Proceedings of the 3rd International Conference on Business and Policy Studies
DOI: 10.54254/2754-1169/81/20241567

Achieving Canada's Nationally Determined Contribution: Assessing the Cost of Reducing GHG Emissions

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Abstract: Amidst the growing urgency of climate change, this study delves into Canada's commitment to reducing greenhouse gas (GHG) emissions as part of its Nationally Determined Contributions (NDCs) under the Paris Agreement. It aims to comprehensively understand the economic dimensions of Canada's NDC goals. Through an extensive literature review, the research establishes the groundwork for examining emission reduction targets, policy effectiveness, technological feasibility, and socio- political factors. Building on this foundation, a conceptual framework is developed, outlining key relationships among NDC targets, policies, economics, feasibility, socio-political contexts, and international cooperation. The research employs a multifaceted methodology, incorporating data collection and a marginal cost of abatement analysis to assess cost-effectiveness across emission reduction options. We expect to build the marginal cost of abatement curve based on the results from research institutions, government websites, and other NGOs. All in all, this research contributes nuanced insights into Canada's emission reduction pursuits, unveiling the intricate dynamics between policies, economics, and technology.

Keywords: Greenhouse gas (GHG), Nationally Determined Contributions (NDCs), Paris Agreement, Emission reduction, Cost-effectiveness.

1. Introduction

Since the signing of the Paris Agreement in 2015, climate change caused by global warming has become an ongoing issue. Building on the Copenhagen Accord and the Kyoto Protocol, the Paris Agreement sets emission reduction standards for developed and developing countries to ensure that global warming is limited to 1.5 degrees Celsius. Canada, as a developed country, has signed up to a goal of reducing carbon emissions by 40 percent by 2030 in front of more than 200 countries around the world [1]. Climate change's global urgency arises from rising GHG concentrations, necessitating collective government action. Anthropogenic activities, notably fossil fuel use and deforestation, drive these emissions, prompting a need for radical energy transformation to achieve net-zero

DOI: 10.54254/2754-1169/81/20241567

emissions by 2050. However, the financial ramifications of a nation's pursuit of its Intended NDC remain largely unquantified. This study aims to comprehensively assess the intricate cost-performance dynamics of achieving NDC-related GHG reduction targets.

This study aims to evaluate the financial implications of Canada's efforts to achieve its NDC targets for reducing GHG emissions. Through the lens of the abatement curve framework, the research analyzes cost-effective strategies for emission reduction. Collaboration with Navious Research enhances data accuracy. This investigation addresses a critical gap in the literature, offering tailored insights into Canada's NDC ambitions and guiding effective emission reduction policies.

To address our research question, we apply the abatement curve framework, a potent methodology for assessing the potential of reducing greenhouse gas emissions and their associated costs. Through a systematic evaluation of diverse emission reduction options based on increasing abatement costs, this approach enables us to discern cost-effective strategies that align with Canada's NDC targets. The resulting abatement curve analysis furnishes invaluable insights into optimizing emission reduction pathways, taking into account both carbon reduction efficiency and financial viability.

The research relies on a comprehensive array of crucial datasets to address the research question. These datasets encompass multifaceted aspects of Canada's efforts to reduce GHG emissions, forming the foundation for our analysis. We plan to utilize data from Navious Research, which aligns with the research's focus and encompasses emission targets, abatement costs, and other pertinent information. This data will contribute to constructing the marginal cost of abatement curve, aiding in assessing the ambition of Canada in achieving its NDC goals.

The proposed research fills a crucial research gap by focusing on the cost implications of Canada's NDC under the Paris Agreement, contributing to the climate change policy and economics discourse. While existing studies have explored NDC cost-effectiveness in various countries, a comprehensive analysis tailored to Canada's context is lacking. By evaluating potential costs and identifying optimal emission reduction strategies, the research aligns with prior studies emphasizing the significance of understanding relationships between emissions, energy consumption, economic growth, and green technologies. Incorporating methodologies like marginal abatement cost (MAC) curves and integrated assessment models enhances credibility, bridging insights from studies analyzing other countries' NDCs to Canada's unique circumstances. This research not only addresses a research gap but also contributes to Canada's progress in the international climate landscape while supporting evidence-based policy decisions for diverse audiences.

