strategy for the reduction of SLCP emissions and the strategy had to be technically and economically feasible, cost-effective, and minimize leakage of the livestock industry to other states and countries (S.B. 1383, 2016). Most importantly, CH_4 emissions from enteric fermentation were excluded from the mandate, as the senate bill stated that

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[28] The reductions estimates are so low that they could fall within the margin of error of the baseline emissions.

[29] S.B. 1383 mandated a 40 percent reduction in methane emissions from livestock waste below 2013 levels by 2030 with enforcement starting in 2024

emissions reductions from enteric fermentation can only be achieved through voluntary mechanisms (S.B. 1383, 2016).

One of the key components[30] of this initiative is the Dairy Digester Research and Development Program (DDRDP), which provides grants to dairy farmers to install CH_4 biodigesters which convert CH_4 emissions from manure into renewable natural gas (RNG). The DDRDP aims to reduce emissions while also generating electricity and heat for the farms. Under these initiatives, $289 million USD has been distributed for 118 digester projects and 115 Alternative Manure Management Practices projects, and all should have been operational by the end of 2022 (Fisher, 2022).

The operationalization of S.B. 1383 has been controversial as these incentives favoured Concentrated Animal Feeding Operations (CAFOs) over the organic pasture-raised farms which were ineligible for the funding as they were already employing some alternative manure management practices, despite their costs being 70% higher (CARB, 2018). There were also concerns raised by environmental justice advocates about overusing cap-and-trade dollars to reward a heavily polluting industry, without also requiring these CAFOs to better protect surrounding communities from the negative environmental effects from tons of livestock waste harming the (primarily Latinx) communities where these operations are concentrated[31] (CARB, 2018; Fisher, 2022).

While some have been quick to report the pre-emptive success of these programs, a CARB interim progress report stated that the state is not on track to meet the CH_4 emissions reduction targets established in S.B. 1383 (CARB, 2022). The report estimates that by 2030, CH_4 reductions would be around 4.6 MMT CO_2e (half of the 9MMT CO_2e target) and that an additional 230–420 projects will be necessary to achieve the target (CARB, 2022). Lee and Sumner (2018) also add that because investments in digesters depend on policy revenue rather than market-based sales of natural gas, they are highly vulnerable in the case of policy changes or adjustments to environmental regulations.

[30] The other component is the Alternative Manure Management Practices Program.

[31] These CAFOs are concentrated in the San Joaquin Valley and impacts from concentration of livestock waste include ground and water contamination, airborne pathogens, air pollutants which then lead to negative health impacts on the communities

6.3. New Zealand

Agriculture is the single largest source of New Zealand's GHG emissions, amounting to half of its total emissions (New Zealand Ministry of Environment, 2022). CH_4 makes up 44% of total GHG emissions, with 91% of those being directly from agriculture (New Zealand Ministry of Environment, 2022). In 2019, New Zealand's parliament passed the Climate Change Response (Zero Carbon) Amendment Act which mandates emissions reporting from the agricultural sector beginning in 2024 and specifies a 10% CH_4 emissions reduction target by 2030 and a provisional reduction target of 24–47% by 2050 (New Zealand Ministry of Environment, 2022). New Zealand is in the process of assessing how agricultural CH_4 emissions will be calculated, reported, and priced. Although this is an enormous step forward in CH_4 mitigation policy development, the emissions reduction target for agricultural CH_4 is far less stringent than for other GHG sources, indicating the power of New Zealand's livestock industry in shaping CH_4 mitigation policy (Dorner & Kerr, 2017).

New Zealand is the first country to pass legislation that establishes legally binding CH_4 mitigation targets for livestock agriculture and will include agricultural CH_4 in its Emissions Trading Scheme (ETS) (Fisher, 2022). Within their emissions reduction plan, key actions for the agricultural sector are: the introduction of an agricultural emissions pricing mechanism by 2025; support for early adopters of low-emissions practices; ensuring all producers will have emissions reports by the end of 2022 and a farm plan in place by 2025; and acceleration of mitigation technologies through establishing a new Centre for Climate Action on Agricultural Emissions to drive a step change in mitigation technology innovation and uptake on farms (New Zealand Ministry of Environment, 2022).

New Zealand also has the Agricultural Greenhouse Gas Research Centre (NZAGRC) which is publicly funded to invest and coordinate research aimed at reducing New Zealand's agricultural emissions (NZAGRC, n.d.). This work is undertaken collaboratively by research providers and targets cost-effective practices and technologies for reducing emissions in New Zealand's farm systems.

A significant factor of New Zealand's climate strategy is its collaboration with the Indigenous Māori peoples. Their emissions reduction plan includes a promise to work with Māori to enable Māori-led solutions. This partnership will help ensure the government's actions are informed by a Māori view and provide for tikanga and mātauranga Māori.[32] Additionally, New Zealand's Environment strategy states that "incorporating mātauranga Māori into environmental policy adds value to New Zealand's resource management system" (New Zealand Ministry for Environment, 2022).

6.4. Australia

In 2022, it is estimated that agriculture was responsible for around 14% of Australia's GHG emissions, and for over half (55%) of its CH_4 emissions (Government of Australia, 2023). To tackle this issue, the Australian Government funds the $6 million Methane Emissions Reduction in Livestock (MERiL) program to support research and development of CH_4-reducing livestock feed technologies. The MERiL provides grants to support research into the abatement potential and productivity benefits of low-emissions livestock feed technologies (Government of Australia, 2023). It also funds the development of a Livestock Emissions Framework for feed technologies (LEF) to provide a consistent approach for estimating emission reductions from the use of feed technologies at the farm, industry, state, and national scales (Government of Australia, 2023). Another initiative used is the scaling up of the supply of low-emissions feed technologies through $8.1 million in funding to support the commercialization of seaweed as a low-emissions feed technology and lower barriers to market entry (Government of Australia, 2023).

[32] Maori knowledge which includes cultural principles and cultural practices.

Chapter 7.

