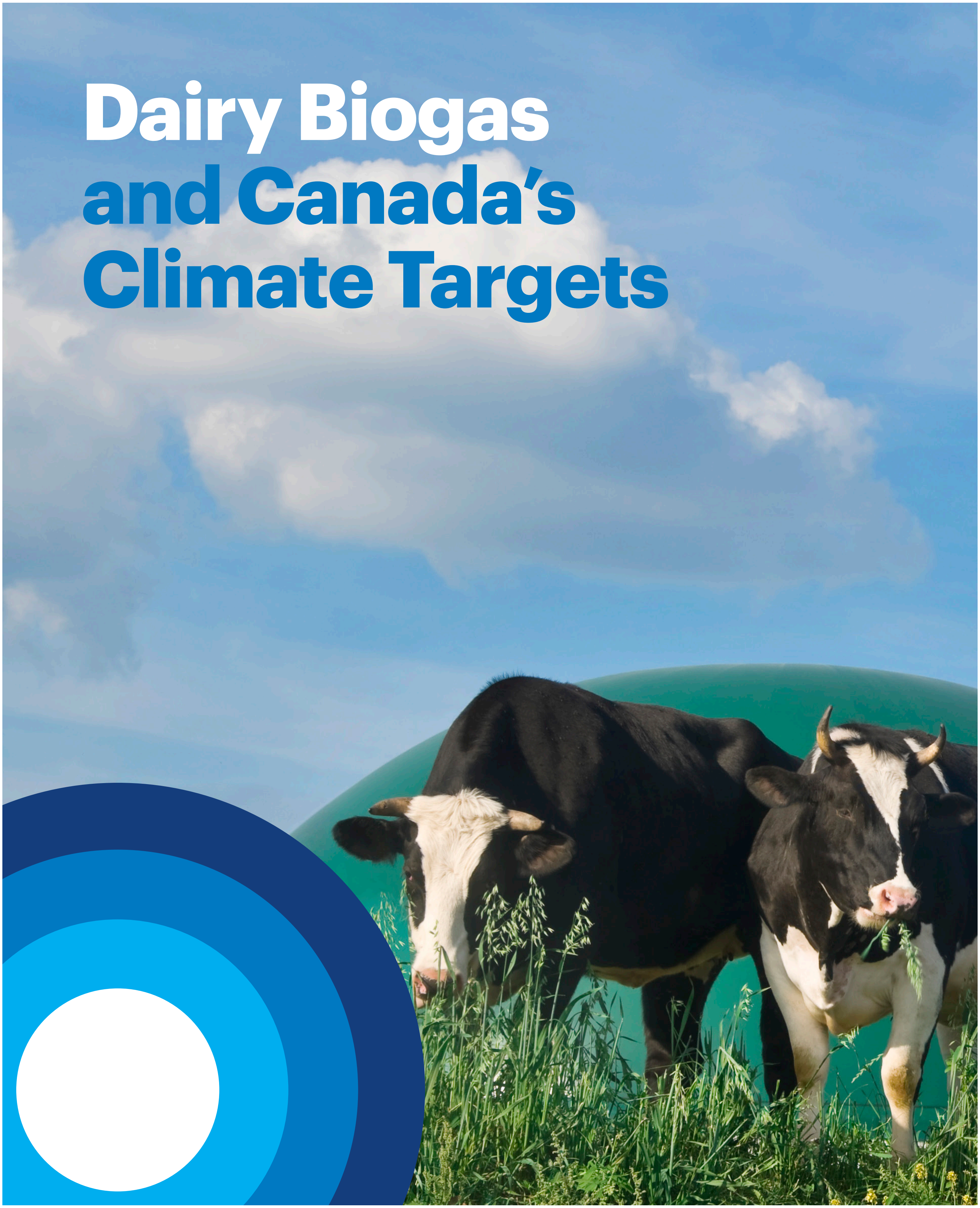
Dairy Biogas and Canada's Climate Targets



March 2022
biogasassociation.ca/climate

Canadian Biogas Association
canadienne de biogaz

Contents

Section A:
Dairy Biogas as a Climate Solution

Canada's dairy sector is a major contributor to Canada's economy. More than 10,000 dairy farms across Canada generate over 9 billion litres of milk and, in so doing, support nearly 221,000 jobs and generate $19.9 billion in annual GDP.[1,2]

But like other traditional sectors, this economic activity comes with a carbon footprint. For Canada's dairy sector, it means a presumed 7.3 Mt of carbon dioxide equivalent emissions every year (CO_2e/yr), amounting to roughly 1 percent of Canada's total greenhouse gas (GHG) emissions.[3]

Canada's dairy sector is taking proactive steps to address its carbon footprint. This is reflected in the dairy sector's increasing environmental performance[4] and its commitment to achieving net zero emissions by 2050, in line with Canada's national goals.[5]

One of the key climate solutions available to dairy farmers is Dairy Biogas.

Biogas is a clean fuel produced by treating organic waste in an anaerobic digester. Through anaerobic digestion, methane emissions are captured from the organic waste and then converted into energy, which can be in the form of heat, electricity or renewable natural gas (RNG). Dairy manure is among the most common organic wastes used for biogas.

Already in Canada, there are 34 Dairy Biogas systems, with the majority of these systems located on farms.[6]

These Dairy Biogas systems act as a climate solution in three important ways: (1) Methane and GHG abatement, (2) Clean energy production, and (3) Clean economic growth.

1. Methane and GHG abatement

The first way that Dairy Biogas acts as a climate solution is through the destruction of methane. Methane is a powerful greenhouse gas with a global warming effect 25 times stronger than carbon dioxide over a one-hundred year period.[7] Meanwhile, livestock manure is responsible for 4 percent of all Canada's methane (CH_4) emissions.[8] As a result, when dairy farms process manure in biogas systems, and thereby collect and destroy the associated methane, they help abate the dairy sector's share of these methane emissions.

According to this study's calculations, Dairy Biogas systems already reduce an estimated 2,250 tonnes of methane in this way, or 56,000 tonnes CO_2e/yr.

A secondary way in which Dairy Biogas helps abate dairy emissions is through digestate. Nutrient-rich digestate is a valuable bi-product of the anaerobic digestion process. When this digestate is used as part of an effective farm nutrient management plan, it can significantly displace nitrous oxide, another powerful greenhouse gas contributing to the dairy sector's emissions.[9]

Methane reductions through Dairy Biogas in 2020: 56,000 tonnes CO_2e

2. Clean energy production

The second fundamental way in which Dairy Biogas acts as a climate solution is through the production of clean energy. When Dairy Biogas systems recover methane, they do not only destroy it but they also convert it into clean energy. This clean energy can then displace fossil fuel-based energy in Canada's electricity, heating and transportation systems, resulting in additional greenhouse gas reductions.

Today Dairy Biogas systems are generating roughly 650,000 GJ of clean energy and thereby displacing roughly an additional 14,000 tonnes CO_2e per year.

GHG reductions through Dairy Biogas clean energy production in 2020: 14,000 tonnes CO_2e

3. Clean economic growth

The third fundamental way in which Dairy Biogas acts as a climate solution is by driving clean economic growth. The Pan-Canadian Framework on Clean Growth and Climate Change, signed by federal, provincial and territorial governments in 2017, identifies economic growth as a key opportunity and corollary to climate action.[10] The development of Dairy Biogas helps drive economic growth by spurring jobs, private investment and GDP, and improving farm revenue and cost-cutting opportunities.