The paper analyzes the cost of reducing greenhouse gas emissions in Canada to meet its NDC targets. It begins with an engaging introduction and motivation, followed by a discussion of the approach using an abatement method and data from a research institution. The literature review covers Canada's GHG emissions background, NDC effectiveness through the MAC curve, reasons for focusing on Canada, and the research's significance. The conceptual framework aims to comprehensively assess Canada's NDC ambition and provide insights for policymakers. The data and method sections detail data sources and the abatement methodology. The paper contributes insights into cost-effective emission reduction strategies, aiding policy decisions for climate mitigation in Canada.

2. Literature Review

The Paris Agreement has set the stage for countries to revise and enhance their NDCs in pursuit of effective climate change policies. There are several key studies that shed light on the cost implications of achieving NDC targets in various countries, including Morocco and Vietnam. Drawing insights from these studies, we aim to assess the potential costs of Canada's NDC and identify strategies to achieve its emission reduction goals cost-effectively. Additionally, another group of studies provides valuable insights into the relationship between GHG emissions, energy consumption, economic

DOI: 10.54254/2754-1169/81/20241567

growth, and the role of green technologies in Canada, which are crucial in assessing the cost implications of achieving Canada's NDC under the Paris Agreement.

2.1. Background of GHG Emission in Canada

The background of greenhouse gas (GHG) emissions in Canada is elucidated through a series of insightful research studies. The research conducted by Hammit-Haggar [2], and Jordaan et al. [3] collectively sheds light on the complex interplay of factors contributing to Canada's emissions landscape. Hammit-Haggar's study uncovers a substantial connection between energy consumption and GHG emissions, revealing a positive and statistically significant impact over time [2]. This relationship is further nuanced by the identification of a non-linear association between GHG emissions and economic growth, as evidenced by the environmental Kuznets curve. Nikzad's work highlights the pivotal role of green innovations, particularly in the manufacturing sector, in curbing emissions [4]. Their emphasis on energy conservation, improved transport, and alternative clean energy resources underscores the efforts Canada is making to address climate change through technological advancements. In parallel, Jordaan et al.'s research delves into the realm of energy technology innovation and its role in emission reduction, emphasizing the success of policies like high carbon fuel phase-out and renewable standards in contributing to emissions reduction [3]. These studies collectively illuminate Canada's intricate emissions landscape, underlining the significance of energy consumption, economic growth, and innovative strategies in shaping the nation's GHG emissions trajectory.

2.2. Literature Assessing the Effectiveness of NDC through MAC curve.

The literature assessing the effectiveness of Nationally Determined Contributions (NDCs) through the use of Marginal Abatement Cost (MAC) curves reveals valuable insights into emission reduction strategies across various countries. The studies conducted by [1,2] collectively contribute to a comprehensive understanding of this approach. They focus on Vietnam's mitigation pledges, utilizing a MAC curve to identify untapped potential for emission reductions, particularly in the agriculture, forestry, and other land use (AFOLU) sectors. The research emphasizes the importance of continuous data refinement for effective NDC implementation. Similarly, Hof et al. [5] provide a global perspective on abatement costs associated with NDCs, highlighting the sensitivity of these costs to socio-economic conditions. The study underscores the potential benefits of emission trading to decrease global costs significantly. Fragkos [6] takes this approach to Morocco's ambitious NDC targets, evaluating the energy system, emission, and cost impacts. While the existing studies offer valuable insights, a research gap remains concerning the application of advanced methodologies and the integration of findings from diverse literatures such as economics, environmental science, and policy analysis. Moreover, the sources of conflicting results among studies and the broader socio-economic impacts of emission reduction strategies have not been comprehensively addressed. Addressing these gaps is essential for providing policymakers with a well-rounded understanding of the potential outcomes and cost implications of NDCs through the lens of MAC curves [1, 2].

2.3. Reasons for Choosing Canada

There are serval reasons for focusing on Canada. Firstly, the datasets are clear and transparent on the official website of the Government of Canada [7], leading to a convincing research result. Secondly, Canada is one of the top GHG emitting countries, their plans on climate change involve both current policies that enable us to quantify the costs. Lastly, Canada has been trying to control GHG emissions since 1988 so Canada is highly experienced and has plenty of useful policies. These are the key results for Canada's National greenhouse gas emissions.