Policy Evaluation Framework

This chapter outlines the five criteria and five measures employed in the multi-criteria analysis to evaluate the policy options' potential trade-offs: effectiveness, administrative ease, cost, equity, and stakeholder acceptance. Table 7.1 outlines a summary of the criteria and measures. The policy options are evaluated to determine how they address the barriers to adoption of CH_4 mitigation strategies.

Table 7.1 Summary of Criteria and Measures

Criteria	Measure	Rating
Effectiveness (/3) X2		
Reduction in Barriers to Adoption	Extent to which the policy is projected to facilitate agricultural methane reductions	Good (6)
		Moderate (4)
		Poor (2)
Administrative Ease (/3)		
Ease of implementation	Number of changes to existing programs or introduction of new programs	Good (3)
		Moderate (2)
		Poor (1)
Cost (/3)		
Cost to Government	Cost to provincial government to establish and administer policy per year	Good (3)
		Moderate (2)
		Poor (1)
Equity (/3)		
Farmer Access	Extent to which different farms and farmers can access the policy	Good (3)
		Moderate (2)
		Poor (1)
Stakeholder Acceptance (/3)		
Farmer's support of the policy	Extent to which relevant stakeholders support the policy	Good (3)
		Moderate (2)
		Poor (1)
TOTAL SCORE: x/18		

7.1. Key Objective: Effectiveness

The main objective of this research is to address the barriers to the adoption of agricultural CH_4 mitigation strategies to facilitate CH_4 emissions reductions. The effectiveness of a policy is assessed by the extent to which it reduces barriers to the adoption of CH_4 mitigation strategies and measured by the projected facilitation of emissions reductions. As effectiveness is the key objective, it is double weighted to reflect the importance of the projected ability of the policy to facilitate CH_4 emissions reductions. Policies that significantly reduce barriers through projected decreased emissions receive a good rating.

7.2. Administrative Ease

Administrative ease assesses the complexity of implementing a policy or program through the number and degree of changes necessary to existing programs or the development of new ones. Policies or programs that require little administrative burden through few changes to an existing policy or new policies that are easy to implement receive a good score. Policies or programs that require increased collaboration between stakeholders, creation of new teams, long implementation processes, and other factors increasing complexity receive either a moderate or poor score depending on the number and degree of these factors.

7.3. Cost

Cost considers the cost to the BC government for the implementation of and administration of the policy or program. Whenever possible, this is measured in annual dollars or initial costs (depending on the scenario). Policies with lower costs to government receive a good score, and as cost increases, this rating goes to moderate or poor if costs are too high. When projected costs are unknown, the estimates for the costs are taken from estimations based on similar programs in other jurisdictions and on back-of-the-envelope calculations.

7.4. Equity

Equity assesses how each policy benefits different types of agricultural producers. This criterion considers characteristics such as farm size, location, nature of operations, administrative burden, cost to producers, among other relevant factors. This criterion also considers possible distributional impacts the policy might have on disadvantaged communities in rural areas who may be impacted by environmental consequences of proposed policies. A policy that benefits many different types of agricultural producers and does not have any anticipated harms on vulnerable communities receives a good score.

7.5. Stakeholder Acceptance

Stakeholder acceptance assesses the expected support for a policy from relevant stakeholders. The stakeholders include agricultural producers; provincial agricultural departments; private agricultural organizations; relevant non-profit organizations; Indigenous agricultural producers and communities; climate experts; and climate activists. Policies that are expected to be supported and accepted by stakeholders receive a good score, options with mixed responses from different stakeholders receive a moderate score, and options with a lot of resistance from stakeholders receive a poor score.

Chapter 8.

Policy Options to Reduce Agricultural Methane Emissions in British Columbia

Five policies are derived from research on reducing barriers to the adoption of agricultural CH_4 mitigation in BC. These policies are informed by mitigation strategies which can be found in the Appendix.

8.1. Agricultural Methane Reduction Offset Protocol (AMROP) and Subsidies

This option is a market-based instrument that would operate under BC's existing GHG Offset Credit system. AMROP would generate offset credits for agricultural producers in BC who implement CH_4 reduction strategies. The offset credit refers to a reduction in GHG emissions that is used to compensate for emissions that occur elsewhere-- it is a transferrable instrument certified by the province to represent an emission reduction of one metric ton of CO_2e (Davies, 2022).

To be eligible to generate offset credits, agricultural producers implementing CH_4 reduction strategies must achieve real, additional, quantified, verified, unique, and permanent GHG reductions or removals by following this proposed protocol. This means that the emissions reductions are otherwise unclaimed, and exceed what would have occurred in a business-as-usual scenario (Davies, 2022).

Proposed CH_4 reduction strategies for the AMROP include:

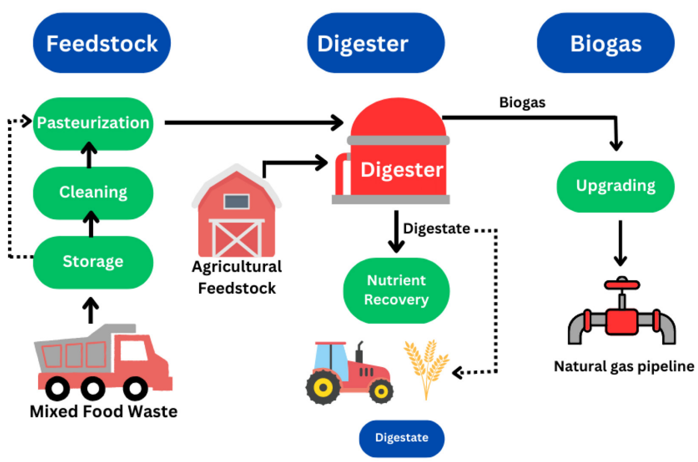
- Using low-emission livestock feed additives such as seaweed, or 3-NOP
- Implementing practices to improve feed efficiency (i.e., selective breeding) and reduce enteric fermentation in livestock
- Implementing anaerobic digesters
- Implementing manure management practices such as solid-liquid separation, composting, or covered manure storage

Producers would be incentivized to employ CH_4 mitigation strategies as they would be able to sell these offset credits. Producers with smaller operations for whom mitigation strategies would be more costly, could buy offset credits as the offset credit price would be lower than the cost to implement the new technologies.