According to this study's estimates, Dairy Biogas is already supporting 576 jobs, $5 million in annual private investment, and $37 million in annual GDP.

Section B:

Dairy Biogas' Potential Contributions to Canada's Climate Targets

Dairy Biogas is a proven climate solution. Through methane abatement, clean energy production and clean economic growth, Dairy Biogas is already making an important contribution to Canada's climate goals.

But Dairy Biogas is far from meeting its full potential. A comprehensive mapping exercise conducted by Torchlight Bioresources in 2020 finds that the vast majority of Canada's dairy manure-based biogas resources is not being utilized.[11] Of the 9.1 PJ of annual energy production determined to be theoretically available from dairy manure in 2016, we are tapping just 14 percent.

In other words, there is significant room for unlocking more methane abatement and more clean energy production using Dairy Biogas, particularly if Canada's dairy sector continues to grow.

This report's new modelling and analysis finds that the right mix of policies could harness much of this untapped potential and give a significant boost to hitting Canada's three major climate targets.

Climate Target #1: Reducing GHG emissions 40-45% by 2030

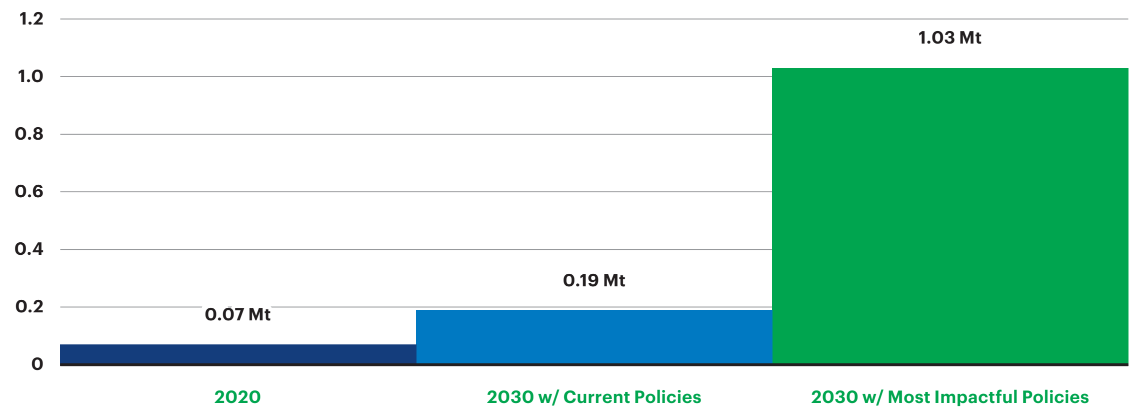
In 2021, Canada formally ratcheted up its official target under the Paris Agreement to reducing greenhouse gas emissions 40 to 45 percent below 2005 levels by 2030. This updated target requires Canada to cut annual GHG emissions up to 332 Mt CO_2e per year beyond the most recent measurements by 2030.[12]

Potential GHG Reductions through Dairy Biogas: 1,030,000 tonnes CO_2e by 2030

Dairy Biogas can help fill this gap.

Modelling shows that with the right government policies in place, Dairy Biogas could cut 1,030,000 tonnes (1.03 Mt) CO_2e by 2030. This is compared to just 190,000 tonnes (0.19 Mt) CO_2e in reductions from Dairy Biogas by 2030 under current policies. In other words, the right policy mix could drive over five times more GHG reductions through Dairy Biogas by 2030.

Figure 1:
GHG Reductions through Dairy Biogas in 2030 (Mt)



Climate Target #2: Reducing methane emissions 30% by 2030

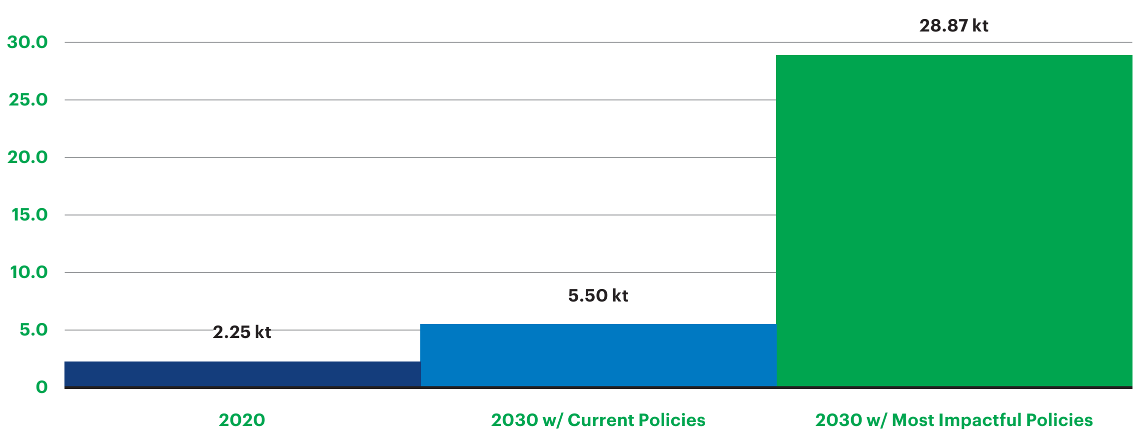
In addition to ratcheting up its overall GHG commitments under the Paris Agreement in 2021, the Government of Canada also joined 110 countries in signing on to the Global Methane Pledge. The Global Methane Pledge is a complementary and voluntary initiative in which signatory countries are committed to a 30 percent cut in methane emissions below 2020 levels by 2030. For Canada, then, this means cutting 1173 kilotonnes (kt) of methane emissions from our annual total by 2030.[13]

Dairy Biogas can make an important contribution to this target.

According to this study's modelling, the right policy mix could drive 28,870 tonnes (28.87 kt) in methane reductions through Dairy Biogas in 2030, or 2.5 percent of Canada's total necessary reductions. In comparison, current policies would drive only 5.5 kt of methane reductions in 2030.

Potential Methane Reductions through Dairy Biogas : 28,870 tonnes CH_4 by 2030

Figure 2:
Methane Reductions through Dairy Biogas in 2030 (kilotonnes)



Climate Target #3:
Achieving net zero emissions by 2050

In 2018, the Intergovernmental Panel on Climate Change called for reaching "net zero" greenhouse gas emissions globally by 2050.[14] Since then, more than 130 countries have begun setting individual targets to achieve that.[15] In Canada, this target has been legislated through the Canadian Net-Zero Emissions Accountability Act, which also adds the requirement to establish supporting incremental targets in 2035, 2040 and 2045.

