Informing the development of Our Clean Future: a Yukon strategy for climate change, energy and a green economy

Report prepared for the Government of Yukon

SUBMITTED TO

Government of Yukon
Box 2703
Whitehorse YT Y1A 2C6

September 5, 2020

SUBMITTED BY

Navius Research Inc.
Box 48300 Bentall
Vancouver BC V7X 1A1

Contact@NaviusResearch.com

About Us

Navius Research Inc. ("Navius") is a private consulting firm in Vancouver. Our consultants specialize in analysing government and corporate policies designed to meet environmental goals, with a focus on energy and greenhouse gas emission policy. They have been active in the energy and climate change field since 2004, and are recognized as some of Canada's leading experts in modeling the environmental and economic impacts of energy and climate policy initiatives. Navius is uniquely qualified to provide insightful and relevant analysis in this field because:

- We have a broad understanding of energy and environmental issues both within and outside of Canada.
- We use unique in-house models of the energy-economy system as principal analysis tools.
- We have a strong network of experts in related fields with whom we work to produce detailed and integrated climate and energy analyses.
- We have gained national and international credibility for producing sound, unbiased analyses for clients from every sector, including all levels of government, industry, labour, the non-profit sector, and academia.

Please note that this analysis was conducted prior to the spread of COVID-19. It does not account for the impact of the pandemic on economic activity and greenhouse gas emissions, which may be substantive in 2020.

Summary

The Government of Yukon's strategy for climate change, energy and a green economy – *Our Clean Future*[1] – includes a package of policies and programs (referred to as "policies") designed to reduce the territory's greenhouse gas emissions, as well as to enhance energy security, adapt to the impacts of climate change, and build a green economy.

This report documents the methodology, assumptions and results of a comprehensive analysis into the impacts of a subset of these policies on greenhouse gas emissions and economic activity. This comprehensive analysis was conducted for all policies that are anticipated to have a measurable impact on Yukon's greenhouse gas emissions between the present and 2030.

Our modeling toolkit

Navius Research's gTech model was used to forecast the development of Yukon's energy-economy. It is ideally suited for this task because it includes:

- A realistic representation of how households and firms select technologies that affect energy consumption and greenhouse gas emissions.
- An exhaustive accounting of the economy at large, including how Yukon interacts with other provinces, territories and the rest of the world.
- A detailed representation of energy supply, including electricity, liquid fuel and gaseous fuel markets.

These unique features allow gTech to simulate the impact of virtually any climate and energy policy, or groups of policies, ranging from economy-wide (e.g., carbon pricing) to technology and sector specific policies (e.g., efficiency standards for clothes washers).

The ability of this modeling toolkit to examine such a range of policies and dynamics makes it possible to accurately quantify the impacts of *Our Clean Future*, subject to the limits of forecasting discussed in Chapter 2.

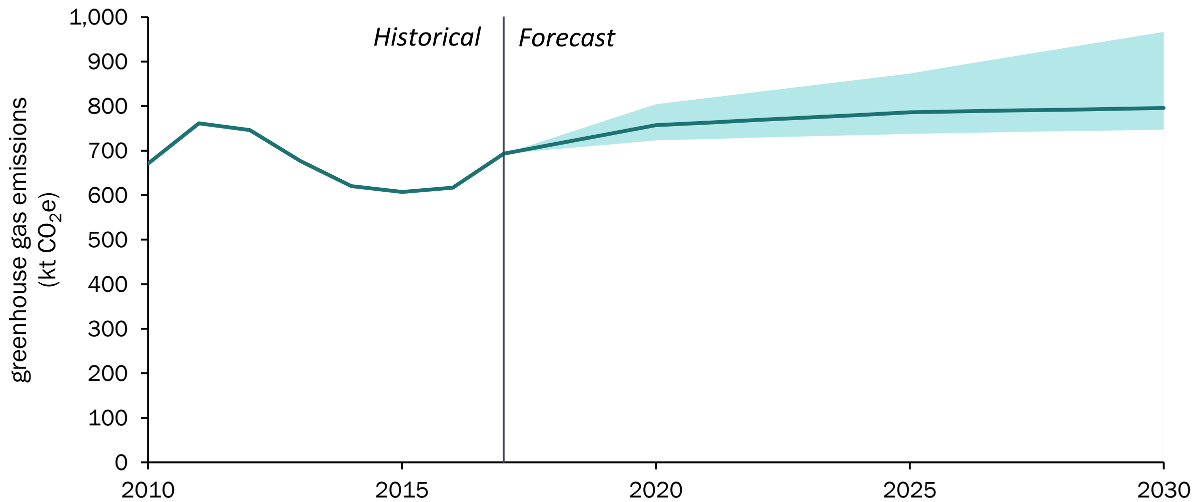
---

[1] Government of Yukon. 2020. Our Clean Future. https://Yukon.ca/our-clean-future

How are Yukon’s emissions anticipated to change in the absence of new policies?

In the absence of new policies, Yukon’s greenhouse gas emissions are forecast to rise to 796 kilotonnes of carbon dioxide equivalent in 2030. In 2017, the most recent year for which territorial data are available, Yukon’s greenhouse gas emissions were 693 kilotonnes. Accounting for the impact of existing territorial and federal policies, emissions are expected to reach between 747 and 967 kilotonnes in 2030, depending on potential economic growth, under “business as usual”.

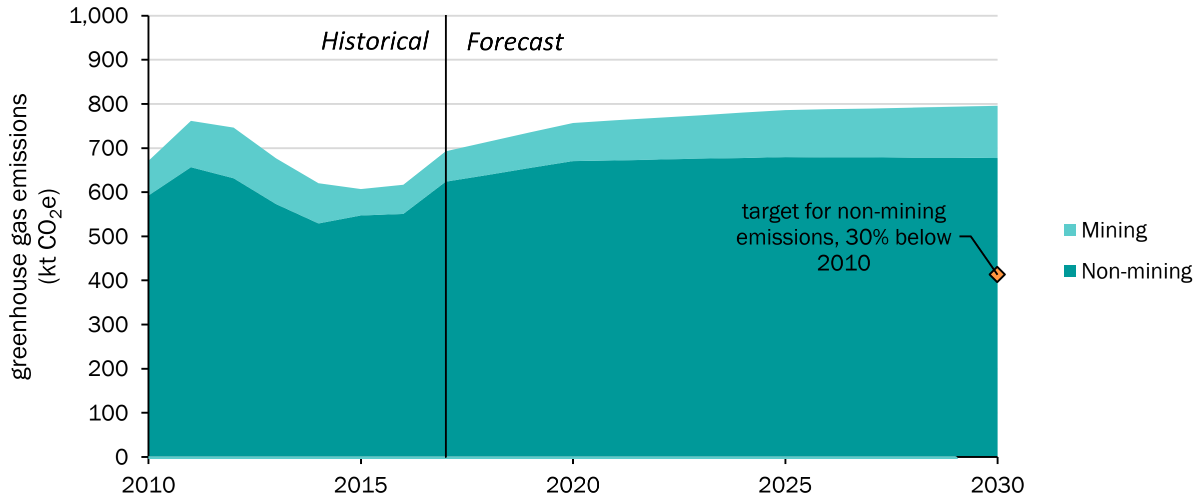
Figure 1: Territorial emissions to 2030, existing policy forecast



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by Yukon Climate Change Secretariat. (2) Navius forecast using gTech.

New policies are required to achieve Yukon’s target for non-mining emissions. Figure 2 distinguishes between mining and non-mining emissions in the existing policy forecast. Non-mining emissions account for between 84% and 90% of territorial emissions, forecasted to reach 678 kilotonnes in 2030 if no additional policies are implemented. This forecast suggests that new policies will be required to achieve Yukon’s target for non-mining emissions of 414 kilotonnes (i.e., 30% below 2010 levels).

Figure 2: Non-mining emissions to 2030, existing policy forecast



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by Yukon Climate Change Secretariat. (2) Navius forecast using gTech.

What policies can help Yukon transition to a clean energy economy?

Yukon has formulated *Our Clean Future*, a package of policies designed to put the territory on track to meet its greenhouse gas target. These policies are summarized in Table 1. More detail about these policies and how they are modeled is provided in Chapter 5.

Table 1: Summary of *Our Clean Future* policies included in this analysis

Sector / Policy	Description
Electricity	
Renewable portfolio standard for on-grid communities	*Our Clean Future* will require 93% of the electricity on Yukon's main grid to be generated from renewables, calculated as a long-term average. The modeling assumes 93% renewable generation in 2025, rising to 97% in 2030[2].

[2] Successful implementation of the projects identified in the Yukon Energy Corporation's 10-year plan is expected to exceed the regulatory requirement of a 93% long-term average. The modelling also assumes certain percentages of renewable generation in 2025 and 2030 whereas the regulatory requirement will set a minimum long-term average renewable generation.

Sector / Policy	Description
Renewable electricity generation and renewable fuels for remote communities	Boost generation from renewables in remote communities and use 20% biofuels (by volume), decreasing fossil diesel consumption to 45% below 2010 levels by 2030.
Biofuel blending for on-grid diesel generation	Mandate a 20% minimum renewable content (by volume) for diesel used for on-grid electricity by 2030.
Transport	
Zero emission vehicle standard for light-duty vehicles	Require zero-emission vehicles to account for 30% of new light-duty vehicle sales by 2030.
Zero emission vehicle subsidy for light-duty vehicles	Provide rebate of up to $5,000 for new light-duty zero-emission vehicle purchases.
Renewable fuel content for diesel	Require minimum renewable content of 20% (by volume) in diesel pool beginning in 2025.
Renewable fuel content for gasoline	Require minimum renewable content of 10% (by volume) in gasoline pool beginning in 2025.
Public and active transport	Achieve City of Whitehorse mode share targets by investing in public and active transport infrastructure.
Buildings	
Low-interest financing for building retrofits	Support $23 million of incentives and low-interest loans for thermal efficiency retrofits that reduce emissions by 30-40% per building.
Heat pump incentives	Provide $20 million of incentives and low-interest loans for the adoption of heat pumps.
Bioenergy incentives	Provide $1.8 million of incentives and low-interest loans for the adoption of biomass heating.
Incentives to retrofit existing buildings	Provide $16.4 million of incentives annually to improve thermal efficiency and switch to low carbon heating options.
Building code	Require all new buildings to meet strengthened envelope and energy performance improvements relative to the 2015 National Building Code.
Reduce emissions from Yukon Government operations	Reduce emissions from Government of Yukon buildings by 30% by 2030 compared to 2010 levels through retrofits and renewable heating.

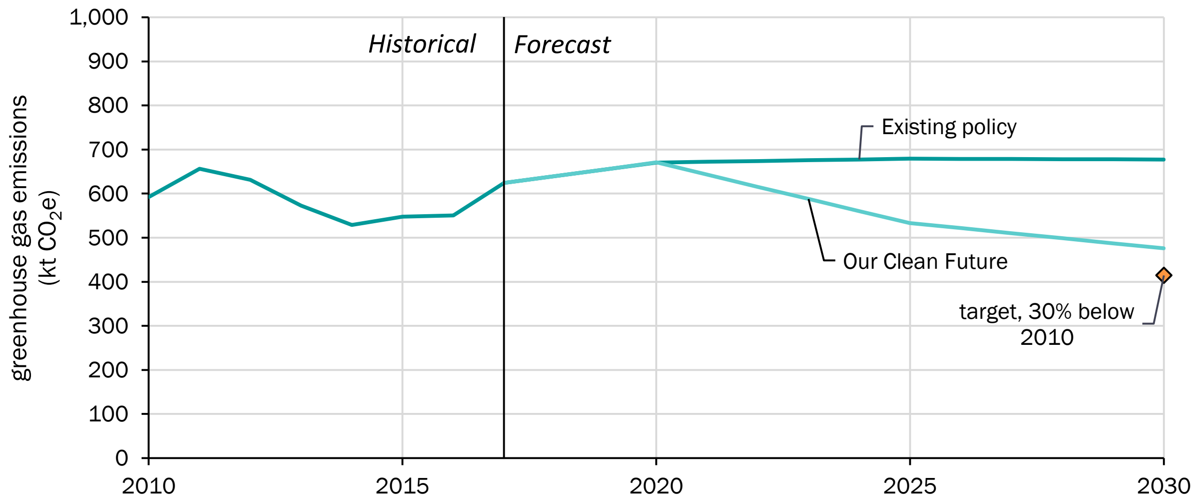
How will *Our Clean Future* affect Yukon?

Our Clean Future is expected to:

- Reduce total greenhouse gas emissions by 227 kilotonnes of carbon dioxide equivalent in 2030, including 201 kilotonnes from "non-mining" sources.
- Boost the adoption of low carbon technologies across many sectors of the economy.
- Help the territory transition towards lower carbon activities and a greener economy.

Our Clean Future **closes 77% of the gap to Yukon's 2030 greenhouse gas target from non-mining emissions.** In response to *Our Clean Future*, territorial greenhouse gas emissions from non-mining sources are forecasted to decline to 476 kilotonnes of carbon dioxide equivalent in 2030, a reduction of 201 kilotonnes relative to the existing policy forecast (Figure 3).

