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Costs and Benefits of Reducing Nitrous Oxide Emissions from Canadian Agriculture

by Kenneth P. Green

Summary

- Canada's government has launched an initiative to reduce Canadian emissions of nitrous oxide ($N_2$0), a greenhouse gas emitted mainly by Canada's agricultural sector.
- Canada's total GHG emissions amount to 1.6 percent of global emissions. Canada's $N_2$0 emissions are approximately 4.5 percent of its total, hence, (.016*.045=0.0007) or about seven one-hundredths of one percent of global greenhouse gas emissions.
- Canada's nitrous oxide emissions have been declining as a share of global $N_2$0 emissions since 1850, dropping from above two percent of the global total to its current level of 1.6 percent. Despite Canada's small, and diminishing share of global $N_2$0 emissions, its proposed nitrous oxide control policies will incur significant government spending. Recently announced government spending initiatives intended to reduce agricultural nitrous oxide emissions are approximately CDN$1.6 billion. This is to complement approximately CDN$283 million per year in spending by the agriculture sector to the same end. These additional costs to the agriculture sector would likely be passed on to consumers.
- These changes would produce nitrous oxide emission reduction equivalent to 50–75 percent of government's emission reduction target, suggesting additional measures will be required.
- The net impact of the government's proposed nitrous oxide emission reduction programs will impose costs on Canada's agriculture sector and its derivative products, but provide no measurable (climate) benefit, violating a fundamental principle of sound public policy.

Policy background

The genesis of Canada's plans to reduce agricultural emissions of N_20 flow from larger plans to reduce its overall emissions of greenhouse gas to "net-zero" by the year 2050, as follows:

In 2021, the Government of Canada enacted the *Canadian Net-Zero Emissions Accountability Act*, which "enshrines in legislation Canada's commitment to achieve net-zero [greenhouse gas] emissions by 2050" (Canada, 2021: 3–4).

In 2022, the government followed up on the *Net-Zero Emissions Accountability Act* with the *2030 Emissions Reduction Plan*, which, according to Minister Steven Guilbeault, "charts a credible path to emissions that are 40 percent lower than 2005 levels by 2030" (ECCC, 2022: 6).

The *2030 Emissions Reduction Plan* also included a section on reducing emissions from the Agricultural Sector, mostly focused on methane emission reductions, but also including fertilizer emission reductions [primarily nitrous oxide]: "Under Canada's strengthened climate plan, Canada committed to setting a national fertilizer emission reduction target of 30% below 2020 levels by 2030 and to work with fertilizer manufacturers, farmers, provinces and territories, to develop an approach to meet it" (ECCC, 2022: 65).

On March 4, 2022, the government published a discussion document, *Reducing Emissions Arising from the Application of Fertilizer in Canada's Agriculture Sector* (Canada, 2022a) (henceforth *Discussion Document)*, followed, on March 18, 2023, by publication of the *What We Heard Report—Fertilizer Emissions Reductions* (Canada, 2023a) (henceforth *What We Heard*).

Neither of these publications lay out concrete regulatory or legislative initiatives pursuant to the broad emission reduction goals set forth in the *2030 Emissions Reduction Plan,* however *What We Heard* outlines a process of Government support for a set of N_20 emission reduction techniques proposed by the agricultural trade group, Fertilizer Canada.