As Alberta has a similar mechanism which has not resulted in any emissions reductions, this protocol would be accompanied by a subsidy available to producers to further incentivize participation. AMROP would also provide information to producers about the eligible CH_4 reduction strategies, as well as support and resources to implement these strategies based on producers' unique conditions.

8.2. Anaerobic Digester Program

Figure 8.1 Overview of Anaerobic Digester System



Source: Author's illustration using data from Hallbar Consulting, 2020

This option would create a program to provide subsidies for interested producers to implement biogas recovery operations using anaerobic digesters (ADs). While ADs provide an opportunity for farmers to generate more income, they are costly to implement and thus most producers would need significant support with funding.

There is demand for an increased supply of RNG, and currently, only 1% of Canada's livestock manure undergoes anaerobic treatment (FortisBC, n.d.). FortisBC states that in order to meet the goals outlined in the Clean BC plan and meet international commitments they are on a mission to replace 75% of their natural gas with renewable gases and state they are on track to meet their 15% RNG target by 2030[33] (FortisBC, n.d.). This RNG is sourced from partnerships with farms, landfills and wastewater treatment plants. Currently, there are only 3 agriculturally-sourced RNG suppliers with only one in BC (FortisBC, n.d.).

The BC On-Farm Biogas Benchmark Study published in 2020, outlines the conditions under which biogas operations are economically feasible in BC. The report highlights that because manure has a relatively low biogas yield, it is best when mixed with food waste which has a biogas yield several times greater than manure. This program would thus implement those findings and mandate that farms would need to use a mix of both manure and food waste.

8.3. Agricultural Methane Emissions Research and Development Program

This policy option would create an Agricultural Methane Emissions Reduction program in BC with the aim of developing feasible strategies to reduce CH_4 emissions from agriculture. The program would be modeled after Australia's Methane Emissions Reduction in Livestock (MERiL) program and New Zealand's NZAGRC and would have an initial budget of $2.5 million.[34] It would allow producers in the province to become involved with trials and collaborate with experts. The program would provide grants to support research into the abatement potential and productivity benefits of low-emissions livestock feed technologies, and manure management practices. To scale up the supply of low emissions feed technologies, funding would be provided to support the commercialization of seaweed as a low-emissions feed technology and lower barriers to market entry. This focus would be on local seaweed species in BC and their potential for CH_4 mitigation as feed additives.

Additionally, inspired by New Zealand's collaboration with the Maori peoples, this program would entail the creation of the Indigenous Climate Solution initiative—a specific Indigenous-led and Indigenous-focused research team which would answer the calls from the BC First Nations Climate Strategy and Action Plan. Involving Indigenous

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[33] Data on FortisBC's website states that currently RNG makes up only 0.3% of their current supply of natural gas (FortisBC, n.d.).

[34] The MERiL program has a $6 million budget. In order to scale this to BC the author conducted a rough calculation based on the difference in geographical land mass.

Peoples in the research and development of mitigation strategies is important as this is an opportunity for essential collaboration, knowledge sharing, and offers potential economic opportunities for First Nations communities.

8.4. Improved Measurement, Quantification, Reporting and Verification Strategy

This option seeks to establish a better measurement, quantification, reporting, and verification system for agricultural GHG emissions in BC. This strategy would include:

1. Building capacity for bottom-up accounting of emissions: Quantification of emission reductions from agricultural BMP needs to be aligned with international reporting requirements to include them in emission reduction strategies (Norgaard et al., 2021). As national and provincial emissions reporting is based largely top-down methods (i.e., national census), options for collecting these data, to be investigated, developed, and tested to develop a robust incentive and reporting system that is adaptable to local data as it becomes available[35].
2. A comprehensive agricultural GHG database: Researchers in BC have been collecting GHG emission and related data for decades, but these data are not readily accessible in the published literature (Norgaard et al., 2021). A database would be created to house and share empirical data to improve the provincial BMP database and modeling efforts. The BC Agricultural Climate Adaptation Research Network (ACARN) has developed a suitable database infrastructure for this purpose that can be employed.[36]
3. Implementing a robust MRV approach: It is critical that any GHG reduction initiative includes a robust measurement, reporting, and verification approach to ensure that anticipated GHG benefits are actually achieved and can be counted towards emission reduction targets. As more empirical data become available, BMP can be re-prioritized using the MCF. An effective MRV approach can

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[35] This could be done through mechanisms such as the Environmental Farm Plan or the Agricultural Land Use Inventory.

[36] The database would include production outcomes for crop or livestock systems, management information, economics, soil properties, GHG emissions, and other environmental impact data

leverage field demonstration and research trials to establish quantification methods and validate models that project GHG benefits and co-benefits across regions and over time.

8.5. Demand Management Strategies

This policy option focuses on decreasing demand of animal products to lower CH_4 emissions. To lower consumption of meat and other animal products and transition to more sustainable food choices, a three-stream program would be implemented. The program would include: education on plant-based sources of protein through educational campaigns; subsidies to producers in the plant-based food industry; and eventually a tax on meat and animal products' consumption.

The educational component of the program would be designed to increase awareness of plant-based food options as a healthy and sustainable alternative to meat and animal products. Social media campaigns could be the primary platform to disseminate information on plant-based sources of protein and how to incorporate them into a healthy diet. This would be complemented by initiatives to encourage and promote plant-based meals in institutions such as schools and hospitals. It could also include increased community services to incentivize the switch in behaviours such as vegetable-forward cooking classes, nutrition workshops, and an increased number of community gardens.

The subsidy component of the program would be aimed at supporting producers in the plant-based food industry. These subsidies would serve as incentives to increase research and development and production of new food items and enable producers to achieve profitability in the industry. This would be critical to ensuring that the supply of plant-based food options meets the demand created by the education component of the program. The subsidies could be structured to prioritize small-scale producers and those using sustainable production practices.

Finally, the taxation component of the program would be aimed at reducing the demand for meat and animal products. While it is acknowledged that taxation of meat and animal products can be politically and socially challenging, it could eventually be an effective mechanism for lowering consumption in the long term. However, prior to implementation, the education and subsidy components of the program would need to be fully operational and successful in increasing demand for more sustainable food options. It is also important to mention that the potential distributional impacts of such a tax should be considered in the design of the policy.