Figure 3: Impact of *Our Clean Future* on non-mining emissions

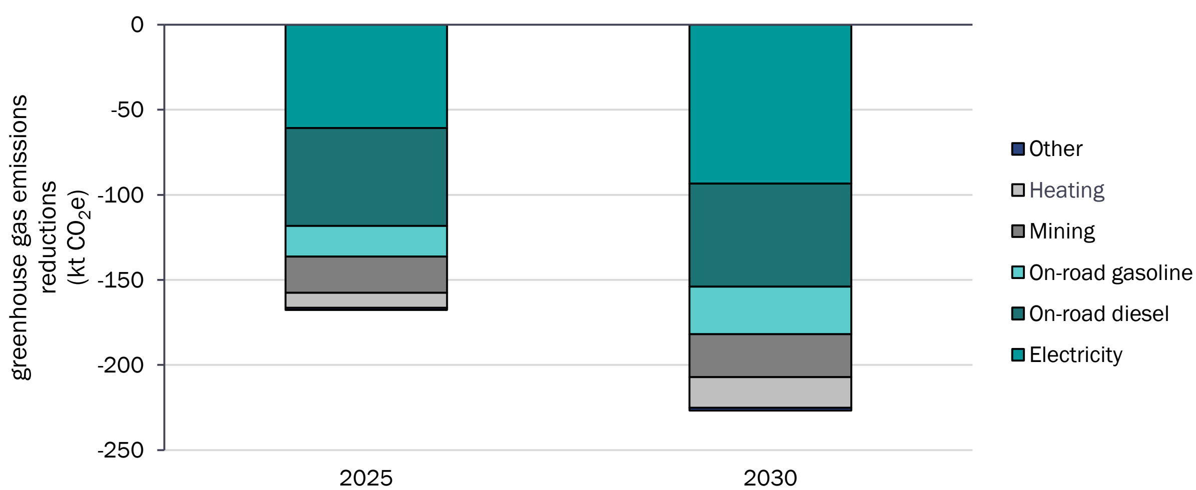


Sources: (1) Yukon greenhouse gas inventory, provided to Navius by Yukon Climate Change Secretariat. (2) Navius forecast using gTech, including the impacts of non-modeled policies as described in Section 5.1.4.

***Our Clean Future* reduces greenhouse gas emissions from most fuel types.** These reductions are measured relative to expected emissions in response to existing policies, as shown in Figure 4:

- The **electricity** sector accounts for the largest reduction in emissions (93 kilotonnes in 2030). These reductions are driven by 97% of grid-supplied electricity being generated from renewable sources like hydro, wind and solar by 2030, efforts to increase renewable generation in remote communities, and the use of biofuels for electricity generation.
- Emissions from the combustion of **diesel for on- and off-road transport** (including fuels used by the mining sector) decrease by 86 kilotonnes in 2030, due to increased blending of renewable fuels into the on and off-road diesel pools. The renewable diesel standard requires that biofuels account for 20% (by volume) of the diesel pool beginning in 2025.
- Emissions from **gasoline** consumption decrease by 28 kilotonnes due to two policies. First, the zero emissions vehicle mandate requires that zero emission vehicles account for a growing share of light-duty vehicle sales, reaching 30% by 2030. Concurrently, the renewable gasoline standard reduces the emissions intensity of the remaining gasoline pool by requiring a 10% minimum renewable content (by volume) by 2025.

Figure 4: Annual greenhouse gas reductions by sector, *Our Clean Future* policy forecast



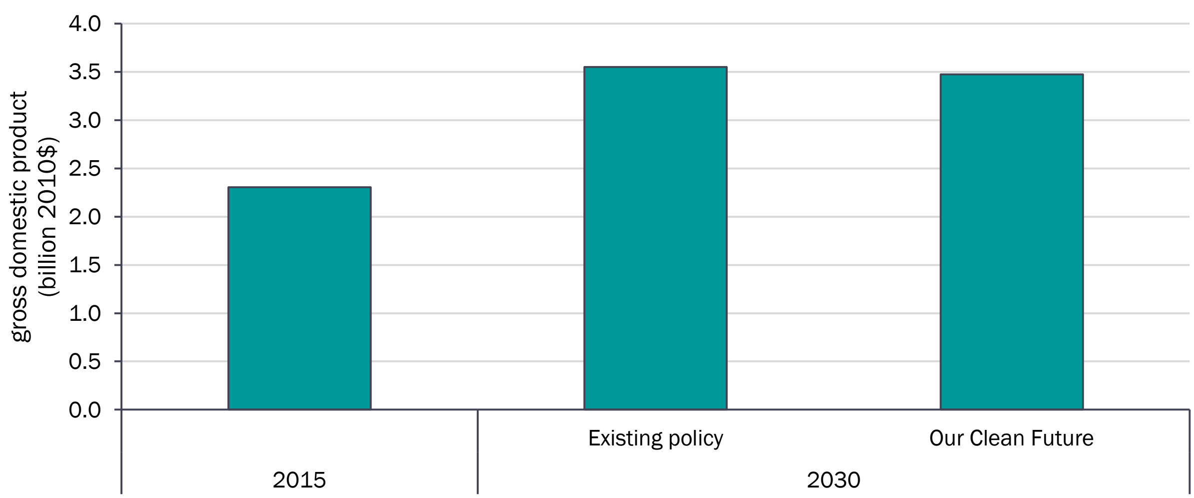
Source: Navius forecast using gTech, including the impacts of non-modeled policies as described in Section 5.1.4.

- Lastly, emissions from building **heating** are reduced by 18 kilotonnes due to financial incentives for low carbon heating equipment and building retrofits, as well as strengthened building codes for new construction. These policies improve the thermal efficiency of buildings (reducing total energy demand) and encourage greater adoption of zero carbon heating equipment like heat pumps.

Yukon's economy continues to grow under *Our Clean Future*. In the existing policy forecast, the territorial economy is assumed to grow at an average annual rate of 2.5% through 2030. As shown in Figure 5, this means that GDP increases from $2.30 billion in 2015 (2010$) to $3.55 billion in 2030. Under *Our Clean Future*, the rate of GDP growth is lower (2.3% annually), but the economy still grows to be 1.5 times larger in 2030 ($3.47 billion) than in 2015.

Please note that this assessment does not account for the benefits of avoided climate change on the economy.

Figure 5: Impact on GDP



Source: Navius forecast using gTech.

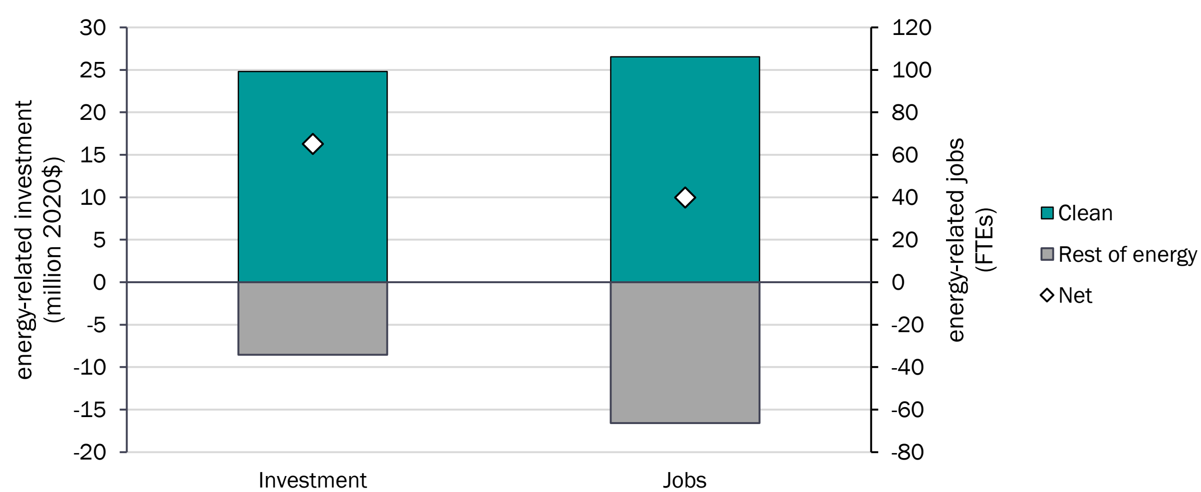
***Our Clean Future* encourages a shift towards a clean economy by boosting investment and jobs in clean energy.** A clean economy produces many of the same goods and services as today's economy while emitting less greenhouse gas emissions.

It is first important to highlight that most economic activity in Yukon is unrelated to energy consumption or emissions. For example, in the existing policy forecast energy-related jobs account for about 3.8% of all jobs in the territory.

Our Clean Future increases both clean investment and clean jobs, as shown in Figure 6. Clean investment (including energy-related purchases by households) nearly triples, increasing by $25 million in 2020. This shift is partially offset by less investment in the "rest of energy". Overall, the territory experiences a total increase in energy-related investment of $16 million in 2030.

Our Clean Future also leads to a shift toward clean jobs, although the shift is less pronounced than it is for investment. The implementation of *Our Clean Future* increases clean energy employment by 106 jobs in 2030. This increase is partially offset by a decline in the rest of energy by 66, but total employment in the energy-related sectors increases by about 40 jobs.

Figure 6: Change in energy-related investment and jobs in 2030 under *Our Clean Future* policy



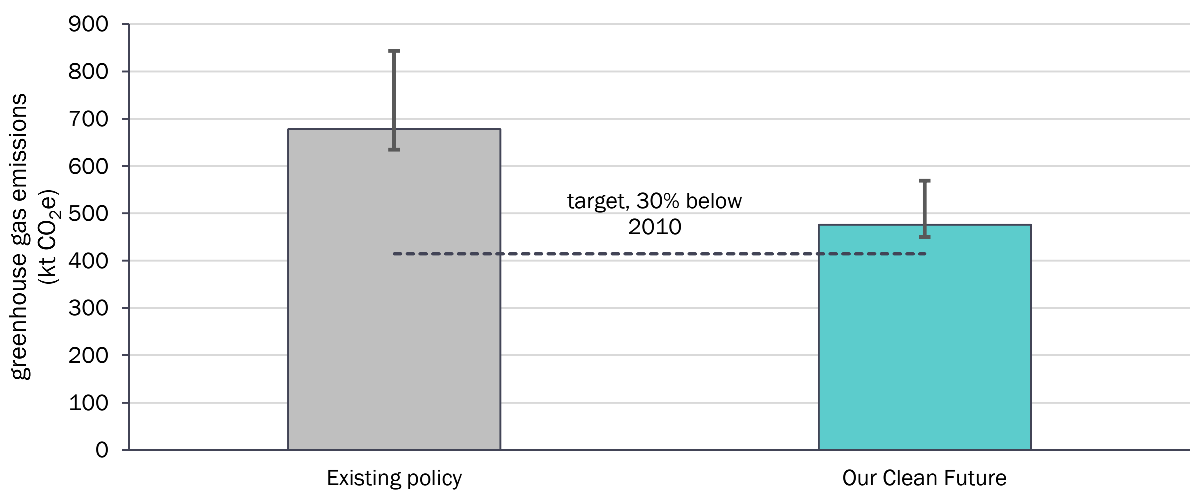
Please note that investment includes household consumption of energy-related technologies. Change is measured relative to the existing policy forecast in that year. Source: Navius forecast using gTech.

An adaptive policy approach is likely required to achieve Yukon's greenhouse gas targets. The territory's greenhouse gas emissions are influenced by a variety of factors, many of which are outside of Yukon's control. For example, Figure 7 shows the impact of varying levels of economic growth on Yukon's non-mining emissions in 2030. These projections demonstrate that *Our Clean Future* will get Yukon closer to its 2030 greenhouse gas target, but also that the remaining gap is uncertain, ranging from 36 kilotonnes to 155 kilotonnes.

Yukon's greenhouse gas emissions are also influenced by the emissions intensity of economic activity. In addition to territorial policy, emissions intensity depends on other factors, such as whether federal policy is tightened or relaxed (e.g., fuel economy standards for new vehicles), future energy prices (e.g., oil prices affect the relative attractiveness of many low carbon technologies in the North) and the pace of technological change (e.g., the cost and performance of cold weather heat pumps).

The implication of this uncertainty is that achieving Yukon's greenhouse gas target requires assessing progress along the way, updating greenhouse gas projections based on new information and modifying policies if necessary. Uncertainty analysis can also help by identifying policies that perform well under a range of future developments.

Figure 7: Non-mining greenhouse gas emissions in 2030



Source: Navius forecast using gTech.

Table of Contents

1. Introduction

Our Clean Future: a Yukon strategy for climate change, energy and a green economy includes a package of policies designed to address the climate change emergency[3]. These policies are designed to address four goals:

1. Reducing greenhouse gas emissions;
2. Ensuring reliable, affordable and renewable energy;
3. Adapting to climate change; and
4. Building a green economy.

With respect to reducing greenhouse gas emissions, Yukon has adopted the following targets through *Our Clean Future*:

- Reducing transport, heating, electricity, other industrial and waste emissions (i.e., emissions excluding the mining sector) by 30% from 2010 levels by 2030.
- An intensity-based target (i.e., greenhouse gas emissions per output) for emissions from the mining sector, which is under development.