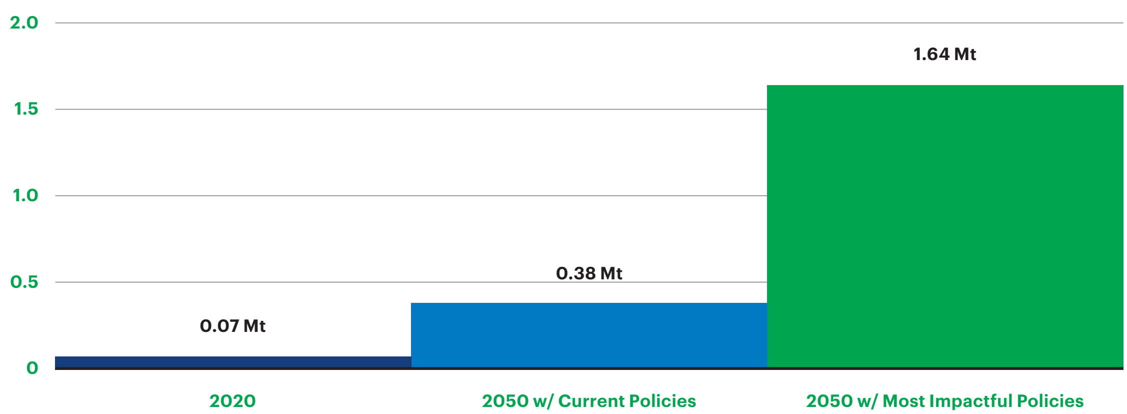
What does it mean to be "net zero"? It means that GHG emissions are reduced to the point that remaining emissions can be balanced out by new activities that remove emissions from the atmosphere, such that the net result is no added GHG pollution. It's expected that Canada could achieve this goal by reducing its emissions to 105 Mt CO_2e, with nature-based and other carbon removal solutions offsetting the remainder.[16] That means, to achieve its net zero goal, Canada needs to cut its emissions 625 Mt CO_2e from current levels by 2050.[17]

Dairy Biogas can support this target.

Modelling shows that with the right policy mix, Dairy Biogas could account for 1,640,000 tonnes (1.64 Mt) CO_2e of reductions in 2050. That's more than 20 times more emissions reduction happening through Dairy Biogas than today.

Potential GHG Reductions through Dairy Biogas: 1,640,000 tonnes CO_2e by 2050

Figure 3:
GHG Reductions through Dairy Biogas in 2050 (Mt)



Section C:
Analysis of Policy Scenarios and Results

Dairy Biogas has the potential to make important contributions to Canada's climate goals. Tapping this potential will require smart policy leadership by Canada's federal and provincial governments.

In order to understand what policy directions could unlock Canada's Dairy Biogas potential, this study simulated six potential policy scenarios and measured the impact on the methane abatement, clean energy production and clean economic growth happening through Dairy Biogas.

This section provides additional analysis and results for each of those scenarios. The policy scenarios are ordered from least impactful to most impactful:

1. **Current policies**
2. **Clean fuel standard**
3. **Renewable gas mandate**
4. **Carbon credits for methane utilization in agriculture**
5. **Carbon credits (4) + Renewable gas mandate (3)**
6. **Most economically efficient policy mix for hitting climate targets**

1. Current policies

The current policy scenario modelled for this study includes both federal and provincial policies that are already implemented. Three policy groupings are known to be having an effect on Dairy Biogas.

a. *Carbon pricing*
The federal government's price on carbon pollution, introduced in 2018, which complements pre-existing provincial systems and sets a minimum price schedule of $30/tonne in 2020 rising incrementally to $170/tonne in 2030. As the price rises, there will be a correspondingly positive effect on the development of Dairy Biogas since it makes it increasingly competitive against fossil fuel alternatives like diesel and conventional natural gas.

b. *Renewable gas mandates*

Two existing renewable gas mandates at the provincial level: Québec's renewable gas mandate requiring a 5 percent renewable blend by 2025 and 10 percent blend by 2030,[18] and British Columbia's emerging renewable gas mandate which will require a minimum 15 percent renewable blend by 2030.[19] Both provincial mandates are stimulating biogas development in the dairy sector. See Appendix A for more.

c. *Offset systems*

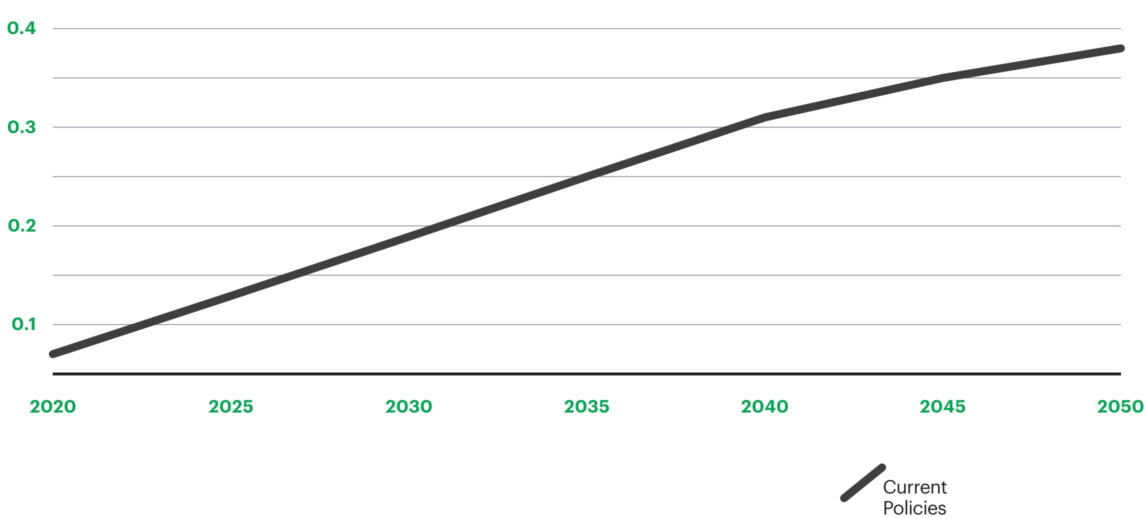
GHG offset systems at the provincial level in Québec[20] and Alberta[21] currently allow credits to be generated through the destruction and utilization of methane from livestock manure, effectively stimulating biogas development in the dairy sector.

One thing the modelling makes clear is that current policies are not sufficient for capturing Dairy Biogas' potential contribution to Canada's climate goals. They deliver only 18 percent of the GHG reductions than the optimal policy scenario. However, current policies still represent a growth opportunity compared with present day. The current policy scenario results in emission reductions that are 2-3 times greater than today's reductions in 2030, and 5-6 times greater than today's reductions in 2050.

Current policies result in GHG reductions 2-3x greater than today in 2030, and 5-6x greater in 2050

- 189,000 tonnes CO_2e/yr of GHG reduction in 2030, and 380,000 tonnes CO_2e/yr in 2050
- 5470 tonnes of methane reduction in 2030
- 1.51 PJ of annual clean energy production in 2030, and 2.83 PJ in 2050
- 890 jobs, $15 million in private investment, and $60 million in annual GDP in 2030; and 1284 jobs, $20 million in private investment, and $103 million in annual GDP by 2050

Figure 4:
GHG Reductions through Dairy Biogas - Under Current Policies (Mt CO_2e)



2. Clean fuel standard

The policy scenario found to have the second least impact on Dairy Biogas is one in which a clean fuel standard is layered on to current policies. This scenario is expected to materialize shortly, with the federal government's Clean Fuel Standard scheduled to come into effect in 2022. The federal Clean Fuel Standard has undergone significant adjustments since its initial design, including the elimination of a dedicated gaseous stream and the move to an exclusive focus on liquid fuels. However, the federal government's latest design allows liquid fuel suppliers to meet up to 10 percent of their compliance needs through gaseous fuels. This is the policy scenario modelled here.