Chapter 9.

Policy Analysis

This chapter evaluates the five policy options through a multi-criteria analysis using the criteria and measures outlined in Chapter 8. These scores are informed by the jurisdictional scan and the results from the literature. A summary of the analysis can be found in Table 9.1 below.

Table 9.1 Summary of Policy Analysis

	Policy 1: Agricultural Methane Reduction Offset Protocol and Subsidies	Policy 2: Anaerobic Digester Program	Policy 3: Agri-CH4 Emissions Reduction Research & Development Program	Policy 4: Improved Measurement, Quantification, Reporting and Verification Strategy	Policy 5: Demand Management Strategy
Effectiveness					
Extent to which the policy is projected to facilitate agricultural methane reductions **(x2)**	6	4	6	4	5
Administrative Ease					
Number of changes to existing programs or introduction of new programs	2	1	2	1	1
Cost					
Cost to provincial government to establish and administer policy per year	2	1	3	1	1
Equity					
Extent to which different types of farms can access/ will benefit from the policy	2	1	3	3	1
Stakeholder Acceptance					
Extent to which stakeholders support the policy	2.5	3	1	2	1
TOTAL SCORE /18	**14.5**	**10**	**15**	**11**	**9**

9.1. Agricultural Methane Reduction Offset Protocol (AMROP) and Subsidies

9.1.1. Effectiveness

Score: Good

This policy's effectiveness is two-fold: 1) it prices agricultural CH_4 emissions, thus providing a financial incentive for employing mitigation strategies and 2) it provides a further financial incentive by subsidizing the mitigation strategies. The reason for the subsidies is that, in the case of Alberta, we can see that the sole mechanism of the offset credits is not enough to incentivize participation as producers see the costs as outweighing the benefits. This policy targets the financial barrier by subsidizing and rewarding implementation.

9.1.2. Administrative Ease

Score: Moderate

This policy would be operating under BC's existing carbon offset system, although it would entail the creation of a new team to develop new protocols and ensure its feasibility within the system. The team would need to be comprised of enough people to develop, implement, and monitor the program. In 2022, the province published the Methane from Waste Offset Protocol for use by projects that capture and destroy methane from landfills or from the anaerobic digestion of organic waste (BC Ministry of Environment and Climate Change Strategy, 2022). This along with ECCC's expected Livestock Feed Management Protocol and their development of a Livestock Manure Management Protocol, signals that the province could explore this policy without too much complexity as it could mirror the federal protocols. However, MRV of emissions reductions would be time consuming and would require coordination between program administrators and agricultural producers.

9.1.3. Cost

Score: Moderate

Government costs would be quite high with this policy as costs would encompass the MRV for the project, as well as the subsidies that producers would receive for their projects. However, exact costs would vary on participation and which projects were being subsidized.

9.1.4. Equity

Score: Moderate

This policy receives a moderate score as the offset credits and subsidies would be more beneficial for larger producers who will produce more methane reductions as they have more emissions to abate. However, it does not rate as poor because the farmers who cannot afford certain mitigation strategies (even after subsidies) are able to purchase offset credits for a lower cost than paying for the implementation of the mitigation strategies on their farms at a smaller scale.

9.1.5. Stakeholder Acceptance

Score: Moderate

Acceptance from agricultural producers would be most relevant to this policy as the success of this policy would depend on their participation. Literature suggests reluctance from farmers to follow such protocols due to the uncertainty in recuperating their costs (Lokuge & Anders, 2022). Lokuge and Anders' (2022) review of Alberta's system determined that despite a willingness to upgrade their farms with feed-efficient cattle breeds, a lack of cost-offsetting mechanisms for producers confined opportunities for participation. Thus, by adding the subsidy, this policy would directly address that barrier. However, it is difficult to say that there would be overwhelming support, as some producers in the research expressed skepticism, including concern about the long-term impacts, such as reliance on subsidies (Davies, 2022).

9.2. BC Farm Anaerobic Digester (AD) Program

9.2.1. Effectiveness

Score: Moderate

While manure management makes up only 11% of BC's agricultural CH_4 emissions,[37] ADs have the potential for the most CH_4 mitigation out of existing manure management practices and are underutilized despite their potential to facilitate reduction of CH_4 emissions (Wang et. al., 2022). This option receives a moderate score because the literature suggests that the current approach to ADs employs perverse subsidies that are inefficient. For example, ADs are usually sought out to produce RNG, however, integrated[38] production is 80% more cost-effective than solely purifying CH_4 into RNG[39] (Hallbar Consulting, 2020; Wang et al., 2022). The GWP benefits arise primarily from three sources: displacement of fossil energy, displacement of synthetic fertilizers, and reduction in direct emissions. Additionally, these operations are most effective when using a mix of manure and food waste, but still use a considerable amount of manure, thus incentivizing more production which in the end leads to more emissions (Hallbar Consulting, 2020). Although reductions are facilitated with this option, as case studies suggest, it is often overly relied upon as a source of major reductions because of its RNG appeal. However, it is important to assess the most viable option for each producer and simultaneously employ strategies to reduce enteric emissions. Lastly, literature suggests that ADs are most effective in farms with 200+ cattle size and average size of cattle operations in BC was 123 cows in 2022 (Statistics Canada, 2022).

9.2.2. Administrative Ease

Score: Poor

This option receives a poor score as it would involve the creation of a new program, but its day-to-day operations would also be complex as AD is complex in and

[37] The other 88% of emissions come from enteric fermentation.

[38] Integrated AD refers to integration with other agricultural activities: biogas is combusted to supply energy to farms, and digestate is used to fertilize crops for food and forage and for other value-added by-products.

[39] Stand-alone AD scenarios can reduce GWP from the baseline scenarios by 380–650 kg CO_2-eq/ tonne waste processed. Meanwhile, integrated AD systems can achieve GWP benefits of 1060–1290 kg CO_2-eq/tonne waste processed (Wang et al., 2022).

of itself—each biodigester project would involve a different plan suited for the specific producer. This would involve coordination from experts and program administrators. Additionally, given that to be most effective, projects would need to utilize food waste, there would need to be the coordination of delivery to the digester sites which would be an added complexity. The timeline would also be considerably long between the building of the project and rollout.