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• Canada's total GHG emissions in 2021 were 670 megatons of carbon dioxide equivalent (Mt CO2 eq), a 1.8% increase from 659 Mt CO2 eq in 2020.
• From 2005 to 2021, Canada's GHG emissions decreased by 8.4% (62 Mt CO2 eq).
• Between 1990 and 2021, Canada's GHG emissions increased by 13.9% (82 Mt CO2 eq).
• Meanwhile, the overall tax revenue for Canada's government in 2023 is $236.2 billion and Canada Revenue Agency is planning to spend $9.00 billion on Climate Action Incentive Payment in order to reach the goal of decreasing 40%-45% GHG emissions in 2030.

2.4. Research Gap

2.4.1. Relatively Little Research on Canada's Context

The current literature lacks comprehensive analyses specific to Canada's emission reduction goals under the Paris Agreement. While studies have examined global strategies, there is a notable research gap concerning Canada's unique challenges. Existing research, such as Hammit-Haggar [2] and Nikzad [4], provides insights but doesn't fully encompass Canada's multifaceted emission reduction journey. This research aims to address this gap by meticulously evaluating Canada's energy system, policies, and technological advancements, offering tailored strategies to align with Canada's NDC and effectively address its distinctive challenges [4].

2.4.2. Lack of Studies with Rigorous Methods

The existing literature provides valuable insights into the financial implications of achieving NDC targets globally. However, a significant research gap exists regarding the application of advanced methodologies to enhance the accuracy of cost assessments. While studies like Hof et al. [5] employ integrated assessment models, there's a need for more rigorous approaches such as sensitivity analyses and simulations to capture potential variations in cost estimates. Bridging this gap is crucial for offering policymakers robust data-driven insights. Our proposed research intends to fill this void by utilizing an abatement curve framework to comprehensively analyze Canada's emission reduction potential and associated costs, employing advanced methodologies to enhance the credibility of findings and inform climate policy decisions [5].

2.4.3. Missing Attempts to Bridge Different Literatures

Existing studies have examined the cost-effectiveness of NDC targets in various countries, yet a notable research gap exists in integrating insights from diverse disciplines such as economics, environmental science, and policy analysis. They employs a MAC curve to assess Vietnam's mitigation pledges, highlighting the importance of data improvement but not fully connecting economic and environmental aspects. This research addresses the gap by synthesizing findings from multiple literatures, aiming to offer policymakers a comprehensive analysis that considers both economic feasibility and environmental impact [8].

2.4.4. Existence of Studies with Conflicting Results

Existing literature presents conflicting findings on the cost-effectiveness of diverse emission reduction strategies, yet a research gap exists in clarifying the sources of these disparities [2]. Although some studies acknowledge the variations, none explicitly delve into investigating the underlying causes behind such discrepancies. This study aims to fill this void by not only identifying conflicting outcomes but also scrutinizing the factors that contribute to these variations. By addressing this gap, the research enhances comprehension of the influences that lead to divergent

DOI: 10.54254/2754-1169/81/20241567

cost-effectiveness results in emission reduction strategies, thus contributing to a more coherent understanding of the field [3]

2.4.5. Lack of Studies Exploring Different Outcomes

Existing research primarily focuses on evaluating the cost implications of achieving NDC targets, leaving a research gap regarding the examination of broader outcomes beyond cost. This gap includes factors like employment, economic growth, social equity, and environmental co-benefits. While Jordaan et al.'s study [3] explores energy technology innovation's role in reducing Canada's GHG emissions, it lacks a comprehensive analysis of associated employment and economic growth effects. Addressing these gaps is crucial for informing policy decisions comprehensively. The proposed research aims to fill these voids by investigating both cost implications and broader socio-economic impacts, enhancing the understanding of effective emission reduction strategies [6].

3. Conceptual Framework

This research's conceptual framework comprehensively evaluates Canada's efforts to achieve its NDC goals for GHG emissions reduction. It seeks to understand the complexities, costs, challenges, and opportunities associated with meeting these targets. By analyzing Canada's NDC commitments, existing climate policies, and mitigation strategies, the study aims to provide valuable insights for policymakers to create effective and cost-efficient climate policies. The framework employs a marginal cost of abatement analysis to assess the most efficient strategies, considering factors like renewable energy adoption, energy efficiency, and carbon capture technologies. It also examines the technological feasibility and socio-political context influencing policy implementation, including public acceptance and international cooperation. Ultimately, this research aims to offer a holistic perspective on Canada's climate policies, guiding informed decision-making for achieving NDC targets while considering practicality, cost-effectiveness, and broader socio-political dynamics.