This report presents Navius Research's assessment of the impact of Yukon's climate change mitigation policies on territorial energy consumption, greenhouse gas emissions and the economy.

This report is structured as follows:

- Chapter 2 introduces gTech, the modeling tool used to forecast energy consumption and greenhouse gas emissions.
- Chapter 3 summarizes key forecast assumptions.
- Chapter 4 reviews how Yukon's emissions may change through 2030 in the absence of new policy.
- Chapter 5 quantifies the impact of *Our Clean Future* policies to reduce greenhouse gas emissions.

[3] Government of Yukon. 2020. Our Clean Future. https://Yukon.ca/our-clean-future

2. Approach

This Chapter provides an overview of the approach used to quantify the impacts of Yukon's greenhouse gas reduction policies. It begins with an introduction to energy-economy modeling (Section 2.1), followed by a description of Navius' gTech model (Section 2.2). It concludes with a discussion about the limits of forecasting (Section 2.3).

2.1. Introduction to energy-economy modeling

Yukon's energy-economy is complex. Energy consumption, which is the main driver of anthropogenic greenhouse gas emissions, results from the decisions made by tens of thousands of residents. For example, households must choose what type of vehicles they will buy and how to heat their homes; industry must decide whether to install technologies that might cost more but consume less energy; municipalities must determine whether to expand transit service; and investors need to decide whether to invest their money in Yukon or somewhere else.

Existing policies and those required to achieve Yukon's greenhouse gas reduction targets will have effects throughout the economy and interact with each other. For example, territorial policies (e.g., building codes, energy efficiency rebates) and federal policies (e.g., carbon pricing, energy efficiency regulations) influence greenhouse gas emissions from buildings in Yukon. Likewise, multiple policies seek to influence emissions from passenger vehicles, such as federal vehicle emission standards, federal zero emission vehicle incentives and the federal carbon price. The interactive effects among such policies can be complex.

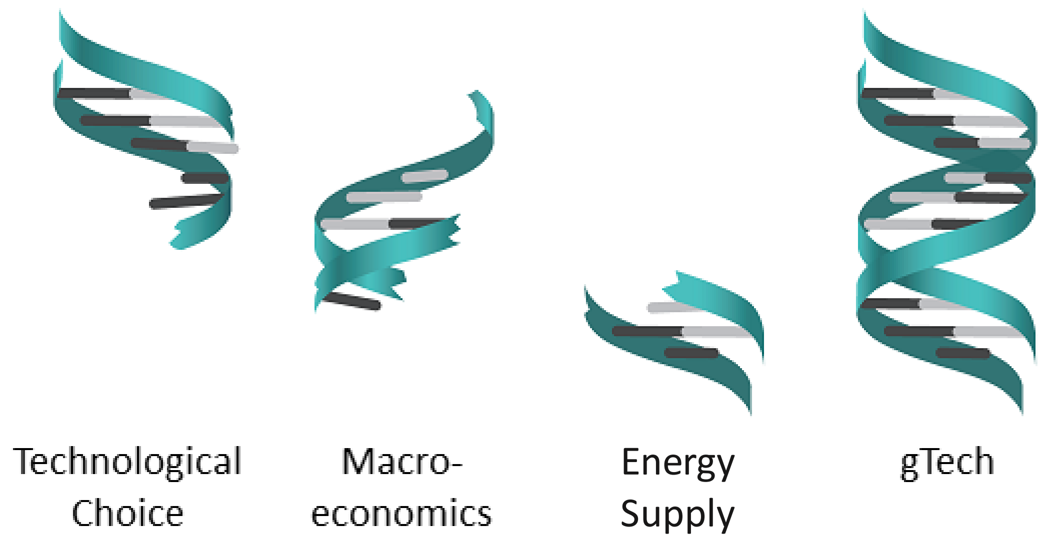
Estimating the greenhouse gas and economic impacts of climate policy therefore requires a modeling framework that captures much of the complexity of the energy-economic system as well as the range of policies implemented and proposed across multiple levels of government.

2.2. Introduction to gTech

gTech is unique among energy-economy models because it combines features that are typically only found in separate models (see Figure 8):

- A realistic representation of how households and firms select technologies and processes that affect their energy consumption and greenhouse gas emissions.
- An exhaustive accounting of the economy at large, including how provinces and territories interact with each other and the rest of the world.
- A detailed representation of energy supply, including liquid fuel (crude oil and biofuel), gaseous fuel (natural gas and renewable natural gas) and electricity.

Figure 8: The gTech model



gTech builds on three of Navius' previous models (CIMS, GEEM and OILTRANS/IESD), combining their best elements into a comprehensive integrated framework.

Simulating technological choice

Technological choice is one of the most critical decisions that influence greenhouse gas emissions in Canada. For example, if a household chooses to purchase an electric vehicle over a gasoline car, that decision will reduce their emissions. Similarly, if a mining facility chooses to electrify its operations, that decision reduces its emissions.

gTech provides a detailed accounting of the types of energy-related technologies available to households and businesses. In total, gTech includes 200 technologies across more than 50 end-uses (e.g., light-duty vehicle travel, residential space heating, industrial process heat, management of agricultural manure). For a list of end-uses and fuels represented in the model, please see Appendix A: “Covered sectors, fuels and end-uses in gTech”.

Naturally, technological choice is influenced by many factors. Table 2 summarizes key factors that influence technological choice and the extent to which these factors are included in gTech.

Table 2: Technological choice dynamics captured by gTech

Criteria	Description
Purchasing (capital) costs	Purchasing costs are simply the upfront cost of purchasing a technology. Every technology in gTech has a unique capital cost that is based on research conducted by Navius. Everything else being equal (which is rarely the case), households and firms prefer technologies with a lower purchasing cost.
Energy costs	Energy costs are a function of two factors: (1) the price for energy (e.g., cents per litre of gasoline) and (2) the energy requirements of an individual technology (e.g., a vehicle’s fuel economy, measured in litres per 100 km). In gTech, the energy requirements for a given technology are fixed, but the price for energy is determined by the model. The method of “solving” for energy prices is discussed in more detail below.
Time preference of capital	Most technologies have both a purchasing cost as well as an energy cost. Households and businesses must generally incur a technology’s purchasing cost before they incur the energy costs. In other words, a household will buy a vehicle before it needs to be fueled. As such, there is a tradeoff between near-term capital costs and long-term energy costs. gTech represents this tradeoff using a “discount rate”. Discount rates are analogous to the interest rate used for a loan. The question then becomes: is a household willing to incur greater upfront costs to enable energy or emissions savings in the future? Many energy modelers use a “financial” discount rate (commonly between 5% and 10%). However, given the objective of forecasting how households and firms are likely to respond to climate policy, gTech employs behaviourally-realistic discount rates of between 8% and 25% to simulate technological choice. Research consistently shows that households and firms do not make decisions using a financial discount rate, but rather use significantly higher rates.[4]

[4] For example, see: Rivers, N., & Jaccard, M. (2006). Useful models for simulating policies to induce technological change. *Energy policy*, *34*(15), 2038-2047; Axsen, J., Mountain, D.C., Jaccard, M., 2009. Combining stated and revealed choice research to simulate the neighbor effect: The case of hybrid-electric vehicles. Resource and Energy Economics 31, 221-238.

Criteria	Description
Technology specific preferences	In addition to preferences around near-term and long-term costs, households (and even firms) exhibit “preferences” towards certain types of technologies. These preferences are often so strong that they can overwhelm most other factors (including financial ones). For example, buyers of passenger vehicles can be concerned about the driving range and available charging infrastructure, some may worry about the risk of buying new technology, and some may see the vehicle as a “status symbol” that they value[5]. gTech quantifies these technology-specific preferences as “non-financial” costs, which are added to the technology choice algorithm.
The diverse nature of Canadians	Canadians are not a homogenous group. Individuals are unique and will weigh factors differently when choosing what type of technology to purchase. For example, one household may purchase a Toyota Prius while their neighbour purchases an SUV and another takes transit. gTech uses a “market share” equation in which technologies with the lowest net costs (including all the cost dynamics described above) achieve the greatest market share, but technologies with higher net costs may still capture some market share[6]. As a technology becomes increasingly costly relative to its alternatives, that technology earns less market share.
Changing costs over time	Costs for technologies are not fixed over time. For example, the cost of electric vehicles has come down significantly over the past few years, and costs are expected to continue declining in the future[7]. Similarly, costs for many other energy efficient devices and emissions-reducing technologies have declined and are expected to continue declining. gTech accounts for whether and how costs for technologies are projected to decline over time and/or in response to cumulative production of that technology.
Policy	One of the most important drivers of technological choice is government policy. Current federal, provincial and territorial initiatives in Canada are already altering the technological choices households and firms make through various policies such as: (1) incentive programs, which pay for a portion of the purchasing cost of a given technology; (2) regulations, which either require a group of technologies to be purchased or prevent another group of technologies from being purchased; (3) carbon pricing, which increases fuel costs in proportion to their carbon content; (4) variations in other tax policy (e.g., whether or not to charge GST on a given technology); and (5) flexible regulations, like the federal clean fuel standard, which will create a market for compliance credits. gTech simulates the combined effects of all these policies implemented together. Policies included in the forecasting are described in Section 4.1 and Section 5.1.

---

[5] Kormos, C., Axsen, J., Long, Z., Goldberg, S., 2019. Latent demand for zero-emissions vehicles in Canada (Part 2): Insights from a stated choice experiment. Transportation Research Part D: Transport and Environment 67, 685-702.

[6] Rivers, N., & Jaccard, M. (2006). Useful models for simulating policies to induce technological change. *Energy policy*, *34*(15), 2038-2047.

[7] Nykvist, B., Sprei, F., & Nilsson, M. (2019). Assessing the progress toward lower priced long range battery electric vehicles. *Energy Policy*, 124, 144-155.

Understanding the macroeconomic impacts of policy

As a full macroeconomic model (specifically, a “general equilibrium model”), gTech provides insight about how policies affect the economy at large. The key macroeconomic dynamics captured by gTech are summarised in Table 3.

Table 3: Macroeconomic dynamics captured by gTech

Dynamic	Description
Comprehensive coverage of economic activity	gTech accounts for all economic activity in Canada as measured by Statistics Canada national accounts[8]. Specifically, it captures all sector activity, all gross domestic product, all trade of goods and services and the transactions that occur between households, firms and government. As such, the model provides a forecast of how government policy affects many different economic indicators, including gross domestic product, investment, household income and jobs.
Full equilibrium dynamics	gTech ensures that all markets in the model return to equilibrium (i.e., that the supply for a good or service is equal to its demand). This means that a decision made in one sector is likely to have ripple effects throughout the entire economy. For example, greater demand for electricity requires greater electricity production. In turn, greater production necessitates greater investment and demand for goods and services from the electricity sector, increasing demand for labor in construction services and ultimately leading to higher wages. The model also accounts for price effects. For example, the electricity sector can pass policy compliance costs on to households, who may alter their demand for electricity and other goods and services (e.g., by switching to technologies that consume other fuels and/or reducing consumption of other goods and services).
Sector detail	gTech provides a detailed accounting of sectors in Canada. In total, gTech simulates how policies affect over 80 sectors of the economy. Each of these sectors produces a unique good or service (e.g., the mining sector produces ore, while the trucking sector produces transport services) and requires specific inputs into production.
Labor and capital markets	Labor and capital markets must also achieve equilibrium in the model. The availability of labor can change with the “real” wage rate (i.e., the wage rate relative to the consumption level). If the real wage increases, the availability of labor increases. The model also accounts for “equilibrium unemployment”. Capital markets are introduced in more detail below.

[8] Statistics Canada. Supply and Use Tables. Available from: www150.statcan.gc.ca/n1/en/catalogue/15-602-X

Dynamic	Description
Interactions between regions	Economic activity in Canada is highly influenced by interactions among provinces/territories, with the United States and with countries outside of North America. Each province and territory in the model interacts with other regions via (1) the trade of goods and services, (2) capital movements, (3) government taxation and (4) various types of "transfers" between regions (e.g., the federal government provides transfers to provincial and territorial governments). The version of gTech used for this project accounts for Yukon, the two other territories in an aggregated "region", 10 Canadian provinces and the United States. The model simulates each of the interactions described above, and how interactions may change in response to policy. In other words, the model can forecast how a policy may affect the trade of ore between Yukon and British Columbia; or whether a policy would affect how corporations invest in Yukon.
Households	On one hand, households earn income from the economy at large. On the other, households use this income to consume different goods and services. gTech accounts for each of these dynamics, and how either changes with policy.

Understanding energy supply markets

gTech accounts for all major energy supply markets, such as electricity, refined petroleum products and natural gas. Each market is characterized by resource availability and production costs by province and territory, as well as costs and constraints (e.g., pipeline capacity) of transporting energy between regions.