9.2.3. Cost

Score: Poor

Digester projects are highly expensive, there are multiple factors to consider. There are several factors that increase necessary equipment and therefore the costs of a project.[40] Overall, as mentioned earlier, it is more cost-effective to build bigger facilities as the marginal costs for a bigger plant are lower. For instance, the BC On-Farm Biogas Benchmark Study, Version 2, projects that building costs of one AD project of 150 cows costs $5 million while for 300 cows the cost is $6.5 million (Hallbar Consulting, 2020).[41] It should be noted that in various situations, these costs would be higher due to the addition of necessary equipment which would be specific to each operation and these costs would range between an additional $1-3 million per project. Depending on the number of desired projects and considering that average cattle sizes in BC are smaller than what is typically considered most profitable for AD facilities, this policy option would be very expensive, especially in comparison to other more cost-effective solutions targeting enteric emissions reductions.[42]

[40] Feedstock cleaning equipment is required in situations where feedstock may include contaminants (e.g., bits of plastic, metal, etc.); most mixed food waste must be pasteurized to kill bacteria and some mixed food waste comes with a tip fee, the price paid for accepting the feedstock (Hallbar Consulting, 2020).

[41] Without any additional equipment (including nutrient recovery or feedstock cleaning)

[42] BC has 4660 farms reporting cattle and an average of 123 cattle per farm (Statistics Canada, 2023). Typically, it is most profitable to have ADs in farms with 200+ cattle (Hallbar Consulting, 2020).

9.2.4. Equity

Score: Poor

This option has been critiqued in the literature for its tendency to benefit large producers with CAFO rather than small producers who may already be implementing more sustainable practices.[43] This will directly translate into large producers who already have larger profitability, increasing their operations into the sale of biogas or RNG, while small producers will not have this option. It also has the possibility of having negative effects of human toxicity especially in downstream facilities or in areas with concentrated operations, where marginalized communities may directly face impacts.[44] For these reasons it receives a poor score.

9.2.5. Stakeholder Acceptance

Score: Good

This option receives a good score as there seems to be a lot of interest in AD, particularly from government. The federal government, for example, is said to start developing a protocol for AD (ECCC, n.d.). It also would likely be supported by bigger producers who would profit from this program as it would provide them with additional income from selling the biogas or RNG. Due to the high costs, there may be some pushback from small producers, experts, and agricultural lobby groups critical of this option, but this hasn't been widely proven in the literature.

9.3. Agricultural Methane Emissions Research and Development Program

9.3.1. Effectiveness

Score: **Good**

Although indirectly, this option has the potential to significantly facilitate agricultural CH_4 reductions. Through increased research and development, specific

[43] See the California case study (CARB, 2022).

[44] RNG specifically, as costs outweigh benefits.

strategies and solutions can be explored to find the best strategies for producers in BC. Having their own research program will allow agricultural producers in the province to become involved in the trials and collaborate with experts and academics allowing for theory and practice to yield the most feasible strategies. Because agricultural CH_4 mitigation is constantly innovating, this program would allow BC to stay up to date with the most recent advancements. Promoting the research of local seaweed species' CH_4 abatement potential would also create a new economic venue for the province. The increased investment in this area of research would also allow for increased affordability and the adoption of mitigation practices (Herrero et al., 2016).

9.3.2. Administrative Ease

Score: Moderate

While this would be a new program, involving collaboration between different organizations, separate initiatives would be ongoing and managed independently. Thus, the score is moderate. It is not a program that is projected to require intensive monitoring or complex coordination from the province.

9.3.3. Cost

Score: Good

The combined annual budget of AFF and the Environment and Climate Change Strategy is around $340 million (BC Ministry of Finance, 2022) That makes the proposed annual $2.5 million spending on this program 0.75% of their combined budgets, making it an affordable strategy. However, some of these technologies are costly, and setting up the initial research program may also be more expensive. If the costs end up being higher, it is probable that funding could be acquired from federal initiatives or private benefactors wishing to make contributions to this new area of research.

9.3.4. Equity

Score: Good

The results from this research would benefit all types of farmers as several different technologies would be developed and tested simultaneously. Research would have to take different agricultural producers into account to come up with the most beneficial strategies to abate the greatest quantity of emissions possible.

9.3.5. Stakeholder Acceptance

Score: Good

As this option seeks to find strategies for CH_4 mitigation specifically targeting BC's agricultural producers, this option doesn't anticipate any pushback from relevant stakeholders described before. On the contrary, it is expected that stakeholders will embrace this option as it brings opportunities for creating a sustainable sector.

9.4. Improved Measurement, Quantification, Reporting and Verification Strategy

9.4.1. Efficiency

Score: Moderate

This option receives a moderate score as it has the potential to facilitate CH_4 emission reductions indirectly. To achieve any sort of viable reduction of emissions, there must first be an enhanced system for measuring, quantifying, reporting and verifying emissions that can be adopted throughout the province. This will establish bottom-up reporting which will include providing producers with demonstrations and resources on how to conduct measurements resulting in more accurate reporting; the implementation of the GHG emissions database would also allow for more precise modelling and management systems for producers leading to improved practices, and this would facilitate better development of future policy. The reason the score is moderate is because establishing these strategies does not guarantee that producers will adhere to CH_4 mitigation strategies, it only provides better systems for managing those strategies and provides better tools for the facilitation of emissions reductions.

9.4.2. Administrative Ease

Score: Poor

This strategy receives a poor score as it is made up of several initiatives and would entail the creation of a new body within the AAF to set out these goals. It would involve the development of bottom-up measurement accounting guidelines for all types of producers (and this must be aligned with international reporting requirements); the development of guidelines for how these measurements will be reported; how they will be verified, including setting up a team to handle verification and reporting; a team to work alongside the BC Agricultural Climate Adaptation Research Network to utilize their database infrastructure towards its integration and availability of a provincial agricultural GHG emissions database for the sector; the strategy would also involve setting up an outreach team to provide support, training and demonstrations to providers across the province. This would therefore also entail collaboration between all the different teams, as well as existing organizations, and producers, adding complexity.