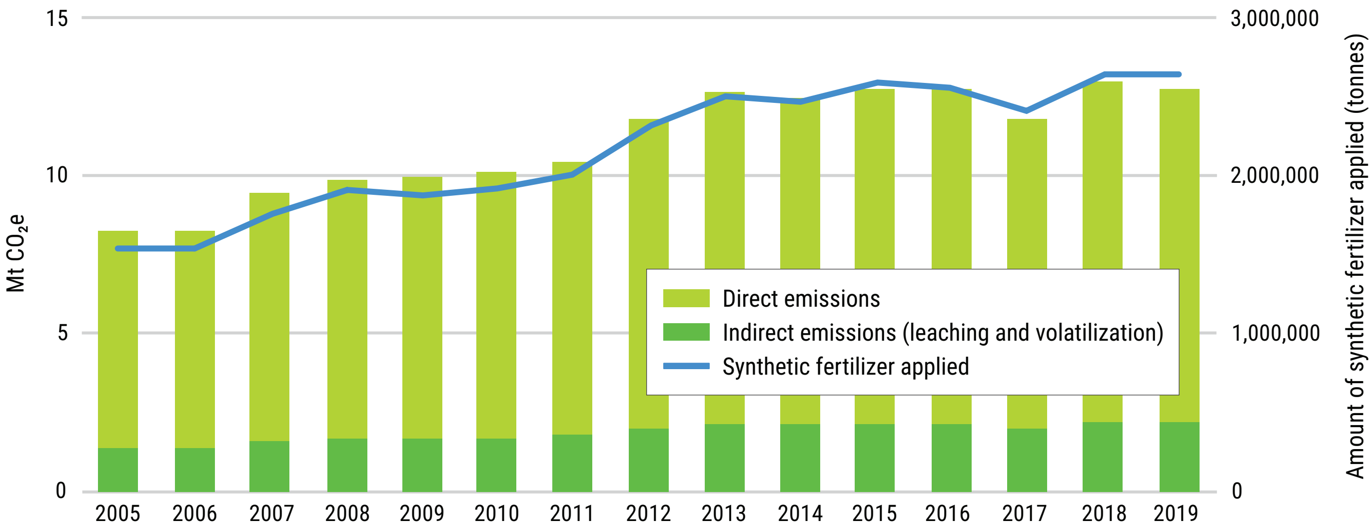
Nitrous oxide emissions and fertilizer use in Canada

According to the Discussion Document released by Agriculture and Agri-Food Canada, "the application of nitrogen (N) fertilizer in particular results in nitrous oxide (N_20) emissions, a potent greenhouse gas with a global warming potential 265 to 298 times that of carbon dioxide (CO_2) over a 100-year period" (Canada, 2022a).

The *Discussion Document* outlines Canada's trends in fertilizer use as well as its relationship to nitrous oxide emissions: "Between 2005 and 2019, fertilizer use increased by 71% in Canada, primarily driven by growing fertilizer sales in Western Canada (BC, AB, SK, and MB). Over the same period, N_2O emissions from fertilizer application in Canada increased by 54% with direct and indirect emissions associated with synthetic fertilizer N_20 emissions in 2019 at 12.75Mt CO_2e." (CO_2e stands for CO_2-equivalent, a common unit used for discussion of the different greenhouse gases.)

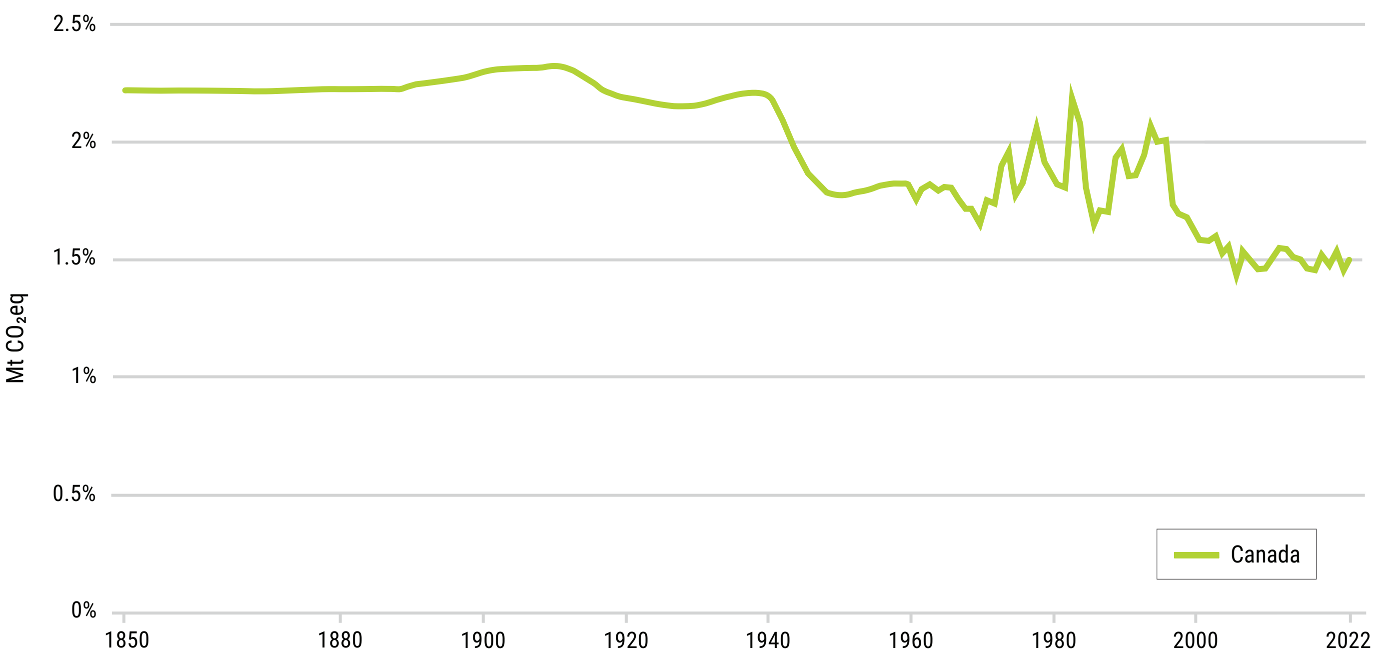
At the national scale, nitrous oxide emissions in Canada have been increasing over the period from 2005 to 2019, though as this figure from the *Discussion Document* shows, the trend has been largely level since 2013. It is worth noting here that despite increased fertilizer use, N_2O emissions have been level for a decade, indicating that farmers are already engaging in activities reducing N_20 emissions from their fertilizer use.