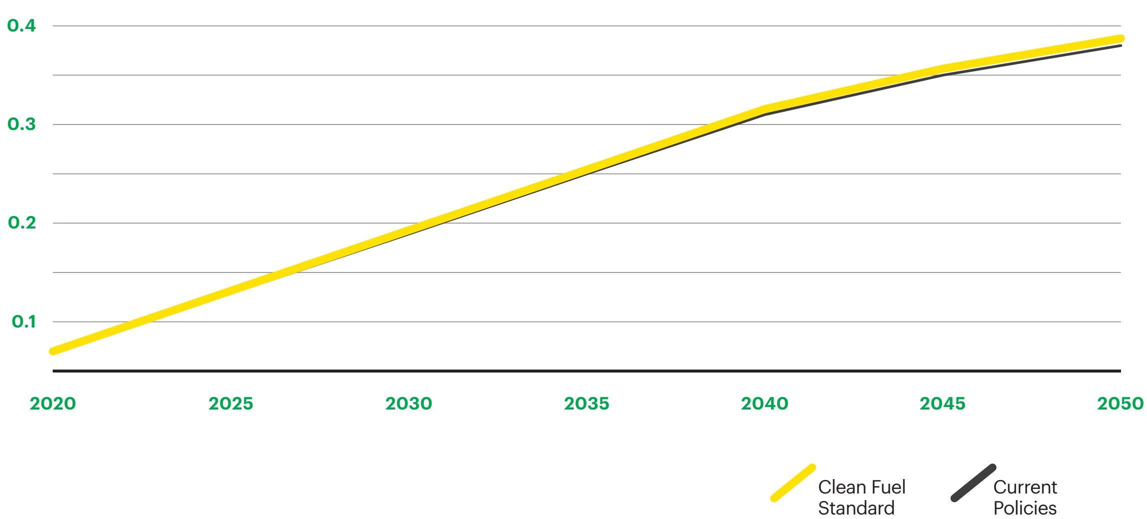
The modelling shows that the federal Clean Fuel Standard, as currently designed, will have minimal effect on emission reductions through Dairy Biogas, resulting in maximum 0.5 percent additional GHG reductions beyond what current policies already achieve in both 2030 and 2050.

The CFS will result in only 0.5% more GHG reductions from Dairy Biogas than existing policies

The federal Clean Fuel Standard, with a 10 percent allowance for gaseous fuels, results in:

- 190,000 tonnes CO_2e/yr of GHG reduction in 2030, and 380,000 tonnes CO_2e/yr in 2050
- 5490 tonnes of methane reduction in 2030
- 1.52 PJ of annual clean energy production in 2030, and 2.82 PJ in 2050
- 893 jobs, $15 million in private investment, and $61 million in annual GDP in 2030; and 1284 jobs, $20 million in private investment, and $102 million in annual GDP by 2050

Figure 5:
GHG Reductions through Dairy Biogas - Under Clean Fuel Standard (Mt CO_2e)



3. Renewable gas mandate

The policy scenario having the third lowest impact, or fourth greatest impact, on Dairy Biogas is a renewable gas mandate. Renewable fuel mandates have important precedents in Canada. These include the federal mandate for renewable content in liquid fuels, which has been in place since 2011, as well as provincial renewable gas mandates in Québec and British Columbia.

The renewable gas mandate modelled for this study is based closely on BC's policy, requiring that natural gas distributors blend a minimum of 15 percent renewable gases into their supply by 2030. The policy scenario then models that minimum renewable blend rising steadily to 30 percent by 2040-2050. Similar to British Columbia, the policy scenario allows for a variety of renewable gases to contribute to the mandate, including RNG from Dairy Biogas, low-carbon hydrogen and synthetic natural gas.

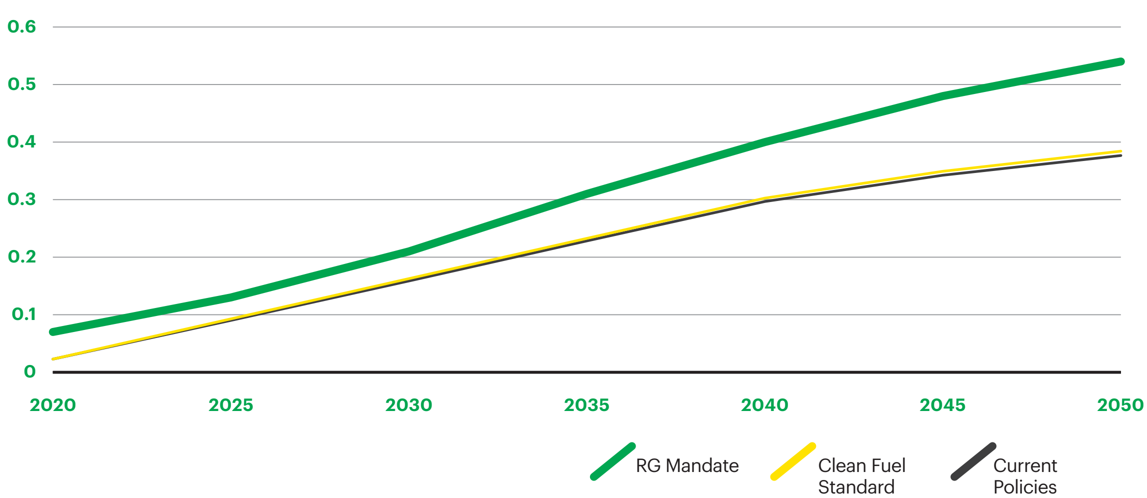
The outcome in this policy scenario could be achieved through a single federal renewable gas mandate, or through multiple new provincial mandates in provinces that don't already have (most notably Ontario and Alberta).

A Renewable Gas Mandate results in GHG reductions 2.5-3x greater than today in 2030, and 6-8x greater in 2050

A renewable gas mandate helps the dairy sector achieve emission reductions through biogas on the order of 2.5-3 times greater than today's reductions in 2030, and 6-8 times greater than today's reductions in 2050.

- 210,000 tonnes CO_2e/yr of GHG reduction in 2030, and 540,000 tonnes CO_2e in 2050
- 6070 tonnes of methane reduction in 2030
- 1.67 PJ of annual clean energy production in 2030, and 3.96 PJ in 2050
- 1096 jobs, $23 million in private investment, and $75 million in annual GDP in 2030; and 2228 jobs, $34 million in private investment, and $180 million in annual GDP in 2050

Figure 6:
GHG Reductions through Dairy Biogas - Under Renewable Gas Mandate (Mt CO_2e)



4. Carbon credits for methane utilization in agriculture

The policy scenario having the third greatest impact on Dairy Biogas is a GHG offset system that allows credits to be generated for methane utilization in agriculture. As noted above, this policy has important precedents at the provincial level in Alberta[22] and Québec.[23]

The policy modelled in this study is based on the emerging Federal GHG Offset System, which allows offsets to be purchased by industrial firms regulated under the Output Based Pricing System (OBPS) in order to meet their compliance obligations.