9.4.3. Cost

Score: Poor

Due to the complexity of this strategy, the costs of implementation and operation would be significantly high. While the literature does not include estimates for MRV in the agriculture sector, estimates for the forestry sector in developing countries is provided. The estimates include mechanisms similar to those that this strategy includes. Based on a rough back-of-the-envelope calculation,[45] the strategy would cost an estimated $3.25 million to set up and the annual costs would be an estimated $1-3 million per year.[46]

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[45] The estimate takes into account BC’s land size, and relative purchasing power parity to adjust the numbers found in the literature.

[46] These costs could be much higher than the prediction as the exact calculations are beyond the scope of this study, however it is known that the costs will be high due to the complexity of this strategy.

9.4.4. Equity

Score: Good

This option has a good score as the anticipated strategy's anticipated benefits would be aimed to reach all types of producers. The goal of this strategy is to streamline measurement, reporting, quantification, and verification across the sector and thus its impacts should be felt equitably by small and large producers, in different operations and regions of the province.

9.4.5. Stakeholder Acceptance

Score: Moderate

This policy option receives a moderate score as its acceptance is expected to be controversial for producers. While experts have advocated for improved technologies in the sector for MRV, some producers—especially big ones—might see this as a threat, as their emissions will be more accurately reported and could then face consequences. However, the benefits of this strategy are something that academic, experts, non-profit, government organizations, and producers who are already making an effort to have clean operations, will welcome.

9.5. Demand Management Strategies

9.5.1. Efficiency

Score: Good

This option receives a good score as the literature underscores that one of the only proven strategies to obtain substantial reductions in emissions of agricultural CH_4 is changing human diets away from reliance on ruminant animals. This policy would facilitate CH_4 reductions (and other GHG emissions) through providing options for plant-based and more sustainable sources of food, as well as education on shifting diets and a cultural shift away from meat-centric eating. Depending on the design of the tax, this would decrease consumption, especially if alternatives were subsidized and thus cheaper to consumers.

9.5.2. Administrative Ease

Score: Poor

This policy receives a poor score as it is composed of several different initiatives and coordination between different agencies across the province, including curriculum changes in schools, municipal incentives, and private sector. Additionally, due to its controversial nature, it would have to be gradually implemented , depending on initial success.

9.5.3. Cost

Score: Poor

Although it is difficult to estimate the cost of this policy without a thorough analysis, due to the multi-stream nature of this initiative—including launching education campaigns and municipal workshops; increasing in community gardens; launching social media campaigns, providing accessibility to nutritional counseling; and subsidizing greener alternatives—as well as the long term, this would be a costly option.

9.5.4. Equity

Score: Poor

The distributional effects of this policy for producers[47] would not be equal, which earns it a poor score. While the policy's goal is to shift dietary habits through decreasing meat consumption, this would be most felt by small producers. It would be ideal for this to be able to target big, COFA, factory-farming producers with higher adverse environmental impacts but the reality is that policies placing taxes on consumption would make products that are already more expensive (due to better practices, smaller scale operations) more expensive for consumers and the decrease in demand may be too much to bear for these producers' survival in the market.

[47] Consumers' equity impacts are not considered in this measurement but unless the tax was able to be adjusted for income, or some other sort of mechanism could be implemented as to have the impacts equally distributed across income, it would also unequally affect consumers.

9.5.5. Stakeholder Acceptance

Score: Poor

This policy obtains a poor score as it is an option that aims to achieve wide societal changes, which can be a challenging endeavour for policymakers. The policy is projected to face skepticism and pushback from relevant stakeholders and the public.

Chapter 10.

Recommendations

Given the results from the analysis in Chapter 9, this study recommends a policy bundle of options 1 and 3 to reduce agricultural CH_4 emissions in BC.

Option 3, the Agricultural CH_4 Emissions Reduction Research and Development Program ranked the highest, and option 1, the Agricultural Methane Reduction Offset Protocol and Subsidies ranked (closely) second. While livestock agriculture makes up the single largest source of methane emissions, strategies for mitigation are not widespread as there are many barriers adoption. Option 3 addresses many of these barriers as it will be a dedicated program whose aim will be to research and develop mitigation strategies specific to BC's agricultural sector. This program will determine the best and most effective solutions for the progress of the entire sector and work collaboratively with multiple stakeholders to achieve these goals. Additionally, its Indigenous Climate Solutions initiative will allow for thoughtful collaboration with Indigenous partners, advancing Indigenous knowledge and partnerships in the sector.

The literature suggests that one of the biggest reasons that there have not been widespread actions targeting agricultural emissions is that they are unpriced. Option 1, the AMROP, addresses this issue. Simultaneously, Option 1 provides a larger incentive for the adoption of mitigation strategies through subsidies-- as case studies suggest GHG offset credits alone are not enough to encourage producers' participation. This option has the potential to benefit producers through the sale of offset credits, as well as through improving their cattle's efficiency through co-benefits of strategies such as certain feed additives or selective breeding (Lokuge & Anders, 2022). As Wreford et al. (2017) report, in the case of mitigation, while indirect effects may generate positive private benefits for the farmers, the primary aim is of a public good nature and therefore policy action may be required to overcome barriers. Thus, as the literature suggests, the use of incentives, or payments will encourage the adoption of climate-friendly policies (Wreford et al., 2017).

While the evaluation results rate options 1 and 3 the highest, the literature underscores that measurement and reporting of CH_4 emissions is a large barrier to policy action as (Dobson et al., 2022; Herrero et al., 2011; etc.). Without accurate baseline emissions, effective measurement strategies, or ways of reporting and verifying these emissions, progress will be difficult. However, more detailed research and further economic analyses are required for developing a version of option 4 (the Improved Measurement, Quantification, Reporting and Verification Strategy) that is best suited for BC.