Figure 1: Direct and Indirect Emissions from Synthetic Fertilizer Application, 2005 to 2021 (NIR, 2021)



Source: Government of Canada, 2022a.

Figure 2: Canada's Share of Global Nitrous Oxide Emissions, 1850 to 2021, in Units of CO_2-Equivalents



Source: Our World in Data, 2023.

Note: Carbon dioxide equivalents (CO_2eq): Carbon dioxide is the most important greenhouse gas, but not the only one. To capture all greenhouse gas emissions, researchers express them in "carbon dioxide equivalents" (CO_2eq). This takes all greenhouse gases into account, not just CO_2. To express all greenhouse gases in carbon dioxide equivalents (CO_2eq), each one is weighted by its global warming potential (GWP) value. GWP measures the amount of warming a gas creates compared to CO_2. CO_2 is given a GWP value of one. If a gas had a GWP of 10 then one kilogram of that gas would generate ten times the warming effect as one kilogram of CO_2. Carbon dioxide equivalents are calculated for each gas by multiplying the mass of emissions of a specific greenhouse gas by its GWP factor. This warming can be stated over different timescales. To calculate CO_2eq over 100 years, we'd multiply each gas by its GWP over a 100-year timescale (GWP100). Total greenhouse gas emissions—measured in CO_2eq—are then calculated by summing each gas' CO_2eq value.

Figure 2, from Our World in Data, shows the trend for nitrous oxide emissions in Canada from a global perspective. As can be seen, Canada's nitrous oxide emissions have been declining as a share of global emissions since 1850, dropping from above two percent of global total to the current 1.6 percent (Our World in Data, 2023). By contrast, global N_2O emissions have been increasing at approximately two percent per decade (Tian et al., 2020).

The distribution of nitrous oxide emissions across Canada is non-uniform. Unsurprisingly, provinces with larger agricultural sectors have higher nitrous oxide emissions. The *Discussion Document* observes that:

> The seasonal pattern of N_2O emissions reflects the interaction between soil temperature, soil water and nitrate availability. Drier regions of the Prairies have much lower N_2O losses than the moister regions of Eastern Canada. N_2O emissions per hectare are greater in Eastern Canada as a result of the wetter climate and greater N application rates. However, the much larger land area in the Prairies vs. Eastern Canada results in greater total N fertilizer application in the Prairies and thus the total emissions are much higher in this region. (Canada, 2022a)

Potential costs of reducing nitrous oxide emissions of agriculture in Canada

The approach spelled out in *What We Heard* outlines a collaborative approach between the government of Canada (represented by Agriculture and Agri-Food Canada) and the industry association Fertilizer Canada to reduce Canadian nitrous oxide emissions. The primary focus of *What We Heard* are a range of measures Canadian Farmers might use to reduce nitrous oxide emissions based on an existing program developed by Fertilizer Canada called "4R Nutrient Stewardship."