The first component of the conceptual framework focuses on understanding Canada's NDC targets and commitments to the international community for mitigating climate change, specifically the reduction in GHG. This entails a comprehensive analysis of the specific emission reduction goals set by Canada under the Paris Agreement, and the timeline for achieving them, such as the goal of reducing the emission of GHG by 43% by 2030. By establishing a clear baseline of the NDC targets, the study can later evaluate the progress made in reducing GHG emissions and the associated costs for Canada.

The study then delves into an in-depth analysis of the existing climate policies and mitigation strategies adopted by the Canadian government. This includes examining a range of regulatory measures, incentives, and carbon taxing mechanisms that have been implemented in Canada to reduce GHG emissions. Understanding the effectiveness and limitations of these policies is crucial for assessing their impact on cost reduction and identifying areas where further improvements might be needed.

In order to identify the appropriate level of tax rate aims to reduce GHG emissions, a marginal cost of abatement analysis is conducted. This economic model allows for the evaluation of the cost-effectiveness of various abatement options, including the implementation of taxes, and the amounts of reduction as a result of the imposed tax rates. With the quantity of reduction in GHG, we can figure out the spending of the Canadian government under the marginal cost of abatement curve. By assessing the costs associated with different sources of emissions and the potential savings achieved through abatement measures, policymakers can make informed decisions about the most efficient strategies to pursue. This economic analysis plays a vital role in estimating the costs of different mitigation options. By conducting a thorough marginal cost of abatement analysis of various

DOI: 10.54254/2754-1169/81/20241567

strategies, the study can determine the most cost-effective approaches to achieving Canada's NDC targets. Specifically, this analysis may include evaluating the costs of transitioning to renewable energy sources, promoting energy efficiency, and implementing carbon capture and storage technologies.

Technological feasibility is another crucial aspect of the framework, aiming to assess the readiness and scalability of emission-reducing technologies. The study will examine the current state of technological development, research and development initiatives, and potential barriers to the widespread adoption of these technologies. Understanding the technological landscape will provide insights into the practicality of achieving NDC targets within given cost constraints. Beyond technical and economic factors, the study recognizes the importance of the socio-political context in determining the success of climate policies. Factors such as public acceptance, awareness, and political will can significantly influence the implementation of these policies. Analyzing public perceptions and gauging the level of political commitment will provide valuable insights into the feasibility of achieving NDC targets and the potential challenges faced in the process. International cooperation is another essential aspect of addressing climate change, and the conceptual framework incorporates an exploration of opportunities for collaboration. This includes examining the potential for carbon trading mechanisms that allow countries to exchange emission reduction credits and financial support mechanisms for developing nations to transition to low-carbon economies. Understanding the impact of these international collaborations on cost-effectiveness will provide valuable insights into Canada's climate policy.

4. Data

4.1. Overview

While researching and estimating expenditures, it was found to be quite difficult to make estimates for each industry, and the data were quite cumbersome to obtain. With the exception of major industries such as new energy utilization, hydroelectricity, and mining. For all other sectors, further interviews and surveys are required.

These figures include the cost of environmental improvements, investments in new energy sources, carbon tax profits, and Adaptation and Resilience Spending, to name a few. Most of the data types are Repeated cross-sections, where the profit or loss of different industries is investigated and presented as line graphs of revenues and investments over some time.

It's important to note that gathering accurate and up-to-date data for such a research question may be challenging, as it could involve accessing multiple sources and databases, and the information may be subject to change over time. Additionally, cost figures and funding allocations may be spread across various government departments and programs, making the data collection process more complex. Nevertheless, a thorough analysis of these data points would be crucial to understanding the financial implications of Canada's efforts to achieve the standards set by the Paris Agreement.