10.1. Implementation Considerations

Implementation of these two policies needs to take on a holistic approach to ensure policies do not cause unintended consequences such as emissions leakage. It is important to look at the net environmental and societal benefits rather than looking at this issue in a policy vacuum. It must also be ensured that the development and implementation of these policies are done with collaboration from producers and that their needs and perspectives are considered. Roundtable discussions could be organized with producers to allow for dialogue and discussion of strategies for reducing CH_4 emissions. Mitigation of CH_4 needs to be framed as a mutually beneficial practice as it will make livestock more efficient and reduce their environmental impacts.

As the proposed programs will take time to develop and implement, it will be important to, in the short-term, continue to encourage adoption of BMP across the province. These practices help producers reduce their impact on the environment and increase their resiliency to climate change, while increasing on-farm efficiency and profitability (Investment Agriculture Foundation, 2022).

While it is outside of this study’s scope, it would be worthwhile to find opportunities that streamline the regulatory approvals process for technologies with GHG emissions reduction potential (e.g., 3-NOP). Advocates suggest practices such as sharing of regulatory portfolios between jurisdictions and/or regulatory agencies, as this could result in shorter timelines from the research pipeline to commercial adoption of new technologies and products whenever feasible (AAFC, 2022b).

Lastly, policies to reduce CH_4 emissions from agriculture should not be taken as a green-washing opportunity to continue or expand factory farming with the excuse that its impact on the environment is lessened. While CH_4 emissions are one of the harms of factory farming, animal rights advocates highlight that many CH_4-reduction strategies fail to address other negative impacts such as animal cruelty, polluted water from farm runoff, considerable water usage that it takes to produce beef, and the fact that it takes 80% of agricultural land to produce a food that provides less than 20% of the world's calories (Kateman, 2023). Although politically challenging, demand management strategies should be explored for future consideration.

Chapter 11.

Conclusion

The concentration of CH_4 in the atmosphere is currently around 2.5 times greater than pre-industrial levels and is increasing steadily. This rise has important implications for climate change, particularly in the near future as it is a short-lived GHG. It has been estimated that the GWP of CH_4 is more than 80 times higher than CO_2 in a 20-year time frame. This indicates an urgent need to decrease CH_4 emissions as a strategy to reduce global warming.

While CH_4 emissions from livestock are the single largest source of CH_4 emissions in Canada, they are unregulated both federally and in BC. This study examines the sources of these emissions, mitigation strategies, and barriers to the adoption of these strategies. Using a jurisdictional scan, policies and mechanisms used in other jurisdictions were highlighted and considered for implementation in BC. The policies this study presents include implementing offset credits for CH_4 emissions reductions in agriculture; an anaerobic digester program which would help fund the creation of these projects; a dedicated research facility to explore solutions specific to BC; an improved quantification and MRV strategy; and the implementation of demand management strategies for reducing the demand of livestock.

The evaluation of these policies leads to the recommendation of the Agricultural CH_4 Emissions Reduction Research and Development Program and the Agricultural Methane Reduction Offset Protocol (AMROP) and Subsidies. These two options can allow for BC to act toward decreasing a source of emissions that has long been ignored. The research program will allow BC to lead the way in CH_4 emissions reductions for the sector and to profit from the novelty and constant technological developments in this area. The AMROP and attached subsidies will provide a practical incentive which can be implemented in the shorter term which will allow for emissions to be priced and provide cost-sharing through the subsidization of these strategies, as high costs have been a significant barrier for participation.

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Appendix.
Agricultural CH_4 Mitigation Options

Potential mitigation strategies are described here, as they were used to inform the policy options, their analysis, and the recommendation.

Polluter-Pay Policies

The 'polluter pays' principle is the practice that those who produce pollution should bear the costs of managing it, as to prevent damage to human health or the environment (London School of Economics, n.d.). If the cost from the pollution is not imposed on the emitters, these costs become an externality to society, making it a market failure, as society has to bear the costs (London School of Economics, n.d.).

In the agriculture sector, implementation of polluter-pay policies has faced many obstacles globally as there is concern the burden on producers will result in competitiveness and leakage (OECD, 2019). As the sector is made up of many different types of producers with diffuse sources of emissions, costs from MRV would be an additional burden disproportionately impacting small producers over intensive livestock operators with lower MRV costs (Dobson et al., 2022).

Beneficiary-Pay Policies

Beneficiary-pay policies compensate producers for emissions reductions (OECD, 2019). These policies are particularly useful for encouraging the adoption of costly technologies. Beneficiary-pay policies have the challenge of having to demonstrate if reductions occurred due to the implemented strategy or if they would have occurred regardless (Heyward, 2021).

Technical Mitigation Strategies

1. **Increasing Genetic Efficiency**

As a cow eats more feed, it produces more CH_4, thus through improving feed conversion efficiency, the amount of feed consumed per kilogram of milk produced or weight gained, decreases CH_4 output (Manzanilla-Pech et al., 2022). Diets that are more highly digestible lower the amount of CH_4 emitted per product produced (Manzanilla-Pech et al., 2022). Increasing productivity per animal also reduces CH_4 emissions intensity, creating opportunities to improve livestock health and reduce waste (Mottet et al., 2017).

Selective breeding for low methane-emitting cattle also falls into this category. Some cows naturally have genes that result in their gut bacteria producing less CH_4 (Genome BC, n.d.). Selecting cows for breeding based on this gene would be a permanent solution that would make the CH_4 reductions continue onto the next generation (Evans, 2019). However, with selective breeding there is the risk when selecting strongly for one gene, that other non-selected traits would be adversely impacted (Evans, 2019).

2. Feed Additives

Feed additives offer two mechanisms for reducing CH_4 emissions: changing the rumen environment as to discourage growth of CH_4-producing bacteria, and those that directly interfere with the CH_4 process (Searchinger et al., 2021).