The report *Getting 4R Sustainability Right* (published by Agriculture and Agri-Foods Canada, the 4R Research Network, and Fertilizer Canada) explains the overall goals of the initiative, which includes an overarching goal of "securing a total of 20 million 4R Designated acres, or 25 percent, of Canadian crop production by 2020."

The 4R framework, summarized in broad strokes, aims to refine fertilizer use in Canadian agriculture in four dimensions: insuring the most appropriate choice of fertilizers by crop use; matching application rates more closely to crop demands (reducing excess application); timing fertilizer application more closely to crop demands; and engaging agricultural practices that reduce fertilizer runoff. In the parlance of Fertilizer Canada, this is "Right Source @ Right Rate, Right Time, Right Place®."

According to *Getting 4R Sustainability Right*, Agriculture and Agri-Food Canada has already been contributing financial assistance to the program, having announced in 2015 (and presumably subsequently given) "$1.1 million in matched funding over three years to support the work of the 4R Research Network."

Additional program expenditures in support of N_2O reduction listed in the *What We Heard* report include:

- $185M—10 years Agricultural Climate Solutions, Living Labs.
- $670M—seven years Agricultural Climate Solutions, On-Farm Climate Action Fund:

nitrogen management, rotational grazing, and cover cropping.

- $495.7M—seven years Agricultural Clean technology program: help adopt clean technology and reduce GHGs.
- Sustainable Canadian Agricultural Partnership—climate change and environment as key priority areas, including a new $250M Resilient Agricultural Landscapes Program: cost-shared with provinces and territories to support carbon sequestration, adaptation, and environmental co-benefits. The new Partnership also includes the $240M AgriScience Program, to accelerate the pace of innovation by providing funding and support for precommercial science activities and research that benefits the agriculture and agrifood sector and Canadians.

The total of these measures is approximately CA$1.6 billion, spent over seven to 10 years.

It is worth noting that in *What We Heard*, then-Minister of Agriculture and Agri-Food, the Honourable Marie-Claude Bibeau, sought to distinguish Canada's approach to nitrous oxide controls in Agriculture, stating that "I would like to be clear, **there is no mandatory reduction in fertilizer use on Canadian farms**. Instead, we want to support measures that producers can take **voluntarily** to reduce their emissions over the long term, without curtailing growth in crop yields" (Canada, 2023a) (emphasis in original).

Data that might be used to evaluate the potential policy impacts of pursuing or achieving the government's nitrous oxide reductions from Canadian agriculture in greater detail are very limited, and primarily come from cooperative research programs between government and the agriculture industry.

Specific to the government's plan and the Canadian industry's comments on costs, the economic impacts of government's plan are highly uncertain. From the *Discussion Document*:

> The potential economic impacts of applying dif-ferent beneficial management practices (BMPs) are expected to span a wide range and may result in either net costs or net benefits to farmers. For example, a recent study prepared for Farmers for Climate Solutions has estimated that the use of enhanced efficiency fertilizer in Prairies for wheat would cost approximately $74 per hectare on average. On the other hand, the same study estimates that the same measure for corn in the Prairies can actually increase revenues by $20 per hectare on average. (Canada, 2022a)

The economic study by Farmers for Climate Solutions, authored by Aaron De Laporte, Daniel Schuurman, and Alfons Weersink (2021) goes into considerably more detail than the broad estimate cited in the government's *Discussion Document*.

For one, De Laporte et al. observe that efforts to reduce greenhouse gas emissions from agriculture are unlikely to be primarily market driven responses—that is, measures undertaken to improve profitability and yields. The authors state that "This report finds that many practices could have either a positive or negative effect on farm incomes. External supports would likely be necessary to increase the adoption of costly on farm GHG mitigating practices."

Further, De Laporte et al. observe that "lower incentives per hectare are necessary to advance 4R (Right Rate, Right Placement, Right Timing, Right Source) N management practices, but that this had lower mitigation potential per hectare. Cover crops, conservation of wetlands and trees and rotational grazing had higher inducement costs per hectare, but also had higher mitigation potential. **The abatement costs range from $31 to $77 per tonne CO_2e**" (emphasis by author).