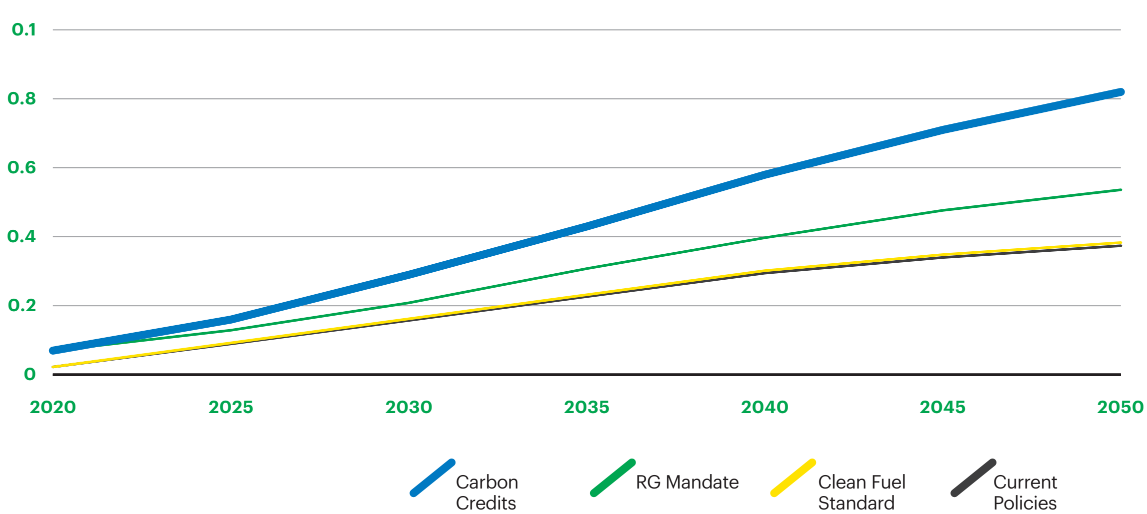
Currently the federal government is developing four offset protocols to initially come into effect under the Federal GHG Offset System. While there is no protocol currently under development for methane utilization in agriculture, the policy modelled here could fit naturally into the Federal GHG Offset System framework.

A Carbon Credits system results in GHG reductions 3-4x greater than today in 2030, and 10-12x greater in 2050

A GHG offset system that allows carbon credits to be generated for methane utilization in agriculture is capable of driving important emissions reductions. It results in GHG reductions that are 3-4 times greater than today's reductions in 2030, and 10-12 times greater than today's reductions in 2050. Specifically:

- 290,000 tonnes CO_2e/yr of GHG reduction in 2030, and 820,000 tonnes CO_2e/yr in 2050
- 8340 tonnes of methane reduction in 2030
- 2.29 PJ of annual clean energy production in 2030, and 6.16 PJ in 2050
- 1393 jobs, $34 million in private investment, and $96 million in annual GDP in 2030; and 2928 jobs, $48 million in private investment, and $236 million in annual GDP in 2050.

Figure 7:
GHG Reductions through Dairy Biogas - Under Carbon Credits Policy (Mt CO_2e)



5. Carbon credits for methane utilization in agriculture + Renewable gas mandate

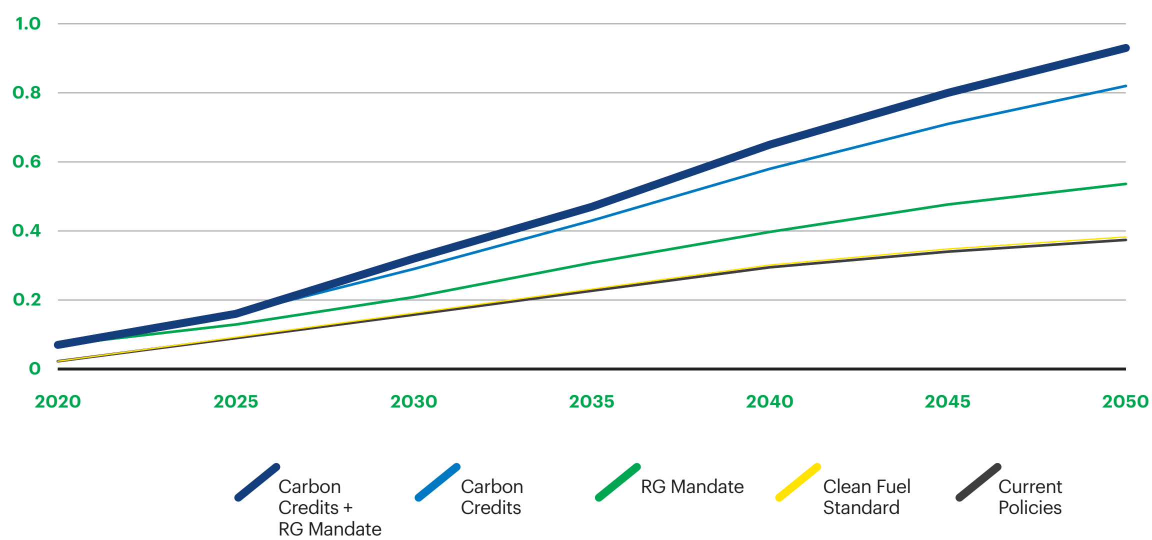
The policy scenario having the second greatest impact on Dairy Biogas is a combination of the previous two policy scenarios: a GHG offset system that allows credits to be generated for methane utilization in agriculture combined with a renewable gas mandate.

It achieves emission reductions that are 4-4.5 times greater than today's reductions in 2030, and 11-13 times greater than today's reductions in 2050.

- 320,000 tonnes CO_2e/yr of GHG reduction in 2030, and 930,000 tonnes CO_2e/yr in 2050
- 8920 tonnes of methane reduction in 2030
- 2.43 PJ of annual clean energy production in 2030, and 6.85 PJ in 2050
- 1600 jobs, $44 million in private investment, and $112 million in annual GDP in 2030; and 3657 jobs, $62 million in private investment, and $303 million in annual GDP in 2050

A combination of Carbon credits + a Renewable gas mandate results in GHG reductions 4-4.5x greater than today in 2030, and 11-13x greater in 2050

Figure 8:
GHG Reductions through Dairy Biogas - Under Carbon Credits Policy + RG Mandate (Mt CO_2e)



6. Most economically efficient policy mix for hitting climate targets

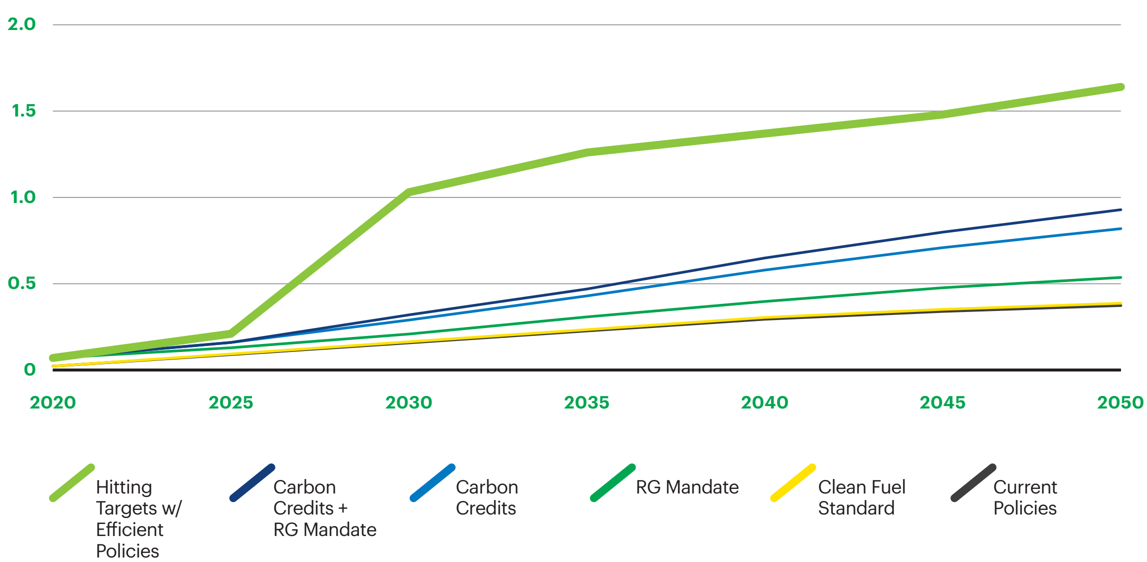
The policy scenario that is the most impactful for Dairy Biogas is an open-ended scenario that simply caps GHG emissions at 45 percent below 2005 levels in 2030, and at net-zero emissions in 2050. This policy scenario does not prescribe specific policies for reaching these targets, but only imposes the assumption that the climate targets will be met and that they will be met using the most economically efficient government policies possible. This scenario shows the maximum realistic contribution of Dairy Biogas to Canada's climate targets.