Low carbon energy sources can be introduced within each fuel stream in response to policy, including renewable electricity and bioenergy. The model accounts for the availability and cost of bioenergy feedstocks, allowing it to provide insight about the economic effects of emission reduction and biofuels policy.

gTech: The benefits of merging macroeconomics with technological detail

By merging the three features described above (technological detail, macroeconomic dynamics, and energy supply dynamics), gTech can provide extensive insight into the effect of climate and energy policy.

First, gTech can provide insights related to technological change by answering questions such as:

- How do policies affect technological adoption (e.g., how many electric vehicles are likely to be on the road in 2030)?
- How does technological adoption affect greenhouse gas emissions and energy consumption?

Second, gTech can provide insights related to macroeconomics by answering questions such as:

- How do policies affect gross domestic product?
- How do policies affect individual sectors of the economy?
- How are households affected by the policy?
- Does the policy affect energy prices or any other price in the model (e.g., food prices)?

Third, gTech answers questions related to its energy supply modules:

- Will a policy result in more supply of renewable fuels?
- Does policy affect the cost of transporting refined petroleum products, and therefore the price of gasoline in Canada?

Finally, gTech provides insight into areas where there is overlap between its various features:

- What is the effect of investing carbon revenue into low- and zero-carbon technologies? This answer can only be answered with a model such as gTech.
- What are the macroeconomic impacts of technology-focused policies (e.g., how might a zero-emissions vehicle standard impact GDP)?
- Do biofuels focused policies affect (1) technological choice and (2) the macroeconomy?

This modeling toolkit allows for a comprehensive examination of the impacts of Yukon's climate change mitigation plans.

2.3. Limits to forecasting

Despite using the best available forecasting methods and assumptions, the evolution of our energy economy is uncertain. In particular, forecasting greenhouse gas emissions is subject to two main types of uncertainty.

First, all models are simplified representations of reality. Navius' gTech model is, effectively, a series of mathematical equations that are intended to forecast the future. This raises key questions: "are the equations selected a good representation of reality?" and "do the equations selected overlook important factors that may influence the future?"

The use of computable general equilibrium models (gTech) is well founded in the academic literature. In addition, Navius undertakes significant efforts to calibrate and back-cast the model to ensure that it captures key dynamics in the energy-economic system (see Section 3.1). However, the availability and quality of calibration data is limited in some jurisdictions. For example, the Government of Yukon has advised that federal data for the territory is in some cases inaccurate.

In addition, Navius' tools do not account for every dynamic that will influence technological change. For example, household and firm decisions are influenced by many factors, which cannot be fully captured by even the most sophisticated model. The inherent limitation of energy-economic forecasting is that virtually all projections of the future will differ, to some extent, from what ultimately transpires.

Second, the assumptions used to parameterize the models are subject to uncertainty. These assumptions include, but are not limited to, oil prices, improvements in labor productivity and a stable climate. If any of the assumptions used prove incorrect, the resulting forecast could be affected.

We explore the impact of uncertainty in future GDP growth on greenhouse gas emissions in Section 5.5. The uncertainties inherent in the forecast could be examined in greater detail in the future if desired.

In sum, gTech is the most comprehensive model available for forecasting the techno-economic impacts of climate policy in Canada. Its representation of technological change, macroeconomic dynamics and fuels markets (as described above) mean that it is ideally positioned to forecast how the broad range of policies implemented in Yukon will affect technological change, energy consumption, greenhouse gas emissions, the economy and a large array of other indicators.

3. Forecast assumptions

This Chapter summarizes data sources and assumptions used to characterize Yukon's energy-economy and forecast greenhouse gas emissions to 2030. It begins with an overview of the various data sources to which the model is calibrated (Section 3.1). Assumptions about future economic growth and energy prices are then provided in Section 3.2 and Section 3.3, respectively. Section 3.4 summarizes key greenhouse gas abatement options included in the analysis. Lastly, Section 3.5 describes the methodology for quantifying the clean energy economy.

3.1. Calibration sources

To characterize Yukon's energy-economy, and that of the rest of North America, gTech is calibrated to a large variety of historical data sources. Not all these data sources are consistent with one another (e.g., household expenditures on gasoline consumption in Statistics' Canada's Supply-Use tables may not be consistent with gasoline fuel tax data collected by Yukon), so Navius' calibration routine places greater emphasis on some data sources relative to others.

Key calibration data sources for Yukon are listed below, in order of priority:

- Yukon Bureau of Statistics Fuel Emissions[9] for combustion emissions.
- Environment and Climate Change Canada's National Inventory Report[10] for non-combustion emissions as well as the relationship of emissions between IPCC category (i.e., the categories used in Canada's National Inventory Report) and economic sector.
- Statistics Canada's Supply-Use Tables[11] for the structure of Yukon's economy including sector activity, gross domestic product, trade of goods and services and the financial transactions between households, firms, government and other regions.

[9] Government of Yukon. 2020. Greenhouse gas emissions in Yukon. https://yukon.ca/sites/yukon.ca/files/env-greenhouse-gas-emissions-yukon.pdf

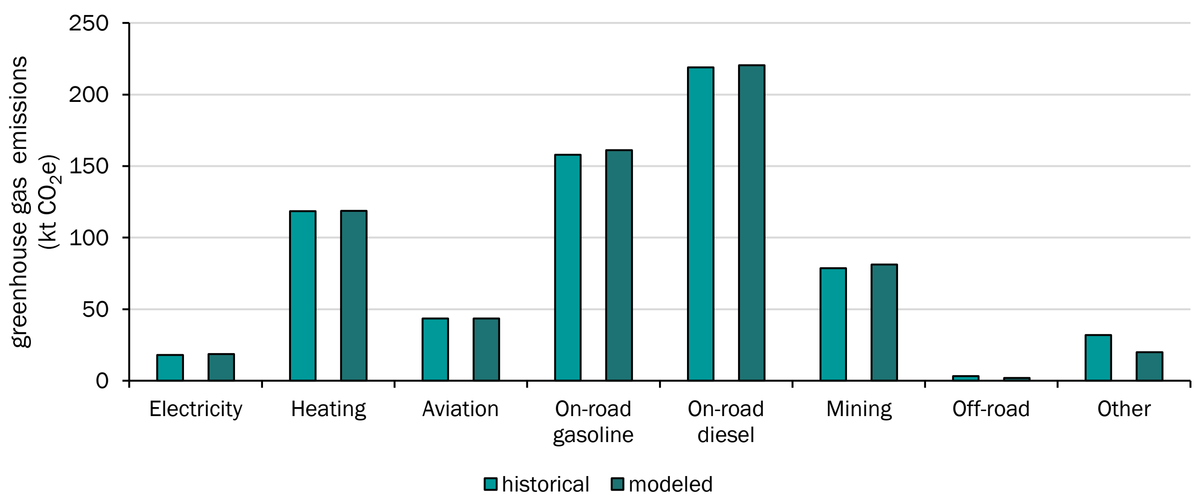
[10] Environment and Climate Change Canada. National Inventory Report. www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/inventory.html

[11] Statistics Canada. Supply and Use Tables. www150.statcan.gc.ca/n1/en/catalogue/15-602-X

- Yukon Energy Corporation and ATCO Electric Yukon data[12] on electricity supply and demand.
- Natural Resources Canada's Comprehensive Energy Use Database[13] for trends in building and transport energy efficiency.
- Statistics Canada's Annual Industrial Consumption of Energy Survey[14] for energy consumption by fuel in industry.

Figure 9: Calibration of greenhouse gas emissions by fuel type in 2010 shows that modeled greenhouse gas emissions in the 2010 base year of the model align closely with Yukon's historical emissions. One area of divergence is the "other" category, which includes emissions from oil and gas production. Since historical oil and gas production in Yukon was small and has since ceased, this sector was not included in the modeling.

Figure 9: Calibration of greenhouse gas emissions by fuel type in 2010



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by the Yukon Climate Change Secretariat. (2) Navius back-casting using gTech. Please note that off-road emissions include diesel and gasoline use for various off-road activities such as farming, fishing, hunting, outfitting, tourism and trapping.

Moving forward, modeled emissions follow historical trends as shown in Figure 10. The ability of the model to replicate historical trends improves our confidence in

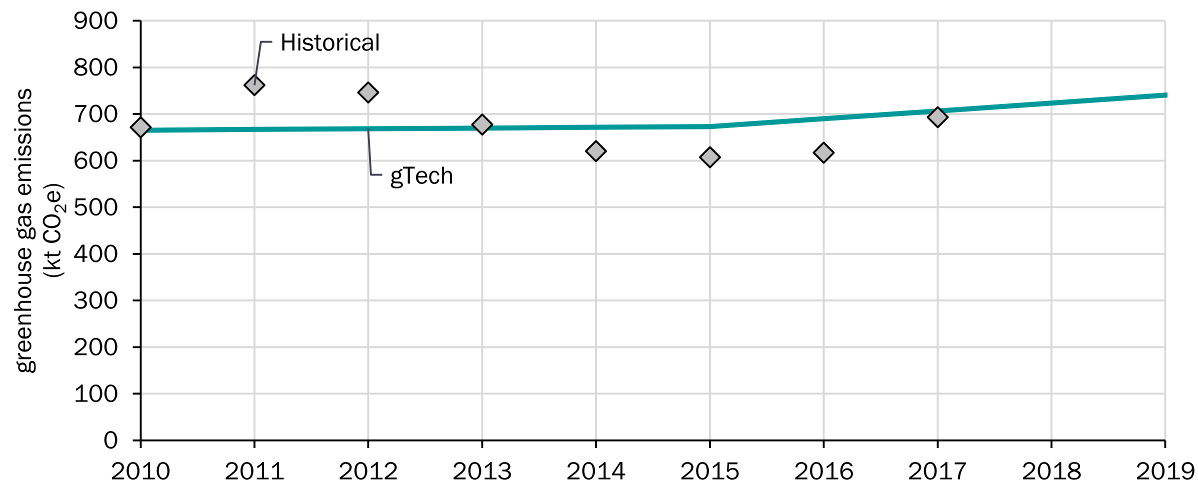
[12] Data provided to Navius via e-mail.

[13] Natural Resources Canada. Comprehensive Energy Use Database. http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm

[14] Statistics Canada. Annual Industrial Consumption of Energy Survey. www.statcan.gc.ca

projections moving forward. Note that the model is intended to capture medium and long-term trends rather than short-term fluctuations due to business cycles and other factors. As a result, it is to be expected that the forecast is smoother than the historical data.

Figure 10: Calibration of greenhouse gas emissions, 2010-2019



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by the Yukon Climate Change Secretariat, excluding upstream oil and gas emissions. (2) Navius forecast using gTech.

3.2. Economic activity

Yukon's economy is calibrated to grow at an average annual rate of 2.5% from 2020 to 2030, based on assumptions provided by the Government of Yukon. We also explore the impact of higher and lower growth through a sensitivity analysis, discussed in Section 5.5.

GDP by sector is largely determined by this rate of growth and the relative capital and labour productivity of each sector (i.e., the value of goods and services produced for a given amount of capital and labour inputs). In other words, the overall economic growth rate of 2.5% per annum is "allocated" amongst sectors based on historical data regarding the structure of North America's economy and changes brought on by policy and other factors.

3.3. Energy prices

Crude oil prices are assumed to reach USD $70/barrel by 2030, based on projections from the Canada Energy Regulator[15]. The price for oil is an exogenous input to the model (i.e., based on an assumed global price).

The price for other energy commodities is determined by the model based on demand and the cost of production. For example, the price of electricity in Yukon depends on a variety of factors that are accounted for by the modeling, such as:

- The cost of generating electricity while meeting any policy constraints.
- The cost of maintaining the transmission and distribution network.
- Any taxes on or subsidies to the sector.

3.4. Abatement options

gTech includes a large number of technologies, fuels and actions that can reduce greenhouse gas emissions. Table 4 lists key commercialized or near-commercialized abatement opportunities that are included in this analysis.