In the research process, we will create an abatement cost curve for greenhouse gas emissions. It included gathering data on different greenhouse gas reduction measures and their corresponding costs that contain technologies, practices, and policies aimed at reducing emissions. Then for each mitigation option, estimate the amount of greenhouse gas emissions that can be reduced or avoided. After we calculate the costs and rank them from high to low, we can plot the graph. Using the data to create a graph with the cost of each option on the X- axis and the emission reductions on the Y-axis. Finally, we will interpret the curve and estimate approximately about the total cost.

DOI: 10.54254/2754-1169/81/20241567

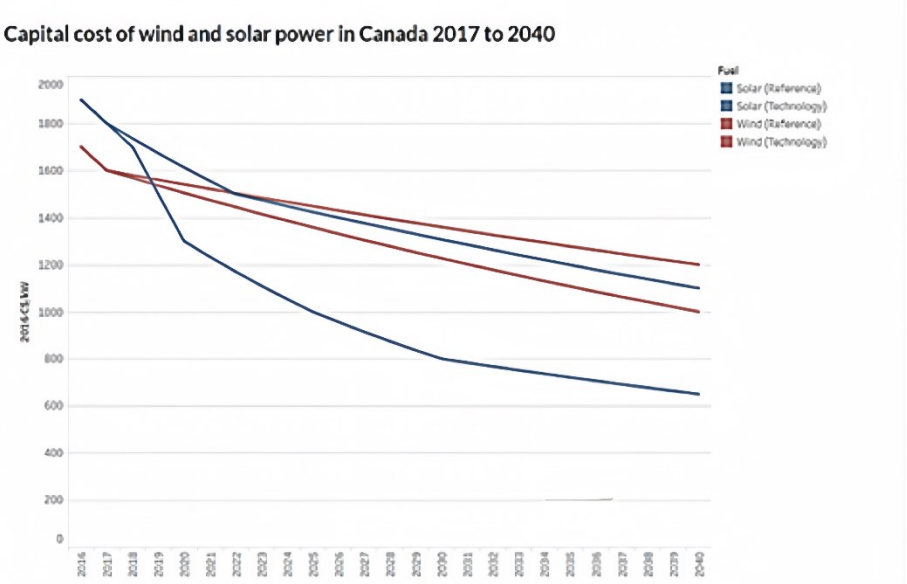

Figure 1: Capital cost of wind and solar power in Canada 2017 to 2040, by National Energy Board released Canada's Energy Future 2018. https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2018/market-snapshot-cost-ins.

As an example, the chart above shows how much is spent on wind and solar in Canada. Included are those already in place and projections of future trends. This chart gives us a clear picture of Canada's spending in these two areas. Combined with the amount of carbon emissions that wind and solar can reduce, it is possible to roughly predict the reduction in spending and the distance from the Paris Agreement targets. The images begin shortly after the Paris Agreement was established when Canada began to take measures and end before the expiration time set out in the Paris Agreement. The cost of the calculations and the resulting savings can be adequately estimated in this range.

However, estimating and calculating each industry is a rather challenging and impractical statistical exercise. The data are also subject to certain limitations, so to the extent that we are able, we will be counting and estimating data for a few important industries in Canada, such as mining, maritime industry, new energy utilization, etc.

4.2. Data Collection and Ideal Datasets

In assessing the cost of reducing GHG emissions to achieve Canada's NDC goals, the necessity for precise and pertinent data becomes paramount. The data required for this analysis encompasses multiple facets of Canada's NDC goals, including sector-wise emission reduction targets, technological feasibility, regional disparities in implementation, and corresponding abatement costs. Given the specificity of our research objective, we have identified Navious Research as a critical source of data. To harness this critical data, we have initiated contact with Navious Research, articulating our research goals, and outlining the specific data sets we seek. We have emphasized the importance of their unique insights, models, and statistical data in analyzing the abatement cost curves relevant to Canada's climate policies. The collaboration with Navious Research presents an unprecedented opportunity to access specialized data that will significantly enrich our analysis of Canada's NDC goals. Their authoritative data sets and analytical tools are integral to our research, offering the depth and specificity required to accurately assess the cost of reducing GHG emissions in Canada. The success of this collaboration will undoubtedly define the robustness and credibility of our findings, underscoring the pivotal role of data in shaping policy-relevant insights.