This policy scenario points to a significant role for Dairy Biogas, in which emission reductions are up to 15 times greater than today's reductions in 2030, and more than 23 times greater than today's reductions in 2050.

- 1,030,000 tonnes CO_2e/yr of GHG reduction in 2030, and 1,640,000 tonnes CO_2e/yr in 2050
- 28,870 tonnes of methane reduction in 2030
- 7.83 PJ of annual clean energy production in 2030, and 12.37 PJ in 2050
- 5097 jobs, $225 million in private investment, and $371 million in annual GDP in 2030; and 6776 jobs, $96 million in private investment, and $537 million in annual GDP in 2050

Hitting targets with the most economically efficient policies results in GHG reductions 15x greater than today in 2030, and 23x greater in 2050

Figure 9:
GHG Reductions through Dairy Biogas - Under Most Economically Efficient Policy Mix (Mt CO_2e)



Conclusion:

Three Takeaways for the Dairy Sector

1. Biogas is an important GHG reduction opportunity for the dairy sector

Under all policy scenarios, Dairy Biogas can contribute to reducing Canada's GHG emissions.

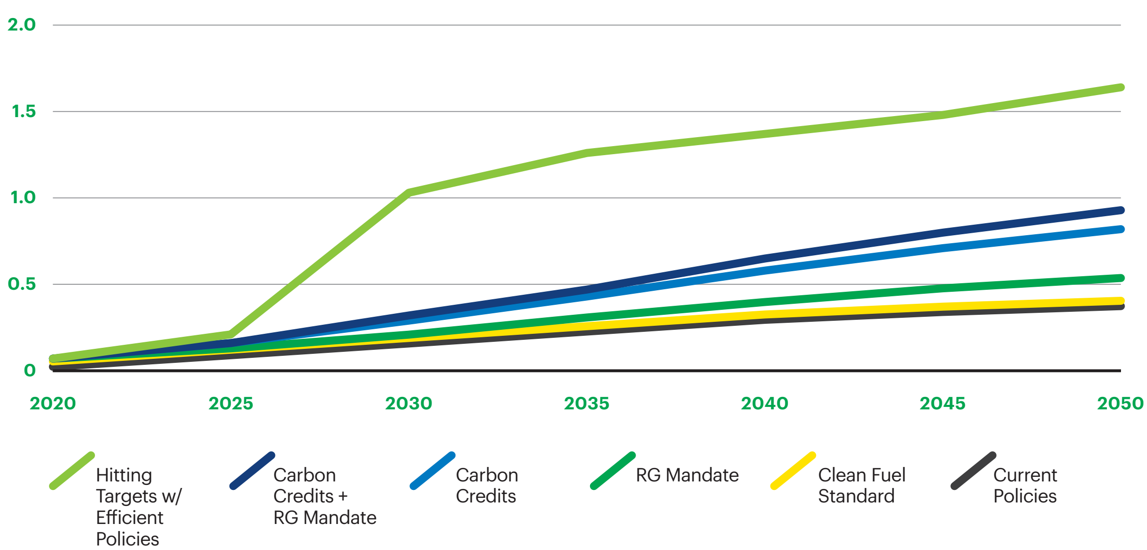
In the most impactful policy scenario for Dairy Biogas, where governments hit Canada's climate targets in the most economically efficient way, Dairy Biogas cuts Canadian emissions by 1.03 Mt CO_2e/yr by 2030. That's over 14 times more GHG reductions through Dairy Biogas than is being achieved today. About 0.72 Mt CO_2e/yr of these total potential reductions in 2030 come directly from the abatement of manure methane emissions. To put that number in context, that methane abatement amounts to roughly 10 percent of today's total dairy sector emissions. Meanwhile, the other 0.31 Mt CO_2e/yr of GHG reduction is achieved through the production of clean biogas energy and the displacement of fossil fuel energy.

Methane abatement through Dairy Biogas in 2030 could cut 10% of today's total dairy sector emissions.

This split in GHG reductions from Dairy Biogas is generally consistent across all policy scenarios, with about 70 percent of GHG reductions coming from methane abatement and 30 percent coming from clean energy production.

While the other policy scenarios modelled in this study deliver fewer GHG reductions than this most impactful policy scenario, even the least-impactful Current Policies scenario, where there are no additional policies supporting Dairy Biogas beyond those that exist today, results in an almost tripling of Dairy Biogas-induced GHG reductions compared to 2020.

Figure 10:
GHG Reductions through Dairy Biogas (Mt CO_2e)



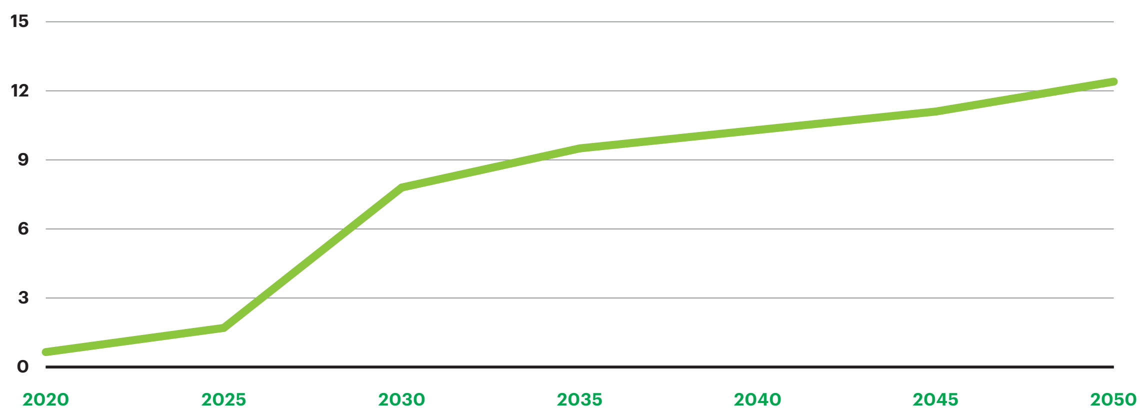
2. Policy and market signals will favour more Dairy Biogas

The second key takeaway is that economic conditions favour growth for Dairy Biogas. This is true under every policy scenario.