Table 4: Summary of key territorial abatement opportunities included in gTech

Greenhouse gas source	Key abatement opportunities	Data sources (see reference list in section 0)
Industry		
Stationary Combustion		
Electricity generation	Renewables	Yukon Energy (2017)
	Electricity efficiency	EIA (2017)
Process heat (high-grade heat)	Fuel switching	Park et al (2017), CIMS
	Carbon capture and storage	CIMS
	Renewables (Biomass and RNG)	DENA (2016)
	Electric resistance	Park et al (2017), CIMS
Process heat (low-grade heat)	Fuel switching	Park et al (2017), CIMS
	Renewables (biomass and RNG)	DENA (2016)
	Industrial heat pumps	Onmen et al (2015)

[15] Canada Energy Regulator. 2019. Canada's Energy Future 2019: Energy Supply and Demand Projections to 2040. www.cer-rec.gc.ca/nrg/ntgrtd/ftr/2019/index-eng.html

Greenhouse gas source	Key abatement opportunities	Data sources (see reference list in section 0)
Compression	Electrification	Greenblatt (2015)
Waste		
Waste	Capture of methane for flaring, generating electricity	Navius waste model
	Organic waste diversion	Navius waste model
Transport		
Energy – Transport		
Light and heavy-duty vehicles	Efficiency improvements	DOE (2003), Transport Canada (2011), NRCan (2007)
	Electrification	Nykvist et al (2019), Bloomberg (2017), Moawad et al (2016), Argonne (2018), Curry (2017), US DOE (2013), Bloomberg (2018), ICCT (2017)
	Renewable fuels	IRENA (2013), APEC (2010), AAFC (2017), Kludze et al (2013), Yemshanov et al (2014), Petrolia (2008), (S&T)² Consultants, (2012), Chavez-Gherig et al (2017), G4 Insights (2018), IEA ETSAP (2013)
	Transport demand change, mode shifting to transit and smaller vehicles	Endogenously determined by gTech
Industrial Processes and Product Use		
Light and heavy-duty vehicles	Abatement is fixed to align with the federal policy to reduce HFCs	
Buildings		
Stationary Combustion		
Space heating	Thermal improvements to building shells	RDH (2018)
	More energy efficient fossil fuel furnaces and boilers	EIA (2016), NREL (2018)
	Electric space heating (resistance and heat pump)	EIA (2016), NREL (2018)
	Biomass space heating	CIMS
Water heating	More energy efficient fossil fuel water heaters and boilers	EIA (2016), NREL (2018)
	Electric water heaters (resistance and heat pump)	EIA (2016), NREL (2018)
	Biomass water heating	CIMS

Greenhouse gas source	Key abatement opportunities	Data sources (see reference list in section 0)
Cooking	Electric ranges	EIA (2016), NREL (2018)
Industrial Processes		
Air conditioning	Thermal improvements to building shells	RDH (2018)
	Abatement is fixed to align with the federal policy to reduce HFCs	
Auxiliary equipment	Efficiency	CIMS

References

(S&T)[2] Consultants Inc. (2012). Update of Advanced Biofuel Pathways in GHGenius.

Argonne. (2018). U.S. DOE Benefits & Scenario Analysis.

Bloomberg New Energy Finance. (2017). Electric Vehicle Outlook 2017.

Bloomberg New Energy Finance. (2018). Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO2. Available from: www.about.bnef.com

Chavez-Gherig, A., Ducru, P., & Sandford, M. (2017). The New Jersey Pinelands and the Green Hospital, NRG Energy Case Study.

CIMS. Technology database. Maintained by Navius Research, Inc.

Curry, C. (2017). Lithium-ion Battery Costs and Market, Bloomberg New Energy Finance.

Energy Information Administration (EIA). (2016). Analysis & Projections: Updated Buildings Sector Appliance and Equipment Costs and Efficiency. Available from: https://www.eia.gov/analysis/studies/buildings/equipcosts/

Energy Information Administration (EIA). (2017). Assumptions to the Annual Energy Outlook 2016: Electricity Market Module. Available from: https://www.eia.gov/outlooks/archive/aeo16/

G4 Insights Inc. (2018). Our Technology. Available from: http://www.g4insights.com/about.html

German Energy Agency (DENA). (2016). Process Heat in Industry and Commerce: Technology Solutions for Waste Heat Utilisation and Renewable Provision.

International Council on Clean Transportation (ICCT). (2017). Transitioning to zero-emission heavy-duty freight vehicles. Available from: https://theicct.org/

International Energy Agency Energy Technology System Analysis Programme (IEA ETSAP). (2013). Biogas and bio-syngas production.

International Renewable Energy Association (IRENA). (2013). Road transport: the cost of renewable solutions.

Jones, S., Meyer, P., Snowden-Swan, L., Padmaperuma, A., Tan, E., Dutta, A., Jacobson, J., & Cafferty, K. (2013). Process design and economics for the conversion of lignocellulosic biomass to hydrocarbon fuels: fast pyrolysis and hydrotreating bio-oil pathway (No. PNNL-23053; NREL/TP-5100-61178). Pacific Northwest National Lab. (PNNL), Richland, WA (United States).

Kludze, H., Deen, B., Weersink, A., van Acker, R., Janovicek, K., De Laport, A., & McDonald, I. (2013). Estimating sustainable crop residue removal rates and costs based on soil organic matter dynamics and rotational complexity. Biomass and Bioenergy, 56, 607-618

Moawad, A., Kim, N., Shidore, N., & Rousseau, A. (2016). Assessment of vehicle sizing, energy consumption and cost through large scale simulation of advanced vehicle technologies (No. ANL/ESD-15/28). Argonne National Lab. (ANL), Argonne, IL (United States).

National Renewable Energy Laboratory (NREL). (2018). National Residential Efficiency Measures Database. Available from: https://remdb.nrel.gov/

Natural Resources Canada (NRCan). (2007). Canadian Vehicle Survey 2007 Summary Report. Available from: http://oee.nrcan.gc.ca/Publications/statistics/cvs07/index.cfm?attr=0

Nykvist, B., Sprei, F., & Nilsson, M. (2019). Assessing the progress toward lower priced long range battery electric vehicles. Energy Policy, 124, 144-155.

Ommen, T., Jensen, J., Markussen, W., Reinhold, L., & Elmegaard, B. (2015). Technical and Economic Working Domains of Industrial Heat Pumps: Part 1 - Single Stage Vapour Compression Heat Pump, International Journal of Refrigeration, 55, 168-182.

Park, N., Park, S., Kim, J., Choi, D., Yun, B., & Hong, J. (2017). Technical and economic potential of highly efficient boiler technologies in the Korean industrial sector. Energy, 121, 884-891.

Petrolia, R. (2008). The economics of harvesting and transporting corn stover for conversion to fuel ethanol: A case study for Minnesota. Biomass and Bioenergy, 32, 603-612.

RDH Building Science. (2018). Building shell performance and cost data. Prepared for Navius Research.

Transport Canada. (2011). Operating Costs of Trucking and Surface Intermodal Transportation in Canada.

UBS Evidence Lab, Global Research. (2017). UBS Evidence Lab Electric Car Teardown – Disruption Ahead? Available from: https://neo.ubs.com/shared/d1wkuDIEbYPjF/

US Department of Energy (US DOE). (2003). The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks. Available from: http://www.osti.gov/bridge/product.biblio.jsp?osti_id=810465

US Department of Energy (US DOE). (2013). EV Everywhere Grand Challenge Blueprint.

Yemshanov D., McKenney, D.W., Fraleigh, S., McConkey, B., Huffman, T., & Smith, S. (2014). Cost estimates of post harvest forest biomass supply for Canada. Biomass and Bioenergy, 69, 80-94.

Yukon Energy Corporation. (2017). Yukon Energy 2016 Resource Plan. Available from: https://yukonenergy.ca/about-us/business-documents/resource-plans

3.5. Defining the clean energy economy

To describe how the economy changes over time, gTech identifies the share of investment, GDP and jobs that can be classified as "clean energy" (i.e., related to the supply and use of low carbon technologies). This methodology builds on work developed for Clean Energy Canada[16].

The first step in this process is to flag "clean energy" technologies in the model. Doing so allows the model to assign investment into one of three categories:

- **Clean energy** (e.g., renewable electricity generation, electric vehicles).
- **Rest of energy** (i.e., most activities related to fossil energy supply and use, other than those considered clean such as emissions control efforts).
- **Non-energy** (e.g., insurance services, education).

Clean energy investment is defined as:

- Any investment into a sector that produces clean energy services. Relevant sectors in Yukon include renewable electricity generation, electricity transmission and distribution, and transit.
- Investment into a technology or process determined to be clean. These technologies can occur in any sector of the economy (e.g., electric trucks in the trucking sector).

Please note that consumption of clean technologies is reported as "investment" (e.g., a household purchasing a heat pump)[17].

---

[16] Navius Research. 2019. Quantifying Canada's Clean Energy Economy: A forecast of clean energy investment, value-added and jobs. Report prepared for Clean Energy Canada. https://cleanenergycanada.org/report/the-fast-lane-tracking-the-energy-revolution-2019/

[17] We deliberately diverge from Statistics Canada's definition of "investment" when referring to "household investments". Household "consume", rather than "invest" in, durable goods, such as passenger vehicles. On the other hand, residential construction would be defined as "investment". For simplicity, we call the consumption of durable goods that relate to energy consumption "household investment", even though this definition is technically incorrect.

4. How are Yukon's emissions expected to change in the absence of new policy?

This Chapter presents a forecast of how Yukon's greenhouse gas emissions may change through 2030 without the implementation of new climate mitigation policies. This forecast provides a baseline against which the impacts of new policies are measured in Chapter 5.

This Chapter is structured as follows:

- Section 4.1 summarizes existing policies that will influence Yukon's emissions and how they are simulated.
- Section 4.2 describes how total territorial emissions may change through 2030.
- Section 4.3 reviews energy and emissions trends by fuel type.

4.1. Existing policies

Existing policies implemented by the federal and territorial governments are influencing Yukon's greenhouse gas emissions now and will continue to do so moving forward. The policies described below are included in the "existing policy" forecast described in this Chapter.

4.1.1. Territorial policies

- **Building codes.** Yukon adopted the 2015 National Building Code in 2016[18]. In addition, buildings constructed in Whitehorse must exceed this code by 20%.
- **Residential energy efficiency rebates.** Rebates are available from the Energy Solutions Centre for a variety of building equipment and appliances, including heat pumps ($1500), biomass heating systems ($300-800), oil or propane heating systems with an annual fuel utilization efficiency of 95% or more ($500), and ENERGY STAR appliances ($100-300). In addition, a $10,000 rebate is available for

[18] Government of Yukon. 2019. Get Yukon-related updates to the National Building Code. https://yukon.ca/en/housing-and-property/building-and-renovating/get-yukon-related-updates-national-building-code

new homes built to 50% better than the 2015 National Building Code. These rebates are implicitly included in the forecast by calibrating the model to historical trends.

4.1.2. Federal policies

- **Carbon Pricing[19].** This policy includes two components: (1) a carbon levy applied to fossil fuels that reaches $50/t CO_2e by 2022 and is constant thereafter in nominal terms and (2) an output-based pricing system for industrial facilities emitting more than 50 kt CO_2e annually. The policy generally applies to all combustion emissions except for those associated with diesel use for electricity generation in remote communities, aviation fuels and greenhouse operators. Mining operations are assumed to opt-in to the output-based pricing system. Revenue raised by the policy is returned to households (44%), mines (27%), other businesses (25%) and government (4%)[20].

- **Federal Hydrofluorocarbon Controls[21].** The Canadian government was one of the signatories of the 2016 Montreal Protocol-amending Kigali Agreement on ozone-depleting substances. Canada has pledged to reduce its HFC-related GHG emissions by 15% by 2036 relative to 2011/2013 levels by revising the Regulations Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulations.

- **Federal Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations[22].** New passenger vehicles and light-commercial vehicles/light trucks sold in Canada must meet fleet-wide GHG emission standards. By 2025, fleet targets reach 99 g/km for passenger cars and

---

[19] Government of Canada. 2019. Pricing pollution: how it will work. www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work.html

[20] Government of Yukon. 2019. Yukon Government carbon price rebate. https://yukon.ca/sites/yukon.ca/files/fin/fin-yukon-government-carbon-price-rebate-levy-rebate-credit-estimates.pdf

[21] Government of Canada. 2018. Canada agrees to control hydrofluorocarbons under the Montreal Protocol. www.canada.ca/en/environment-climate-change/services/sustainable-development/strategic-environmental-assessment/public-statements/canada-agree-control-hydrofluorocarbons.html

[22] Government of Canada. 2018. Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations. http://www.gazette.gc.ca/rp-pr/p2/2014/2014-10-08/html/sor-dors207-eng.html

140 g/km for light trucks and SUVs[23]. For context, a 2019 Toyota Prius has a 105 g/km rating and a 2019 Toyota RAV4 Hybrid has a 140 g/km rating[24].

- **Federal Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations[25].** New heavy-duty vehicles sold in Canada must meet GHG emissions standards between 2014 and 2018. These regulations require that GHG emissions from 2018 model-year heavy-duty vehicles will be reduced by 23%.
- **Federal Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations[26].** The federal government amended the Heavy-Duty Vehicle Emissions Standard to increase the vehicle emission stringency for vehicles manufactured in model years 2018 to 2027. The overall decrease in emissions intensity is expected to be around 20% for vehicles manufactured in the 2027 model year relative to 2015 model year.
- **Federal energy efficiency regulations[27].** Federal standards exist for new space conditioning equipment, water heaters, household appliances, and lighting products sold in Canada. Relevant standards for Yukon include a minimum annual fuel utilization efficiency of 78% for oil-fired furnaces, a minimum energy factor of 0.61 for propane water heaters and ban of incandescent light bulbs. Of note, the Yukon's building code exceeds some of these requirements.
- **Federal ZEV incentives[28].** This policy provides between $2,500 and $5,000 for new battery electric and plug-in hybrid electric light-duty vehicles, depending on their electric range. Based on allocated funds ($300 million) and expected electric vehicle adoption, the incentive program is assumed to operate from 2019 until the end of 2021.