For reference purposes:

- The current allowance price of a tonne of CO_2-equivalent emission offsets in the US-based Regional Greenhouse Gas Initiative was USD$16 as of March 13, 2024, or CA$ 21.60 at the time of writing (RGGI, 2024).
- The price for an equivalent carbon allowance on California's emission market was approximately USD$42.00/tonne, or CA$56.70 at time of writing (CARB, 2024).
- The "reserve price" in Quebec's carbon market was between CA$56.61 and CA$55.58 as of Feb 14, 2024 (Quebec, 2024).
- Canada's current carbon price (the federal carbon tax) stands at $80/tonne, with a plan to increase it to $170/tonne in 2030 (Canada, 2023b).

In summary, De LaPorte et al. find that "Overall, the total costs of the four programs proposed to improve adoption of nitrogen management, cover crops, rotational grazing, and the conservation of wetlands and trees on agricultural lands are estimated to be $283 million dollars per year. The total GHG emissions reduction in CO_2e is more than 9.5 million tonnes across 17 million hectares. This results in an approximate total average abatement cost of $29.69/t CO_2e…"

Thus, the lower bound estimate of the costs of GHG abatement via the 4R program falls below the cost spread of carbon emission offset credits, while the upper bound is higher than the prices found on those carbon offset markets. The average abatement cost is lower than the costs in either the

Table 1: Summary of Program Costs, GHG Emissions Reductions, Covered Area and Abatement Costs for 4R Implementation, Rotational Grazing Adoption, Cover Crop Adoption, and Set-aside Trees and Wetlands

Best Management Practice	Change	Cost Share Equivalent ($/ha)	Area Affected (ha)	Total Program Cost ($)	Total GHG Mitigation (t CO_2e)	Abatement Cost ($/t CO_2e)
4R (50% Cost Share)	15% New and improved Adoption	8.35	13,861,276	115,698,825	2,919,111	39.63
Cover Crops	15% New adoption in ROC + 15% adoption in ROC +1% New adoption in Prairies	47.98	2,360,073	2,216,471	2,216,471	51.09
Rotational Grazing	10% new adoption	24.22	967,132	302,414	302,414	77.46
Set Aside	40% Vulnerable Wetlands and Trees Preserved for 20 years	2363.71	13,104	4,105,652	4,105,652	7.54
Total		16.47	17,201,584	9,543,648	9,543,648	29.69

Source: De LaPorte et al. (2021).
Note: BMP = Best Management Practices
Change = changes to BMP proposed to reduce N_2O emissions
ROC = Rest of Canada (as opposed to the prairie provinces)

California or Quebec emission markets, but significantly above that of the offset credit prices on the Regional Greenhouse Gas Initiative exchange as listed above.

For those wishing for a bit more detail of what the 4R program activities, expenditures, and government "cost share equivalents," see table 1.

What is worth noting is that the carbon abatement cost of most of the specific emission mitigation measures listed are at or below the current market price for greenhouse gas emission allowances today. The abatement cost for planting cover crops for example (which gets a 50 percent cost share, presumably from government), comes in at approximately \$40-\$50/t of CO_2e abated. This is about two times the current trading price on the Regional Greenhouse Gas Initiative emission offset market, but below the price of emission offsets in the Quebec's carbon market.

Further, De LaPorte's average abatement cost value is significantly skewed downward by one component of the plan: setting aside 40 percent of vulnerable wetlands and preserving their trees for 20 years. This component of the plan comes in at a low cost of CA\$7.54/ton of CO_2e abated. If we were to remove this outlier from consideration, the average cost of the remaining abatement measures is CA\$56.05, significantly above the cost of carbon abatement allowances on the Regional Greenhouse Gas Initiative, and in line with those of the California and Quebec carbon markets.

Other cost estimates of N_2O abatement (unrelated to Canada)

In a 2018 article published in the National Bureau of Economic Research (NBER), economists Kenneth Gillingham and James Stock estimate the cost of reducing greenhouse gas emissions of all sorts, including those related to agriculture. Gillingham and Stock estimate costs (in \$/ton of CO_2-eq abated) for agricultural emissions policies of US\$50-65; and for soil management policies of \$50/ton (Gillingham and Stock, 2018).

In an 2016 article published by the Austrian International Institute for Applied Systems Analysis, researchers Wilfried Winiwarter and Sajeev Erangu Purath Mohankumar employ the GAINS model (Greenhouse Gas—Air Pollution Interactions and Synergies model) to estimate the costs of nitrous oxide emission reduction from agriculture (GAINS Online, 2023). The model shows costs for emission abatement ranging from six percent to 36 percent, range from 12.8 Euros/tonne of CO_2-eqivalent to 1,069 euros per tonne CO_2-equivalent.