Under the most impactful policy scenario for Dairy Biogas, where governments implement the most economically efficient policies to hit Canada's 2030 and 2050 targets, conditions are extremely favourable for Dairy Biogas, leading to a potential twelve-fold increase in activity by 2030 and an almost twenty-fold increase by 2050. Based on historic trends, that could mean a jump from 34 Dairy Biogas operations in 2020 to 408 Dairy Biogas operations in 2030, and 665 in 2050, effectively harnessing all of Canada's feasible Dairy Biogas.

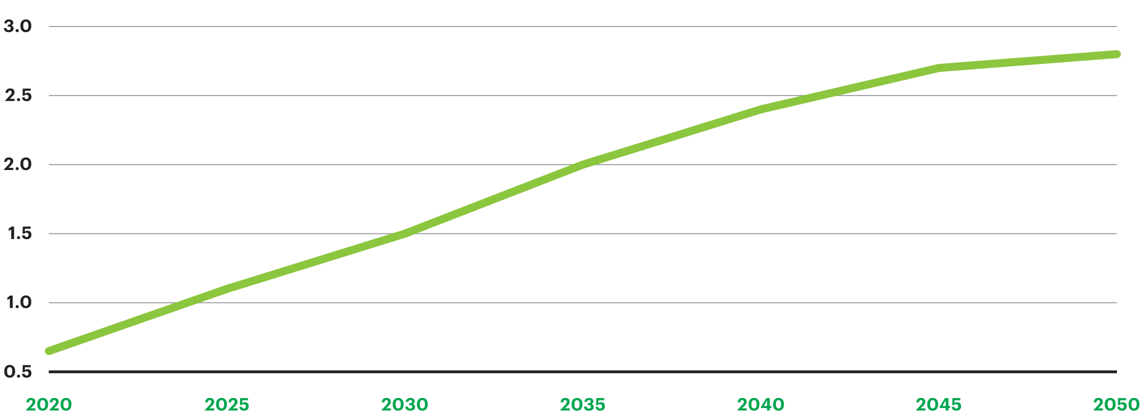
There could be a jump from 34 Dairy Biogas operations today to 408 in 2030 and to 665 in 2050

Figure 11:
Energy Output from Dairy Biogas - Under Most Economically Efficient Policy Mix (PJ)



However, even in the Current Policies scenario, where there are no additional policy signals beyond those that already exist, we see growth for Dairy Biogas, including a potential doubling of Dairy Biogas activity by 2030 and an additional doubling between 2030 and 2050.

Figure 12:
Energy Output from Dairy Biogas & RNG - Under Current Policies (PJ)



The modelling shows that growth in Dairy Biogas is highly sensitive to capital costs. In a scenario where capital costs are at the highest end of the expected range, Biogas activity in the dairy sector is curtailed by about 50 percent in 2030 and 8 percent in 2050.

Ultimately, there is no realistic scenario in which Dairy Biogas is not stimulated to grow, while the most likely scenarios, including a continuation of today's policies, favour significant growth in the sector.

3. Dairy Biogas energy opportunities could shift

The majority of Canada's current agricultural biogas operations produce electricity as their primary energy output. That's because, as documented in the 2020 Biogas & RNG Market Report[24], a key policy driver for agricultural biogas from 2009-2016 was Ontario's Feed-in-Tariff policy, which offered competitive rates exclusively for renewable electricity generation.

Recent years have seen a gradual shift away from agricultural biogas-to-electricity towards other energy outputs. The modelling shows this shift will likely continue, with the policy scenarios modelled here clearly favouring the production of heat and the production of RNG from Dairy Biogas.

All policy scenarios see the production of heat rapidly becoming the most popular utilization of Dairy Biogas. That would represent a major shift, increasing from today's 4 percent of overall energy output to 40-60 percent under the various policy scenarios between 2030 and 2050. The smaller scale of these systems make them a simpler choice for small and medium-sized dairy farms while their ability to reduce farm energy costs will become increasingly competitive.

RNG production also increases in all policy scenarios, from approximately 15 percent of today's overall Dairy Biogas energy output to about 40 percent over the longer term.

Meanwhile, the policy scenarios modelled in this study result in a smaller role for dairy biogas-to-electricity. While the number of biogas-to-electricity systems will grow, they grow more slowly than their counterparts, ultimately dropping from 79 percent of overall energy output today to 10-30 percent of overall energy output over the longer term.

This modelling result has two important implications for Dairy Biogas. First is that, because there has been successful experience for dairy farmers with biogas-to-electricity, if those kinds of systems are going to continue to be attractive and rewarding for farmers, it will require a different policy or set of policies than those modelled here. Provincial clean electricity integration incentives, or a program supporting the emerging federal Clean Electricity Standard, are places to start.

The second implication is that, whether or not new policies are created that favour biogas-to-electrcity, the dairy sector will need to embrace biogas-to-heat and biogas-to-RNG practices if it wants to seize the full Dairy Biogas opportunity. While these practices haven't been as common in the dairy sector up until now, they are widely used by other sectors and are cost-effective. They also open up new opportunities for cost cutting, revenue generation and GHG reductions for dairy farmers. For example, RNG-fuelled tractors are now hitting the market, which permit farmers to produce their own tractor fuel through biogas-to-RNG systems.[25]

These shifting energy output opportunities will represent a pivot for the dairy sector and may require coordinated education and communication to help farmers take advantage of them.

Figure 13:
Energy Outputs from Dairy Biogas - 2020

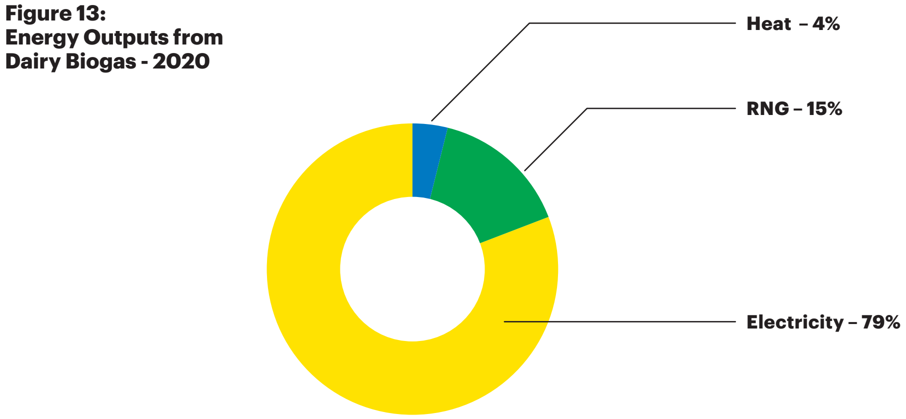
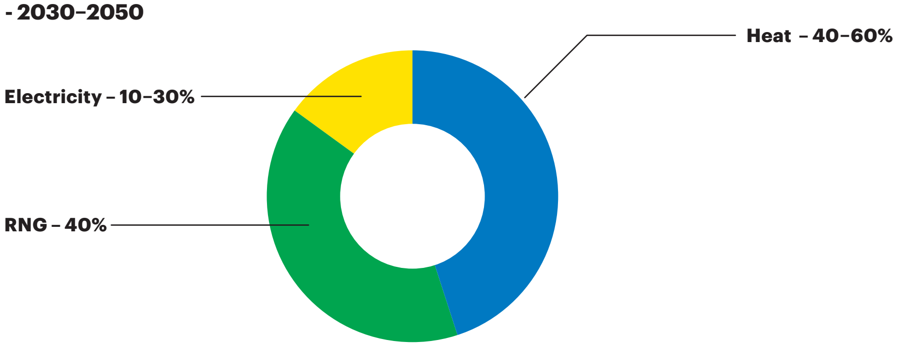