---

23 International Council on Clean Transportation. (2019). Chart library: Passenger vehicle fuel economy. https://theicct.org/chart-library-passenger-vehicle-fuel-economy

24 Natural Resources Canada. 2019. 2019 Fuel Consumption Guide. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/oee/pdf/transportation/tools/fuelratings/2019%20Fuel%20Consumption%20Guide.pdf

25 Government of Canada. 2019. Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations: SOR/2013-24. https://laws-lois.justice.gc.ca/eng/regulations/SOR-2013-24/

26 Government of Canada. 2018. Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and Other Regulations Made Under the Canadian Environmental Protection Act, 1999: SOR/2018-98. http://gazette.gc.ca/rp-pr/p2/2018/2018-05-30/html/sor-dors98-eng.html

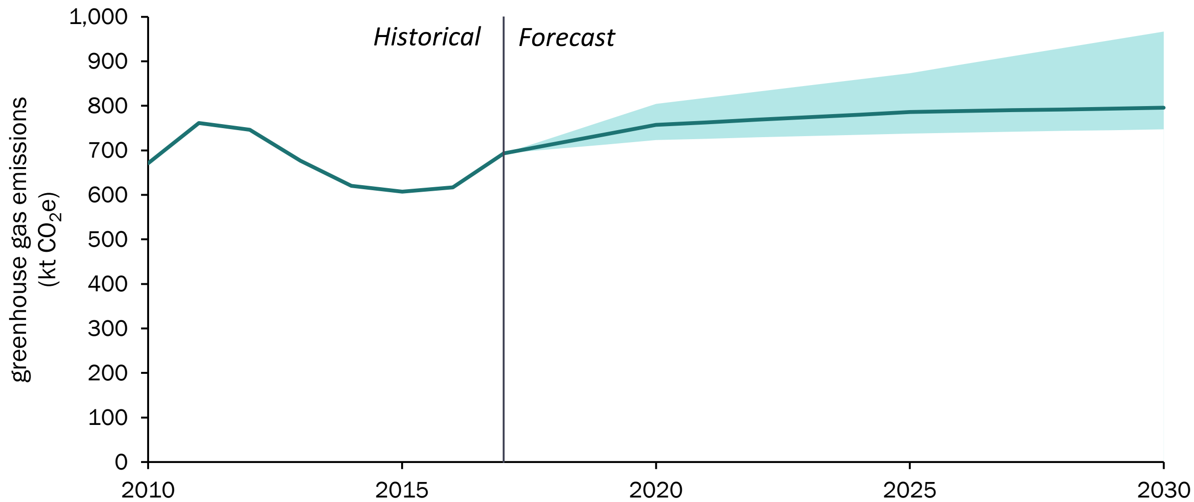
27 Natural Resources Canada. 2017. Canada's Energy Efficiency Act and Energy Efficiency Regulations. www.nrcan.gc.ca/energy/regulations-codes-standards/6861

28 Transport Canada. 2019. Zero-emission vehicles. www.tc.gc.ca/en/services/road/innovative-technologies/zero-emission-vehicles.html

4.2. Territorial emissions to 2030

In the absence of new policies, but accounting for the impact of existing territorial and federal policies, Yukon’s total greenhouse gas emissions are forecast to rise to 796 kilotonnes (kt) in 2030. Historical and forecast reference emissions are shown in Figure 11. In 2017, the most recent year for which territorial data are available, Yukon’s greenhouse gas emissions were 693 kt. Accounting for the range of potential economic growth during this period, emissions could be between 747 kt and 967 kt in 2030.

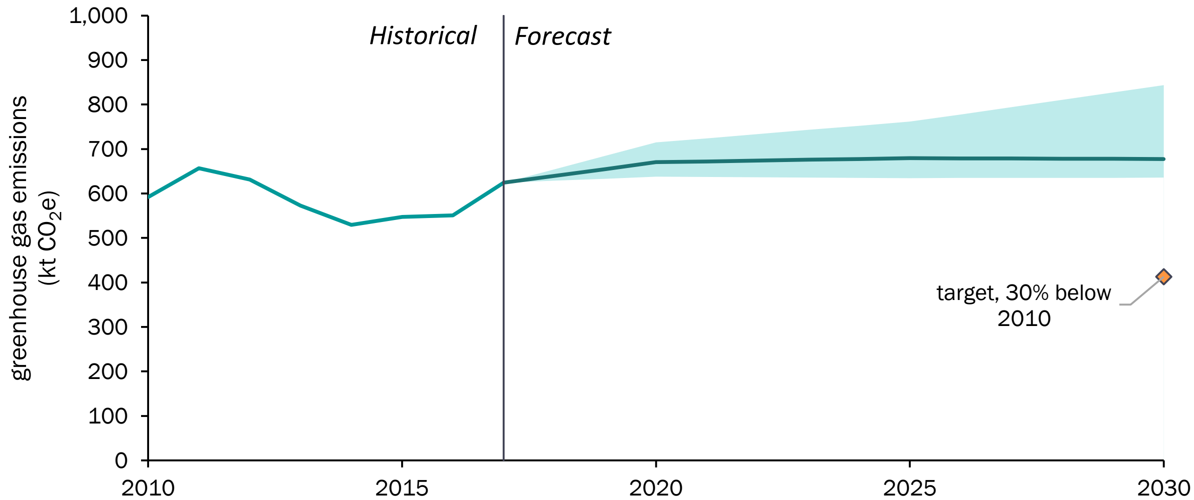
Figure 11: Territorial emissions to 2030, existing policy forecast



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by the Yukon Climate Change Secretariat. (2) Navius forecast using gTech.

Figure 12 presents Yukon’s forecasted emissions to 2030, excluding emissions from the mining sector, as defined in the territorial inventory. It shows that non-mining emissions are projected to rise from 624 Kt in 2017 to 678 kt in 2030. Accounting for the range of potential economic growth rates, emissions could be between 635 kt and 844 kt in 2030. This forecast suggests that new policies are required to achieve Yukon’s target for non-mining emissions of 414 kt in 2030 (i.e., 30% below 2010 levels).

Figure 12: Non-mining emissions to 2030, existing policy forecast



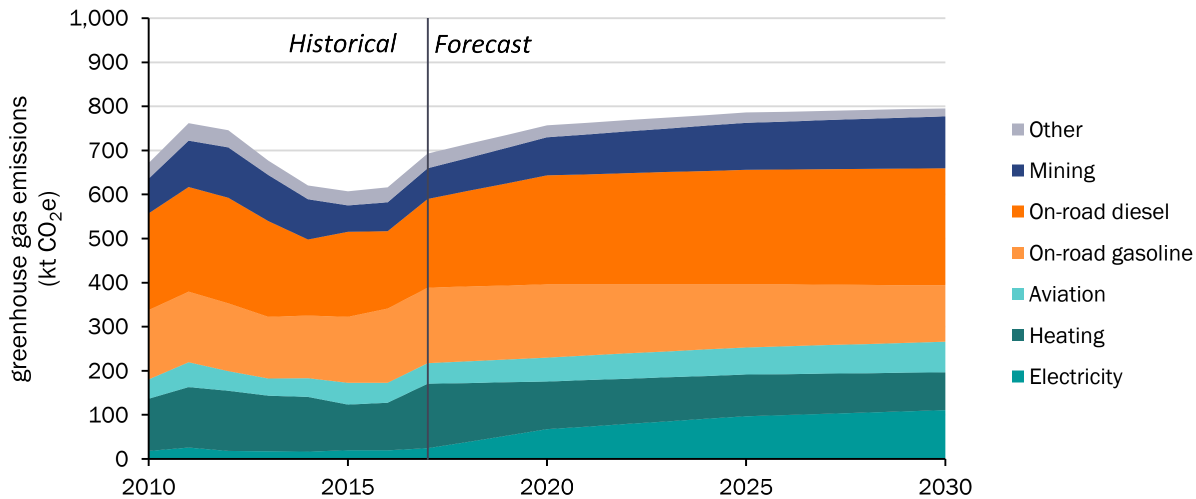
Sources: (1) Yukon greenhouse gas inventory, provided to Navius by Yukon Climate Change Secretariat. (2) Navius forecast using gTech.

4.3. Trends by fuel type

The contribution of different sources to Yukon's emissions are anticipated to change over time, as shown in Figure 13 and Table 5. Several sources of emissions are expected to grow in the absence of new Government of Yukon policies, including electricity generation, mining, trucking and aviation. At the same time, emissions from buildings and light-duty vehicles are anticipated to decline. These trends are discussed in more detail below.

Please note that emissions for each fuel type below are mapped to relevant IPCC categories (i.e., the categories used in Canada's National Inventory Report), reflecting assumptions used to calibrate the model. As noted in Section 3.1, the model is calibrated to emissions inferred from Yukon fuel tax data rather than the National Inventory Report. The National Inventory Report is used for estimates of non-combustion emissions as well as the relationship of emissions between IPCC category and economic sector.

Figure 13: Territorial emissions to 2030 by fuel type, existing policy forecast without new renewable electricity generation projects



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by the Yukon Climate Change Secretariat. (2) Navius forecast using gTech.

Table 5: Territorial emissions to 2030 by fuel type, existing policy forecast without new renewable electricity generation projects

	Historical	*Forecast*		
	2017	*2020*	*2025*	*2030*
Electricity	24	*67*	*97*	*111*
Heating	147	*108*	*94*	*86*
Aviation	47	*54*	*62*	*69*
On-road gasoline	172	*166*	*143*	*128*
On-road diesel	202	*247*	*260*	*265*
Mining	69	*87*	*107*	*118*
Other	34	*27*	*23*	*18*
Off-road	*5*	*2*	*3*	*3*
Waste	*10*	*10*	*10*	*10*
Other industrial processes and product use	*19*	*14*	*11*	*6*
Total	**693**	***757***	***786***	***796***

Sources: (1) Yukon greenhouse gas inventory, provided to Navius by the Yukon Climate Change Secretariat. (2) Navius forecast using gTech. Does not reflect the current plans of the Yukon Energy Corporation as described in section 4.3.1.

4.3.1. Utility electricity generation

Electricity emissions are forecasted to increase from 19 kt in 2010 to 111 kt in 2030, without new renewable electricity generation projects, as shown in Table 6. Two factors are responsible for this modelled increase. First, demand for electricity increases due to both overall demographic and economic growth (e.g., a greater number of buildings) as well as electrification trends in building heating, and to a lesser extent light-duty vehicles, as discussed below.

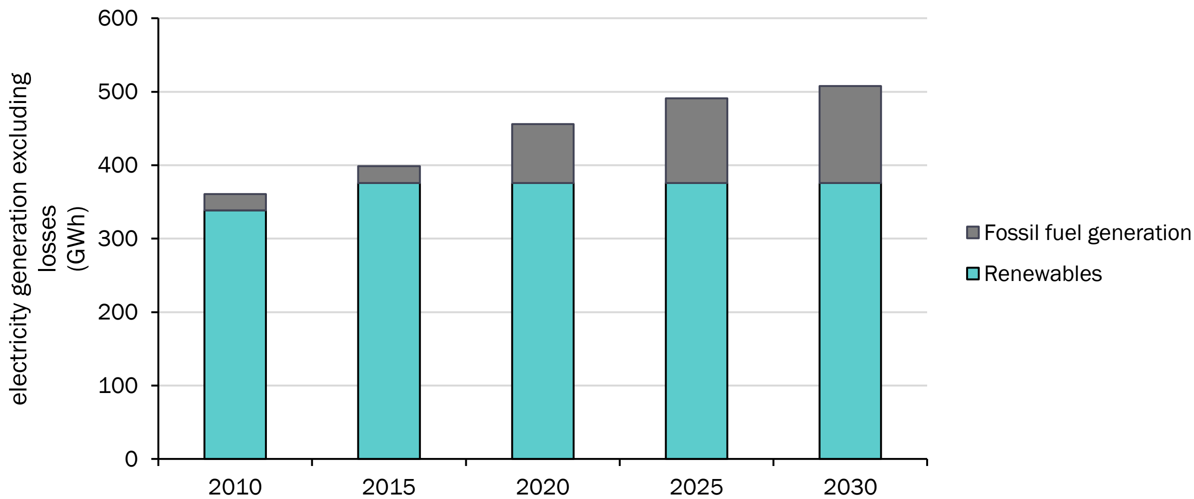
Second, all incremental electricity demand is assumed to be met with thermal resources as shown in Figure 14. This assumption is based on a scenario where liquefied natural gas and diesel are used to meet electricity demand growth. Renewable projects proposed in the Yukon Energy Corporation's 2016 Resource Plan and currently being worked on by the Corporation are not included in the forecast. As such, the existing policy forecast for electricity generation presents a "worst-case" scenario from the perspective of greenhouse gas emissions, demonstrating how much higher Yukon's emissions could be without investment in new renewable electricity projects. As a result of these assumptions, generation from renewable sources (largely hydro) remains fixed at 376 gigawatt hours (GWh) through 2030 in the existing policy forecast, while generation from fossil fuels increases from around 20 GWh to 132 GWh.

Table 6: Utility electricity generation emissions by IPCC category, existing policy forecast without new renewable electricity generation projects (kt CO_2e)

	2010	2015	2020	2025	2030
IPCC category					
Public Electricity and Heat Production	19	19	67	97	111

Source: Navius forecast using gTech. Does not reflect the current plans of the Yukon Energy Corporation as described in the text above.