DOI: 10.54254/2754-1169/81/20241567

Apart from the Navious Research, we also identified several possible places for us to gather useful datasets for us to build the marginal cost of abatement and find out the cost efficiency for Canada to achieve its NDC goals.

- Environment and Climate Change Canada (ECCC): ECCC annually publishes the National Inventory Report, providing detailed information on Canada's greenhouse gas emissions by sector and activity. This dataset includes emissions data from various industries, energy production, transportation, and more. It forms a foundation for understanding current emissions levels and trends.
- Statistics Canada: The Input-Output Tables provide insights into the economic relationships among industries, allowing you to estimate the economic impact of emissions reduction measures on different sectors of the Canadian economy.
- Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC) offers datasets that provide energy consumption and emissions data for different industrial sectors. This data would be valuable for estimating the energy consumption and emissions intensity of various industries.
- Canadian Institute for Climate Choices: Economic Scenarios offers datasets that outline different economic scenarios, including policies and pathways to achieve emissions reduction. These scenarios can help you understand the potential economic implications of various emissions reduction strategies.
- Provincial and Territorial Governments: Each province and territory in Canada has its own climate action plans, which often include emissions reduction targets, policy measures, and projections. These datasets can provide insights into regional variations and policy effectiveness.
- International Energy Agency (IEA): The IEA offers datasets on various clean energy technologies, including their costs and feasibility. These datasets can aid in assessing the technological feasibility of emissions reduction measures.

4.3. Motivation

The proposed dataset is pivotal due to its ability to provide accurate sector-wise emission reduction targets, a crucial element in Canada's pursuit of NDC alignment. Sector-specific insights are vital to identify industries that can significantly contribute to emissions reduction. Additionally, the dataset's inclusion of abatement costs is essential for gauging economic implications, enabling informed decisions on cost-effective strategies. Technological viability insights ensure practical implementation, while regional disparities are addressed for equitable strategies. In essence, the dataset's multifaceted nature imbues the analysis with precision, guiding informed policies that align with NDC commitments and global climate goals.

5. Methods and Results

This section describes the method used for quantifying the costs needed to achieve the nationally determined distributions in Canada. More specifically we discuss:

1) How the MAC curve enables us to calculate the amount of carbon taxes imposed and the amount of costs that occurred for different industries.

2) The construction of the marginal abatement curve for this study.

3) The analytical steps are taken to assess the marginal abatement curve of mitigation potential and costs.

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5.1. How a marginal abatement costs curve works

The MAC curve is defined as a graph that indicates the marginal cost (the cost of the last unit) of emission abatement for varying amounts of emission reduction. Within the framework of greenhouse gas emissions reduction targets, policymakers worldwide face the challenge of identifying an economically viable approach to reduce carbon emissions. In this regard, MAC curve curves have been utilized to demonstrate the economic and technological feasibility of mitigating climate change. It is a tool used in environmental economics to analyze the cost- effectiveness of reducing emissions, which helps policymakers determine the optimal level of carbon taxation by providing insights into the costs associated with different emission reduction measures. The MAC curve plots the cost of reducing one additional unit of emissions against the quantity of emission reduced. This curve illustrates that the initial emission reductions are often achieved at relatively low costs, but as more emissions are reduced, the cost of further reductions tends to increase.

The MAC curves are effective visual representations of a country's climate mitigation efforts. The methodology behind MAC curves involves initially compiling a country's mitigation policies and analyzing the technical and economic aspects of each measure. MAC curves present measures by sector, energy sources, and stakeholders to demonstrate their contribution and resulting emissions reduction across various city activities. It also enables the differentiation between fossil-based and renewable energy sources to showcase decarbonization efforts. Furthermore, the MAC curve can be used to highlight the financial commitments of different stakeholders in implementing these measures.

However, the limitation in the development of a MAC curve of the proper documentation of assumptions and the consideration of uncertainty in the inputs. As urban areas progress, the MAC curve must undergo constant updates and enhancements to ensure its alignment with the changing reality of the country. Sensitivity analyses play a crucial role in determining and calculating uncertainties associated with various inputs, such as technology costs, energy prices, GHG intensity of electricity, adoption rates, market penetration of technology, existing infrastructure stock, implementation of measures, and discount rate. While there has been some innovative work done on upstream emissions, the bottom-up model can still be enhanced over time through comprehensive data collection. It is important to recognize these limitations when utilizing a MAC curve in assessing and addressing emissions reduction strategies within a country.