Figure 14:
Energy outputs from Dairy Biogas under Policy Scenarios - 2030–2050



Appendix: Modelling by Navius Research

The analysis in this report is based on an extensive modelling exercise conducted by Navius Research from November 2021 to February 2022 using its gTech environment-economy model. Below is a summary of the key assumptions used in the model.

i. Biogas & RNG Production Potential

The model factors in a maximum potential for Dairy Biogas production. This potential considers, and is sometimes directly calibrated with, the results of a comprehensive study of RNG feedstocks published by TorchLight Bioresources in 2020.[26] This potential is measured in terms of the total quantity of biogas energy (PJ/yr) that could be produced. Within this study's analysis, the quantity of actual biogas production that occurs is a subset of this maximum. How much of the maximum potential is realized is a function of biogas production costs, and the extent to which energy markets and policies incentivize biogas production.

Figure 15:
Dairy Biogas Energy Production Potential

	Maximum potential used by Navius	**Potential identified by Torchlight study**	**Notes**
Dairy (manure co-digestion)	7 PJ/yr	Theoretical: 9 PJ/yr Feasible: 5 PJ/yr	Navius value higher than "feasible" because it includes all utilization of biogas, not just RNG. Navius potential also scaled for sector growth over time.

ii. Carbon Intensities

Carbon intensities (CI) exist within the gTech model in two ways. First, they are used to define credit generation potential per unit of RNG supplied under policies such as clean fuel standards. Second, and more importantly, they define the parameterization of biogas production pathways in terms of how much energy those pathways consume and what methane or other GHG emissions they produce or emit per unit of energy produced.

These are the CI values used in this study:

Figure 16:
Dairy Biogas Carbon intensities Used in Modelling

Anaerobic Digestion on Farms	10–40 gCO_2e/MJ_{RNG} excluding any credit given for methane abatement	Assuming 2.5% methane leakage rate

iii. Biogas Production Costs

To determine biogas & RNG production costs, Navius Research consulted a wide range of literature and analysis.[27, 28, 29, 30, 31, 32, 33,]

Navius evaluated the range of costs for anaerobic digestion (AD) of animal manure, where the AD production costs are differentiated by energy outputs, including RNG production, electricity and direct heat.

Figure 17:
Production Costs (2020 CAD) implied by Model inputs

	RNG $/GJ	Electricity $/GJ	Heat $/GJ
Anaerobic Digestion on Farms	17.50–25.60	39.00–55.00	13.00–18.00

Notes

1 EcoRessources, (2016). *Update on the Economic Impacts of the Canadian Dairy Industry In 2015*. Dairy Farmers of Canada.
2 Agriculture and Agri-Food Canada, (2021). *Canadian Dairy Information Centre - Canada's dairy industry at a glance*. Government of Canada. Retrieved from: https://agriculture.canada.ca/en/canadas-agriculture-sectors/animal-industry/canadian-dairy-information-centre/canadas-dairy-industry-glance
3 DFC - Dairy Farmers of Canada. *Article: How We're Reducing Emissions*. Retrieved from: https://dairyfarmersofcanada.ca/en/who-we-are/our-commitments/sustainability/emissions
4 Groupe AGECO, (2018). *Canadian milk production LCA Update for Dairy Farmers of Canada – Executive Summary*. Dairy Farmers of Canada.
5 DFC
6 Liebetrau J, et al, (2021). *Potential and utilization of manure to generate biogas in seven countries,* Murphy, J.D. (Ed.) IEA Bioenergy Task 37, 2021:6.
7 Editorial (2021). "Control methane to slow global warming". *Nature* 596, 461. doi: https://doi.org/10.1038/d41586-021-02287-y
8 Government of Canada (2021)
9 Vanderzaag A, et al, (2011). "Strategies to mitigate nitrous oxide emissions from land applied manure". *Fuel and Energy Abstracts*. 166. 464-479.
10 Government of Canada, (2017). *The Pan-Canadian Framework on Clean Growth and Climate Change*.
11 Stephen et al (2020)
12 Commissioner of the Environment and Sustainable Development, (2021). *Reports of the Commissioner of the Environment and Sustainable Development to the Parliament of Canada, Report 5: Lessons Learned from Canada's Record on Climate Change*. Office of the Auditor General.
13 Based on 2019 methane emissions due to 2020 calculations not being available at time of publication
14 Allen MR, et al, (2018). *Special Report: Global Warming Of 1.5ºC – Summary for Policymakers*. Intergovernmental Panel on Climate Change.
15 Hale T, et al, (2021). *Net Zero Tracker*. Energy and Climate Intelligence Unit, Data-Driven EnviroLab, NewClimate Institute, Oxford Net Zero. Retrieved from: https://zerotracker.net/
16 Navius Research, (2021). *Achieving Net Zero Emissions by 2050 in Canada: An evaluation of pathways to net zero prepared for the Canadian Institute for Climate Choices*.
17 Based on Canada's 2021 NIR for 2019
18 Government of Quebec, (2020). *2030 Plan for a Green Economy: Framework policy on electrification and the fight against climate change*.
19 Government of British Columbia, (2018). *CleanBC: Our nature, our power, our future*.
20 Gouvernement du Québec, (2011). *Regulation respecting a cap-and-trade system for greenhouse gas emission allowances, Appendix D – Offset Protocols*.
21 Environment and Parks Alberta, (2020). *Quantification Protocol for Biogas Production and Combustion*. Government of Alberta.
22 Environment and Parks Alberta, (2020)
23 Gouvernement du Québec, (2011)
24 Canadian Biogas Association, (2021). *Canadian 2020 Biogas Market Report*.
25 See: New Holland Agriculture T6 Methane Tractors at: https://agriculture.newholland.com/eu/en-uk/equipment/products/agricultural-tractors/t6-methane-power
26 Stephen J, et al, (2020). *Renewable Natural Gas (Biomethane) Feedstock Potential in Canada*. Torchlight BioResources.
27 Deloitte & WSP, (2018). *Renewable natural gas production in Québec: A key driver in the energy transition. Assessment of technical and economic potential in Québec (2018–2030).*
28 IEA - Energy Technology Systems Analysis Program, (2013). *Biogas and Bio-syngas Production*.
29 IEA, (2020). *Advanced Biofuels – Potential for Cost Reduction*.
30 Hallbar Consulting, (2017). *Resource Supply Potential for Renewable Natural Gas in B.C.*
31 IRENA - International Renewable Energy Agency, (2013). *Road transport: the cost of renewable solutions*.
32 Rajendran K, Brian Ó Gallachóir BO, Murphy JD, (2016). The role of incentivizing biomethane in Ireland using anaerobic digestion. Prepared for the Environmental Protection Agency, Ireland.

Canadian Biogas Association
canadienne de biogaz

Canadian Biogas Association
275 Slater Street
Suite 900
Ottawa ON
K1P 5H9
Canada

biogasassociation.ca