Figure 14: Utility electricity generation, existing policy forecast without new renewable electricity generation projects



Source: Navius forecast using gTech. Does not reflect the current plans of the Yukon Energy Corporation as described in the text above.

4.3.2. Heating

Heating emissions are forecasted to decline from 113 kt in 2010 to 86 kt in 2030 in the existing policy forecast (see Table 7). This decline occurs because reductions in the emissions intensity of buildings more than offsets growth in the number of buildings in Yukon.

Building emissions intensity improves for two reasons. First, buildings become more energy efficient as demonstrated by the overall reduction in forecast energy consumption in Figure 15. This is because new buildings are built to higher building codes, meaning that they require less energy to heat. Likewise, federal policy requires that new furnaces and water heaters be more efficient than older models, whether they are installed in existing buildings (e.g., when an old furnace reaches the end of its lifespan) or in new buildings.

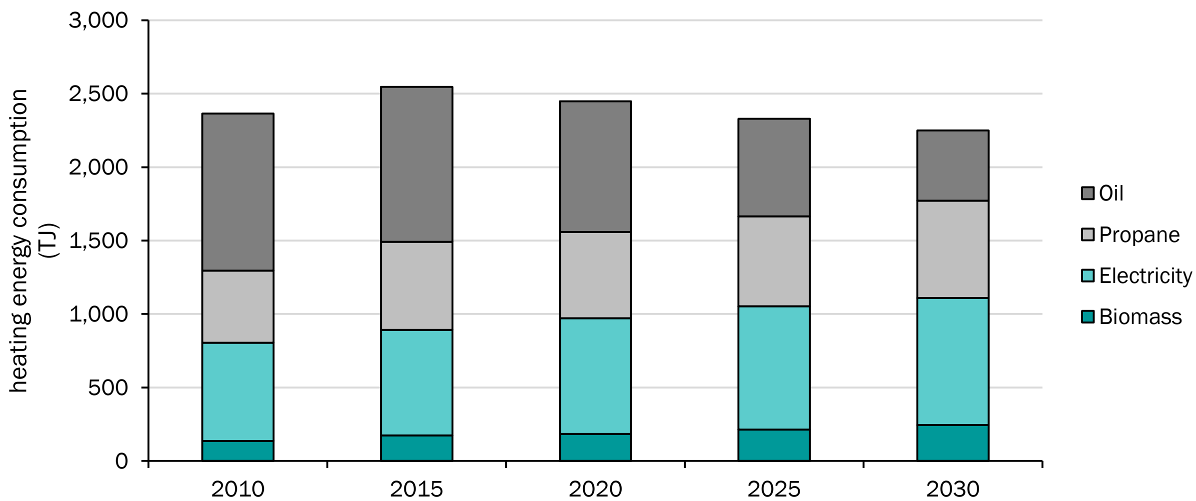
Second, consumers and businesses increasingly move away from oil heating to lower carbon (e.g., propane) and near zero carbon options (e.g., electricity and biomass). As shown in Figure 15, the share of oil consumption declines while that of propane, electricity and biomass increases in the existing policy forecast. The extent to which such fuel shifting will occur is ultimately uncertain and depends on future fuel prices (e.g., the difference between propane and electricity prices), consumer and business preferences (e.g., regarding the use of biomass heating) and policy. Nevertheless, the forecast captures observed trends in heating choices already being made in Yukon.

Table 7: Heating emissions by IPCC category, existing policy forecast (kt CO_2e)

	2010	2015	2020	2025	2030
IPCC category					
Manufacturing Industries	1	1	2	1	1
Commercial and Institutional	44	51	50	47	47
Residential	68	67	57	46	37
Total Heating	113	120	108	94	86

Please note that use of diesel for heating in mining operations is captured under the off-road/exempt category below. Source: Navius forecast using gTech.

Figure 15: Heating energy consumption, existing policy forecast (TJ)



Source: Navius forecast using gTech.

4.3.3. Transport (excluding off-road)

Transport emissions increase in the existing policy forecast reaching 463 kt in 2030 as shown in Table 8. This increase is driven by greater trucking activity and aviation. On the other hand, emissions from light-duty vehicles decline over time because improvements in fuel economy more than offset growing demand for travel.

Energy efficiency improvements in light-duty vehicles are the result of federal regulations, which set requirements for the fuel economy of new vehicles sold in Canada. As described in Section 4.1.2, these policies require that the average new car sold in 2025 has a fuel economy comparable to that of a 2019 Toyota Prius, while the average new light truck/SUV has a fuel economy comparable to a 2019 Toyota RAV4 Hybrid.

Table 8: Transport emissions by IPCC category, existing policy forecast (kt CO_2e)

	2010	2015	2020	2025	2030
IPCC category					
Domestic Aviation	44	46	54	62	69
Light-Duty Vehicles	161	165	166	143	128
Heavy-Duty Vehicles	220	231	247	260	265
Total Transport (excluding off-road)	**425**	**442**	**468**	**465**	**463**

Source: Navius forecast using gTech.

4.3.4. Mining

Emissions from mining reach 118 kt by 2030, as shown in Table 7. Most of these emissions (around 90%) are associated with off-road vehicles, with the remainder coming from stationary sources.

Table 9: Mining emissions by IPCC category, existing policy forecast (kt CO_2e)

	2010	2015	2020	2025	2030
IPCC category					
Stationary Combustion	5	4	6	8	9
Off-road	81	62	81	98	109
Total Mining	**87**	**66**	**87**	**107**	**118**

Source: Navius forecast using gTech.

4.3.5. Other off-road

Emissions from off-road sources (excluding mining) reach 3 kt by 2030, as shown in Table 7. These emissions arise from various industrial and commercial activities such as farming, hunting, sawmills, fishing, logging, tourism and trapping.

Table 10: Off-road emissions by IPCC category, existing policy forecast (kt CO_2e)

	2010	2015	2020	2025	2030
IPCC category					
Off-road	2	2	2	3	3

Source: Navius forecast using gTech.

4.3.6. Non-combustion

Non-combustion sources of greenhouse gas emissions decline over the existing policy forecast, reaching 16 kt in 2030. These emissions arise from two sources, as shown in

Table 11. The first category (other industrial processes and product use) includes the release of hydrofluorocarbons used in air conditioning and refrigerants. Emissions from these sources are expected to decline in response to current federal policy as described in Section 4.1.2.

The second category (waste) includes the release of methane from landfills as organic matter decomposes. Waste emissions remain largely constant over the forecast period.

Table 11: Non-combustion emissions by IPCC category, existing policy forecast (kt CO_2e)

	2010	2015	2020	2025	2030
IPCC category					
Other Industrial Processes and Product Use	12	15	14	10	6
Waste	8	9	10	10	10
Total Other	**20**	**24**	**25**	**21**	**16**

Source: Navius forecast using gTech.

5. How are Yukon's emissions expected to change in response to *Our Clean Future*?

This Chapter quantifies the impacts that the Government of Yukon's *Our Clean Future* policies are expected to have on the territory through 2030. These impacts are estimated by comparing a forecast that includes the new policies against the existing policy forecast described in the previous chapter.

An overview of *Our Clean Future* policies is provided in Section 5.1. The remainder of the Chapter reviews the effects that these policies are anticipated to have on greenhouse gas emissions (Section 5.2), the adoption of low carbon technologies and fuels (Section 5.2.3) and the economy (Section 5.4).

5.1. New policies

Our Clean Future includes a package of policies targeting greenhouse gas emissions from electricity supply, transport and buildings. These policies, and how they are modeled, are described below.

5.1.1. Electricity policies

- **Renewable portfolio standard for on-grid communities** assumes 93% of electricity on the Yukon Integrated System (i.e., Yukon's main electricity grid) is generated from renewable sources in 2025, increasing to 97% by 2030. This level of renewable electricity generation is based on successful implementation of the Yukon Energy Corporation's 10-year plan[29] that is designed to meet and exceed the requirement in *Our Clean Future* for 93 per cent of electricity on the main grid to come from renewables on average[30].

[29] Successful implementation of the projects identified in the Yukon Energy Corporation's 10-year plan depends on federal funding, First Nations partnerships and community participation and support.

[30] The Yukon Energy Corporation's 10-year plan is expected to exceed the forthcoming regulatory requirement for 93% of electricity on the Yukon Integrated System to come from renewable sources, calculated as a long-term average. The modelling also assumes certain percentages of renewable generation in 2025 and 2030 whereas the regulatory requirement will set a minimum long-term average renewable generation.

- **Renewable electricity projects and the use of clean diesel alternatives for electricity generation in off-grid communities** is assumed to result in a 45% decrease in diesel electricity generation in 2030, relative to 2010 levels. The 45% decrease is based on a target to have an operating renewable electricity project in all off-grid communities by 2030 that will reduce diesel consumption by 30% on average, as well as the use of diesel fuel for electricity generation that contains 20% biodiesel or renewable diesel by volume by 2030.

5.1.2. Transport policies

- **ZEV sales mandate for light-duty vehicles** requires that zero-emission vehicles account for a minimum share of new light-duty vehicle sales in the Yukon. The analysis assumes 10% of new sales are plug-in electric vehicles in 2025 reaching 30% by 2030.
- **ZEV purchase incentives for light-duty vehicles** provide a rebate of up to $5,000 for light-duty zero-emission vehicles between mid-2020 and April 2024. This policy is designed to roughly double current federal rebates.
- **Renewable diesel standard** requires a 20% minimum renewable content (by volume) in the transport diesel pool by 2025.
- **Renewable gasoline standard** requires a 10% minimum renewable content (by volume) in the transport gasoline pool by 2025.

5.1.3. Buildings policies

- **Low-interest financing for building retrofits** provides loans and rebates for major thermal energy efficiency retrofits. This policy is simulated by assuming that 0.66% of existing residential buildings and 0.64% of existing commercial and institutional buildings are retrofit each year that otherwise would not have been, consistent with the target in *Our Clean Future* to retrofit 2,000 buildings by 2030. It is further assumed that each retrofit reduces the building's greenhouse gas emissions by 30-40% depending on building type.
- **Heat pump incentives and low interest financing** provide loans and rebates of $16.6 million over 10 years for the adoption of heat pumps in residential buildings and $3.7 million for commercial and institutional buildings.
- **Biomass incentives and low interest financing** provide loans and rebates of $1.8 million over 10 years for the adoption of biomass heating systems in commercial and institutional buildings.

- **Incentives to retrofit existing buildings** allocate $16.4 million annually to improve residential and commercial building thermal efficiency and switch to low carbon heating options such as electricity and biomass, that are not included in the policies above. This policy is simulated by providing subsidies for electric and biomass heating equipment as well as efficient building shells.
- **Strengthened building codes** require that all new buildings meet strengthened envelope and energy performance improvements relative to the 2015 National Building Code as part of Yukon’s progression toward the commitment to net zero energy ready buildings by 2032. As Canada’s net zero energy ready codes are under development, the modelling has assumed envelope improvements of 10% in 2022 and 20% in 2027 and energy use improvements of 20% in 2022 and 40% in 2027.

5.1.4. Non-modeled policies

The greenhouse gas impacts of the following three policies were estimated outside of the modeling and added to the results ex poste:

- **Public and active transport** is assumed to achieve the target for the percentage of commuting trips made by drivers in single occupant vehicles to decrease to 55 per cent of all trips by 2031[31], as set out in the City of Whitehorse’s Transportation Demand Management Plan, through investments in public and active transportation infrastructure and subsidies to encourage alternative modes of transportation. The emissions reduction from achieving this mode share target was estimated based on the number of kilometres of single occupant vehicle commuting trips that could be avoided by meeting the target and an average CO_2e emissions per kilometre travelled based on Navius model results.
- **Retrofits and renewable heating for Government of Yukon buildings** is estimated to reduce greenhouse gas emissions by 8 kt in 2030 through the building retrofit and renewable heating projects that have been identified to reach the target in *Our Clean Future* to reduce greenhouse gas emissions from Government of Yukon buildings by 30% by 2030 compared to 2010 levels.
- **Biofuel blending for on-grid diesel generation** assumes a 20% minimum renewable content (by volume) in diesel used for electricity generation on the Yukon Integrated System (i.e., Yukon’s main electricity grid) by 2030.

---

[31] Because the model forecast ends in 2030, the emissions reduction calculation assumes that Yukon will reach this target in 2030 rather than 2031.