Figure 1: Canada's greenhouse gas abatement potential in 2030

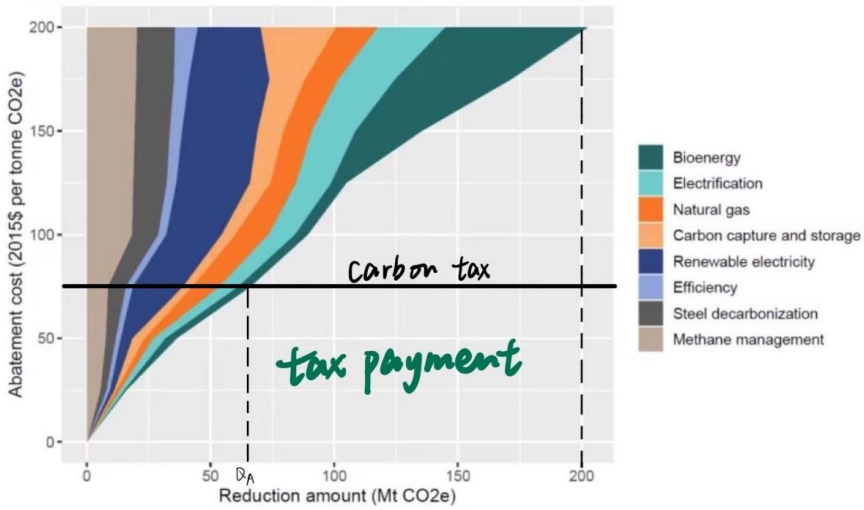

Figure 2: Canada's Greenhouse Gas Abatement Potential in 2023 by Navious Research Inc. https://www.naviusresearch.com/publications/canada-ghg-reduction-options/

DOI: 10.54254/2754-1169/81/20241567

5.2. Constructing a MAC curve for this study

The first step is to identify the emission sources, such as power plants, factories, and so on. Second, determine the baseline emissions, which represent the amount of greenhouse gas emissions that would occur without any mitigation measures. Next, assess potential abatement options and estimate emission reductions. Lastly, plot the marginal abatement cost curve, we assume the carbon tax level is at $75 per ton co2 emission, the tax payment would be 75*(200- QA). When the reduction amount is less than QA, firms in different industries would reduce the emissions of GHG to reach the target instead of paying carbon tax, since it costs them less. But the right-hand side of the intersection of the carbon tax level and marginal cost curve, where costs firms less to pay the carbon tax, would be the amount of the reduction needed to pay the carbon tax. Therefore, the carbon tax generated would be (maximum reduction amount- quantity of intersection) *carbon tax.

5.3. Mitigation potential and costs

This involves analyzing the MAC to identify cost-effective mitigation options. Decision- makers can prioritize measures that offer significant emission reductions at relatively low costs. Additionally, sensitivity analysis and Scenario modeling can be performed to assess the uncertainties and determine the robustness of the results. Overall, the analytical steps involved in assessing the marginal abatement curve of mitigation potential and costs provide valuable insight into identifying cost-effective measures for reducing GHG emissions and guiding policymaking in achieving sustainable development goals.

5.4. Relevant Studies

Several studies have explored the cost implications of NDC targets in various countries, shedding light on both similar and different approaches to assessing emission reduction strategies. Drawing insights from these studies, we can develop a comprehensive understanding ofthe cost-effectiveness of Canada's emission reduction efforts. Here, we review and cite studies that have tackled similar questions or adopted similar approaches, as well as those that provide contrasting perspectives:

5.4.1. Evaluating NDCs Using MAC Curves

Carbonari et al. [8] applied a MAC curve methodology to assess Vietnam's mitigation pledges, focusing on the agriculture, forestry, and other land use (AFOLU) sectors. This study showcases the potential of using MAC curves to identify cost-effective strategies for emissions reduction and highlights the importance of data refinement for monitoring progress towards NDC goals.

5.4.2. Integrated Assessment Models for Abatement Costs

Hof et al. [5] utilized an integrated assessment model to estimate the annual costs of achieving NDC reduction targets under different socio-economic assumptions. Their research provides insights into the sensitivity of abatement costs to socio-economic conditions and emphasizes the role of emission trading in reducing global costs [5].