It should be noted that some studies suggest that nitrous oxide emission reductions from agricultural soils could be essentially free. In *Nitrous Oxide Emissions from Agricultural Soils: Reduction Potentials and Costs,* Sajeev Erangu Purath Mohankumar and Wilfried Winiwarter at the International Institute for Applied Systems Analysis found that "Against projected baseline emissions, we demonstrate that the maximum technically available potential [of GHG emission reductions from agricultural soils] in 2020 is 160 Mt CO_2-eq/year, which would represent a 35% reduction against European agricultural sector emissions in 2005. *For the year 2020, 47 Mt* CO_2*-eq/year of emissions reductions was identified at zero or negative cost compared to baseline emission"* (Winiwarter et al, 2015) (emphasis by author). Of course, if such studies are correct, there would be little need for governmental intervention on the issue, as the pursuit of market efficiencies would lead farmers to adopt N_20 emission reductions to increase their profitability.

Potential benefits of reducing nitrous oxide emissions from agriculture in Canada

Benefits discussed in the *Discussion Document* and *What We Heard* report are somewhat more specific than are cost estimates. From *Discussion Document*, we are told "Existing data from Fertilizer Canada and the 4R Research Network indicate that the implementation of a 4R program can reduce fertilizer-related emissions while maintaining and/or improving crop yields, with suggestions that the widespread adoption of 4R in Western Canada could reduce emissions by 2 to 3 megatonnes—*or 50 to 75% of the Government's emission reduction target*" (Canada, 2022a) (emphasis by author).

From the *What We Heard* report, we are told "Canada can raise production levels with aggressive but realistic adoption rates of 4R N management practices and substantially reduce fertilizer N_2O emissions by 1.6 Mt CO_2e or 14%. This substantial reduction can be realized with growth in production of key grains and oilseeds, maintenance or improvement of the crop-based economy, and reduction in carbon intensity" (Canada, 2023) (statement attributed to Fertilizer Canada).

Canada, however, is a relatively small contributor to global greenhouse gas concentrations in total, emitting only 1.6 percent of the world's greenhouse gas emissions (Canada, 2022b). And of Canada's total greenhouse gas emissions, nitrous oxide emissions from all sources constitute only a small fraction. According to Canada's official greenhouse gas emission inventory, Canada's "N_2O emissions mostly arise from agricultural soil management, accounting for 30 Mt or 4.5% of Canada's emissions in 2021" (ECCC, 2023).

Doing the math, then, Canada's N_2O emissions are approximately 4.5 percent of Canada's total, hence, (.016*.045=0.0007) or about seven one-hundredths of one percent of global greenhouse gas emissions, an amount far too small to generate measurable impacts on the trajectory of climate change, or derivative local changes to either long-term climate patterns, or shorter-term weather dynamics. Even these unmeasurably small emission reductions might be offset by increased agricultural emissions elsewhere, and the importation of less expensive foods from jurisdictions with lower levels of emission controls.

Conclusions and policy recommendations

Sound public policies share a set of fairly commonsense characteristics: they address real problems and work to solve them efficiently and effectively. They avoid creating new problems elsewhere in society, and avoid wasting scarce public resources. Sound public policies produce more benefits than cost, prioritize more-urgent problems over less-urgent problems, and recognize the dead-weight loss that government policies impose on the overall economy and society.

Canada's nitrous oxide control policies, under Canada's Net-Zero 2050 greenhouse gas policies has few of the characteristics of sound public policy outlined above. It will impose significant costs to both Canada's agricultural sector and Canadian citizens, without generating a countervailing benefit.

The current government pledges a sum of over $1.6 billion, and outlays by Canada's farming sector for N_2O reduction activities are predicted to reach $283 million per year. The potential benefit of these expenditures is a small reduction in nitrous oxide emissions (on a global scale), and still represents only a partial attainment of government's emission reduction targets under its Net-Zero 2050 greenhouse gas control policy.

Government would do well to impose a moratorium on plans to intervene in Canadian agriculture as proposed in its plans in pursuit of net-zero greenhouse gas emissions in Canada by 2050, and reconsider whether chasing small reductions of a Canadian-generated greenhouse gas that represents a small, and diminishing share of global emissions is a sound use of public funds, or a sound public policy.

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