Adding fats into feed rations is one of the strategies that has been used to influence the rumen environment, they can be effective for up to 40% reduction of emissions, however it is an expensive method (Searchinger et al., 2021; Caro et al., 2016). Two of the most promising additives which have been at the forefront of research are 3-NOP (3-nitroxypropanol) and red algae. 3-NOP (trademarked as "Bovaer") is a molecule which binds to the enzyme used in the last step of CH_4 production (Norgaard et al., 2021). Over 40 studies have reported reductions in CH_4 emissions ranging from 20-80%, with production results being generally positive (Searchinger et al., 2021)[48]. The second promising feed additive is red algae, particularly using the species Asparagopsis taxiformis, which "changes" the rumen environment as to prevent methane formation, with some studies have suggested that feeding red seaweed to cattle can reduce methane emissions by up to 80% in addition to increases in productivity[49] (Roque et al.,

[48] More than 40 studies have now reported the effects of 3-NOP on methane production in either dairy or beef systems using different, always small, inclusion rates (from 0.004% to 0.02%). Reductions in methane have ranged from as low as 20% in one study to more than 80% in others with typical reductions around 35-40%. Higher dosage rates resulted in greater reductions but may reach a maximum of around 40% in general.

[49] Significantly, these studies have also found increases in productivity in cattle. The dairy study found a 5% increase in milk yield with 25% less feed, while the beef studies found increases in feed conversion efficiency from 7 to 35% (Roque et al., 2021).

2021). While these additives show promising potential in their CH_4 mitigation achievements, they are still being tested and are currently unregulated in Canada[50].

3. Vaccination

Vaccination against methanogenic bacteria in the rumen refers to vaccines that specifically target the CH_4-producing methanogens in the rumen (Wedlock et al., 2013). While still under development, these vaccines hold promise for implementation in large-scale ruminant farming and would be a cost-effective solution. While it has not yet been demonstrated in live animals, all major components of a vaccine chain have been demonstrated[51]. The efficacy of a vaccine is speculative, but an emissions reduction of 30% is considered plausible, given the efficacy of CH_4 inhibitors. Commercial availability of a vaccine has been estimated to take 7–10 years after the demonstration of a prototype (Searchinger et al., 2021).

4. Anaerobic Digestion

Anaerobic digestion is a process that converts organic matter, such as manure and crop residues, into biogas which can be further refined into RNG and can displace natural gas elsewhere in the economy (Hallbar Consulting, 2020). While the combustion of RNG leads to carbon emissions, it is produced from a waste product that would have otherwise been released into the atmosphere as CH_4. Biogas can be used to generate electricity, heat, and/or vehicle fuel and these outputs can be sold by farmers to generate income (Wang et al., 2022).

There are barriers to anaerobic digestion, such as high costs, limited availability of capital, and the need for adapted technology due to intensive operations. Additionally, the adoption of AD is only assumed to be profitable for larger farms with more manure, as community-based ADs may lead to additional GHG emissions due to the added factor of transportation (Hallbar Consulting, 2020). Currently, BC has two active biodigester

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[50] 3-NOP has been approved for use in Brazil and in the EU.

[51] “Genome sequencing of methanogens has identified targets that stimulate antibody production; antibodies can be created by host animals and detected in saliva and the rumen; and those antibodies have been shown to suppress pure methanogen cultures *in vitro*” (Searchinger et al., 2021).

facilities producing RNG and one upcoming project[52] which is expected to be active within the next two years (Canadian Biogas Association, n.d.).

5. Alternative Manure Management Practices

Alternative manure management practices reduce the amount of manure managed or stored under anaerobic conditions with the goal of limiting CH_4 production and emissions. Several techniques can be implemented on farms to mitigate CH_4 emissions from manure. One effective way to reduce methanogenic bacterial activity is to lower the temperature of the manure by removing it from barn buildings during the winter or using below-ground storage tanks during the summer (Searchinger et al., 2021). Another method is to apply manure to fields frequently to ensure it does not remain long under anaerobic conditions. Additionally, minimizing the amount of manure left in storage tanks can also reduce the number of bacteria producing CH_4, and composting solid manure can also reduce CH_4 emissions and odour emissions (Searchinger et al., 2021).

6. Rotational Grazing

Rotational grazing is a nature-based solution method of grazing where livestock are moved between different pastures on a regular basis, allowing grazed areas to rest and recover (Navius Research, 2021). This reduces the amount of time that manure and urine are deposited in one area, which reduces the amount of organic matter available for methanogenic bacteria to break down and produce CH_4 (Thompson & Rowtree, 2020). Additionally, as animals move through the pasture, they trample and break down plant material, which stimulates new plant growth and increases the amount of carbon stored in the soil, further reducing CH_4 emissions. Rotational grazing can also improve soil health and sequester carbon in the soil, further reducing greenhouse gas emissions (Norgaard et al., 2021).

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[52] The active projects are Seabreeze Dairy Farm in Delta which combines anaerobic digestion of cow manure and organic waste from Metro Vancouver, it produces 45,000 GJ annually which is enough to heat 500 homes. The second is Fraser Valley Biogas in Abbottsford which is also a mixed input facility using agricultural and food processing waste and generates 90,000GJ annually, enough to heat 1000 homes.

7. Demand-Side Mechanisms

Despite the literature on agricultural methane emission mitigation being centred on supply-side mechanisms, experts recognize that the most effective solution is reducing reliance on meat[53] and dairy products as they are less efficient than other sources of meat, and plant-based proteins (Ahmed et al, 2021; Ivanovich et al., 2023; Nisbet et al., 2020; Poore & Nemecek, 2018; Searchinger et al., 2021; Smith et al., 2007; etc.).

In addition to reducing CH_4 emissions, making dietary changes for more sustainable foods also decreases other non-CH_4 gases and would result in better health outcomes such as reducing risk for cardiovascular disease, colorectal cancer, type 2 diabetes, and total mortality[54] (Battaglia et al., 2015; UNEP, 2021; National Institute of Health, 2015; Ritchie et al., 2015). However, this approach faces considerable barriers in terms of education and societal reluctance to change traditional habits (especially in different cultural traditions where foods play a large role in tradition

[53] Primarily red meat (beef and pork)

[54] "Evidence from large US and European cohort studies suggest long-term consumption of increasing amounts of red meat is associated with an increased risk of total mortality, cardiovascular disease, colorectal cancer and type 2 diabetes, in both men and women. This association persists after inclusion of known confounding factors, such as age, race, BMI, history, smoking, blood pressure, lipids, physical activity, and multiple nutritional parameters in multivariate analysis" (National Institute of Health, 2015; Ritchie et al., 2015).