5.4.3. Specific Country Case Study - Morocco's NDC

Fragkos' study [6] offers a country-specific perspective by evaluating the energy system, emission, and cost impacts of Morocco's ambitious NDC targets. While this study focuses on Morocco, its insights into the challenges and opportunities of decarbonization efforts align with the broader goal of assessing NDC implications (Fragkos, 2023).

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5.4.4. Linking Energy Consumption, Economic Growth, and GHG Emissions

Hammit-Haggar's research [2] investigates the relationships between energy consumption, economic growth, and GHG emissions in Canadian industrial sectors. While this study focuses on causal relationships, it contributes to the understanding of Canada's emission reduction journey by exploring the dynamics of these interrelated factors.

By referring to and citing these relevant studies, we establish a solid foundation for our research approach. These studies collectively offer insights into the methodologies, analytical tools, and perspectives that can inform our assessment of Canada's NDC and the associated cost implications. Moreover, the diversity of studies enables us to synthesize findings and contribute context-specific recommendations that can guide Canada's emission reduction strategies effectively under the Paris Agreement.

6. Conclusion

In conclusion, this research endeavors to shed light on the intricate relationship between cost-effective emission reduction strategies and Canada's Nationally Determined Contribution (NDC) targets under the Paris Agreement. As the world grapples with the pressing challenge of climate change, it becomes imperative for governments to allocate resources wisely and pursue strategies that yield the greatest impact in reducing greenhouse gas emissions. The motivation for this study stems from the escalating severity of environmental issues and the ongoing debate regarding resource allocation towards emission reduction versus other critical public goods.

By framing the research question around the cost performance of decreasing greenhouse gas emissions, we have embarked on a journey to uncover insights that have far-reaching implications for policy design, business strategies, and future research endeavors. The urgency of addressing climate change cannot be overstated, as the stability of our planet's climate underpins the foundation of all human activities. Climate change transcends national boundaries, making it a global emergency that necessitates collaborative efforts and evidence-based decision-making.

Through an in-depth literature review, we have identified key studies that tackle similar questions and adopt similar or different approaches. These studies emphasize the role of data, integrated assessment models, and innovative methodologies such as marginal abatement cost (MAC) curves in assessing emission reduction strategies. By building upon the findings of these studies and adapting them to Canada's unique context, our research aims to fill critical research gaps and contribute novel insights to the field.

The methodology employed in this research, namely the abatement curve framework, holds the potential to provide a comprehensive evaluation of emission reduction options, their associated costs, and their feasibility within Canada's policy landscape. The collaboration with Navious Research further underscores the importance of precise and pertinent data in shaping credible and robust policy-relevant insights. It offers an unprecedented opportunity to leverage specialized information aligned with our research objectives, enhancing the credibility and relevance of our analysis.

While the study's primary focus is on evaluating the cost implications of Canada's NDC, it also acknowledges certain limitations. For instance, the analysis is conducted within a specified scope and timeframe, and certain factors such as international policy dynamics and technological breakthroughs may not be fully accounted for. Additionally, the study does not delve into new findings or information that should typically be included in the literature review or results section.

Looking ahead, this research carries broader implications for future studies, policy design, and business strategies. It sets the stage for evidence-based decision-making by policymakers, aiding them in making informed choices regarding emission reduction strategies that align with Canada's NDC. Furthermore, the insights gained from this study can serve as a steppingstone for future research

DOI: 10.54254/2754-1169/81/20241567

endeavors, fostering a deeper understanding of the economic, environmental, and social dimensions of climate change mitigation.

In conclusion, this research serves as a steppingstone in the ongoing global effort to combat climate change. By evaluating the cost implications of emission reduction strategies, the study contributes to the collective knowledge base, guiding policy decisions, fostering international commitments, and enhancing our understanding of the intricate economics of climate change mitigation. As we navigate the complex landscape of environmental challenges, this research provides valuable insights that transcend borders and pave the way for a more sustainable and resilient future.

Acknowledgement

Shan She and Yanni Fu are contributed equally to this work and should be considered as co-first authors. Xinyu Jiang and Jiyu Wang are both co-second author.

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