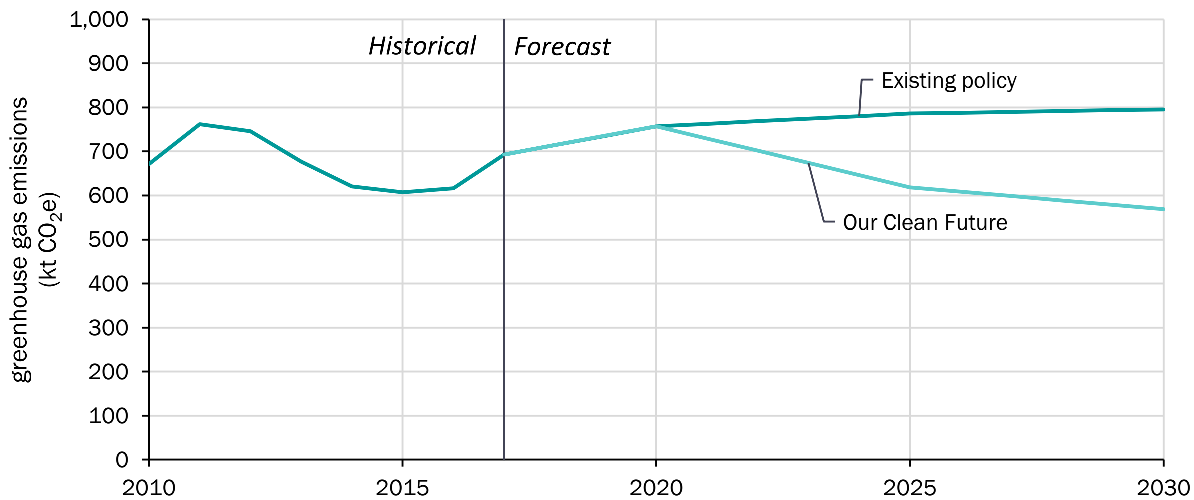
These policies were not modelled by Navius because (1) the level of effort to accurately model them in gTech was high relative to their expected emissions abatement or (2) they weren't finalized until after the bulk of the modeling was complete.

5.2. Greenhouse gas impacts

5.2.1. Impacts on total emissions

The electricity, buildings and transport policies included in *Our Clean Future* are anticipated to reduce Yukon's total greenhouse gas emissions by 227 kt in 2030, as shown in Figure 16. These policies are anticipated to result in territorial emissions declining to 569 kt in 2030, relative to 796 kt in the existing policy forecast.

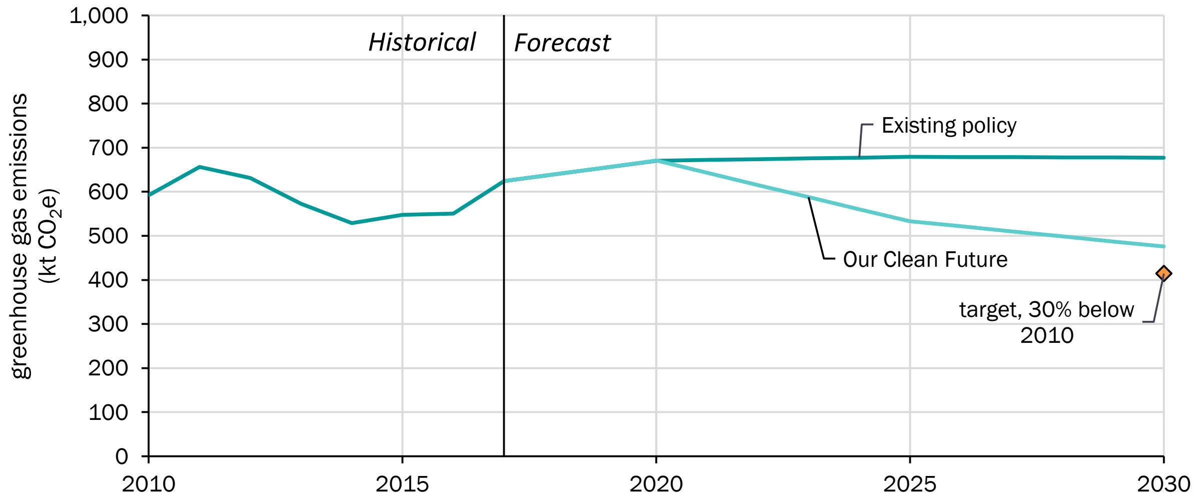
Figure 16: Impact of *Our Clean Future* on Yukon's total emissions



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by the Yukon Climate Change Secretariat. (2) Navius forecast using gTech, including the impacts of non-modeled policies as described in Section 5.1.4.

Figure 17 provides a forecast excluding emissions from the mining sector. It shows that in response to new policies, non-mining emissions are anticipated to decline to 476 kt, which is 62 kt above the target of 30% below 2010 levels. As a result, *Our Clean Future* closes 77% of the gap to Yukon's 2030 greenhouse gas target for non-mining emissions.

Figure 17: Impact of *Our Clean Future* on Yukon's non-mining emissions



Sources: (1) Yukon greenhouse gas inventory, provided to Navius by the Yukon Climate Change Secretariat. (2) Navius forecast using gTech, including the impacts of non-modeled policies as described in Section 5.1.4.

5.2.2. Impacts by emissions source

The new policies reduce greenhouse gas emissions associated with most fuel types, as shown in Figure 18. These reductions are measured relative to the existing policy forecast described in the previous chapter:

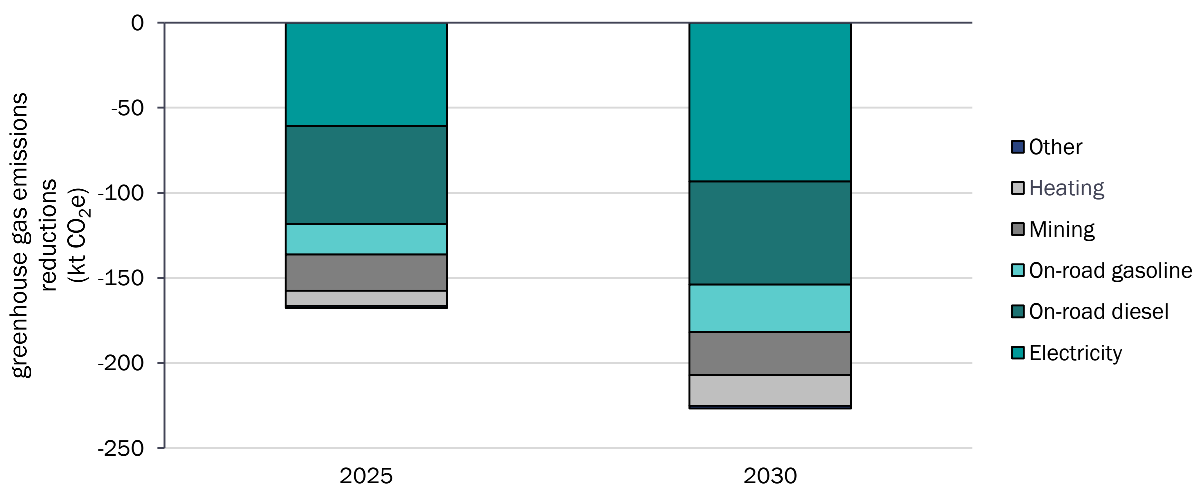
- The electricity sector accounts for the largest change in emissions (93 kt in 2030) due to greater adoption of renewable electricity compared to the existing policy forecast without new renewable electricity generation projects. These emissions reductions are driven by three actions, including (1) 97% of grid-supplied electricity being generated from renewable sources like hydro, wind and solar in 2030, (2) renewable fuels accounting for 20% (by volume) of remaining liquid fuel consumption for on-grid thermal generation and (3) increased adoption of renewable generation in remote communities, including biofuels, that decreases diesel consumption by 45% relative to 2010.
- Emissions from the combustion of diesel for on and off-road transport (including mining), decrease by 86 kt in 2030, primarily due to increased blending of renewable fuels into the on- and off-road diesel pools. The renewable diesel standard mandates that biofuels like biodiesel and hydrogenation-derived renewable diesel account for 20% (by volume) of the diesel pool by 2025.
- Emissions from gasoline consumption decrease by 28 kt due to the zero emissions vehicle mandate and renewable gasoline standard. The zero emissions vehicle

mandate requires that zero emission vehicles account for a growing share of light-duty vehicle sales, reaching 30% by 2030. This policy results in a transition towards electricity as transport fuel (which, as described above, is largely generated from renewable sources). Concurrently, the renewable gasoline standard reduces the emissions intensity of the remaining gasoline pool by requiring a 10% minimum renewable content (by volume) by 2025.

- Lastly, emissions from heating are reduced by 18 kt due to a variety of financial incentives for low carbon heating equipment and building retrofits, as well as strengthened building codes for new buildings. These policies improve the thermal efficiency of buildings (reducing total energy demand) and also encourage greater adoption of near zero carbon heating equipment like heat pumps and biomass heating systems.

The greenhouse gas emissions from each fuel type are also influenced by other factors that are accounted for in the modeling, including economic effects (e.g., the policies induce changes in Yukon's economy which impact demand for energy services) and policy interactive effects (e.g., the zero emissions vehicle mandate boosts demand for electricity, which changes electricity sector emissions).

Figure 18: Greenhouse gas reductions by sector, *Our Clean Future*



Source: Navius forecast using gTech, including the impacts of non-modeled policies as described in Section 5.1.4. Reductions are measured relative to expected emissions in the existing policy forecast.

5.2.3. Impacts by policy

Table 12 identifies the greenhouse gas impact of each *Our Clean Future* policy. These policies generally target different sources of emissions, but they also interact in many ways. For example, efforts to decarbonize the electricity sector increase the emissions reductions associated with electrification of buildings and vehicles. On the other hand, some policies can reduce the effects of others. For example, thermal shell efficiency improvements have no impact on direct greenhouse gas emissions if a building is heated electrically. Due to such dynamics, the net impact of all policies implemented together differs from the sum of individual policy impacts.

Table 12: Greenhouse gas impact in 2030

Policy	Greenhouse gas impact in 2030 ($kt\ CO_2e$)
Electricity	
Renewable portfolio standard for on-grid communities	-79
Renewable generation and biofuels for remote communities	-12
Biofuel blending for on-grid diesel generation*	-2
On- and off-road transport	
Zero emission vehicle standard and subsidy for light-duty vehicles	-13
Renewable fuel content for diesel	-84[32]
Renewable fuel content for gasoline	-11
Public and active transport*	-6
Buildings	
Low-interest financing for building retrofits	-3
Heat pump and biomass incentives	-5
Incentives to retrofit existing buildings	-4
Building code	-5
Reduce emissions from Yukon Government operations*	-8
Total policy package	-227

Source: Navius forecast using gTech, including the impacts of non-modeled policies as marked (*).

[32] Of the 84 kt of abatement anticipated from the renewable fuel content for diesel policy, 25 kt would reduce greenhouse gas emissions from the mining sector. The remaining 59 kt would contribute to reaching Yukon's 30% greenhouse gas reduction target for 2030.

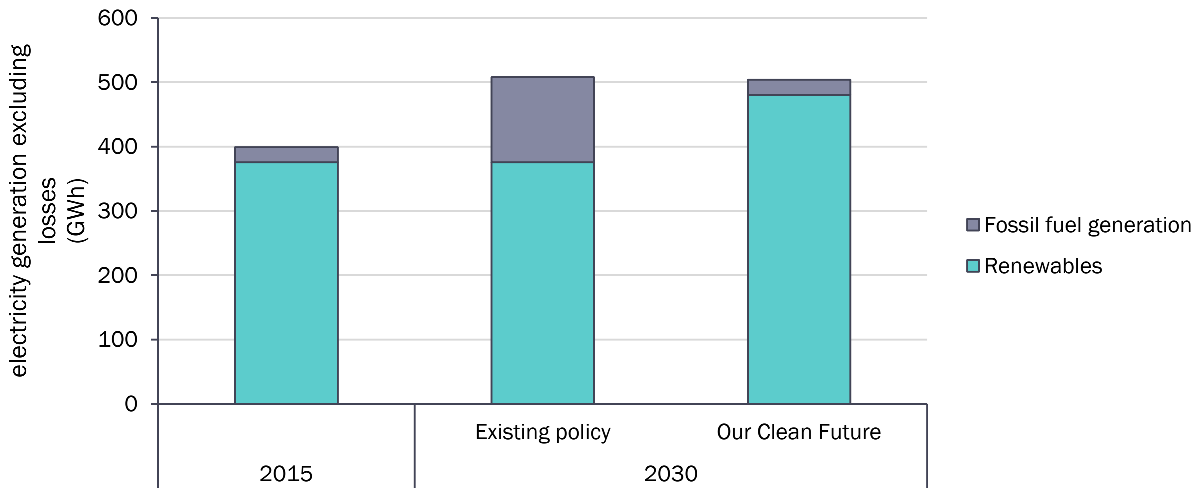
5.3. Technology and fuel transformation

The package of policies specified in *Our Clean Future* reduces territorial greenhouse gas emissions because it transforms the technologies used to supply and consume energy in Yukon. This transformation is described below.

5.3.1. Utility electricity generation

Our Clean Future maintains a decarbonized electricity supply in Yukon by requiring further investment in renewable sources like hydro, wind and solar. Electricity generation is forecast to grow in Yukon to meet rising demand, from 399 GWh in 2015 to over 500 GWh in 2030[33] (see Figure 19). *Our Clean Future*, in combination with the Yukon Energy Corporation's 10-year plan, ensures that this growth in electricity demand is met from renewable sources.

Figure 19: Utility electricity generation under *Our Clean Future*



Source: Navius forecast using gTech. May differ from electricity demand and generation forecasts completed by the Yukon Energy Corporation due to differences in modelling approaches and assumptions.

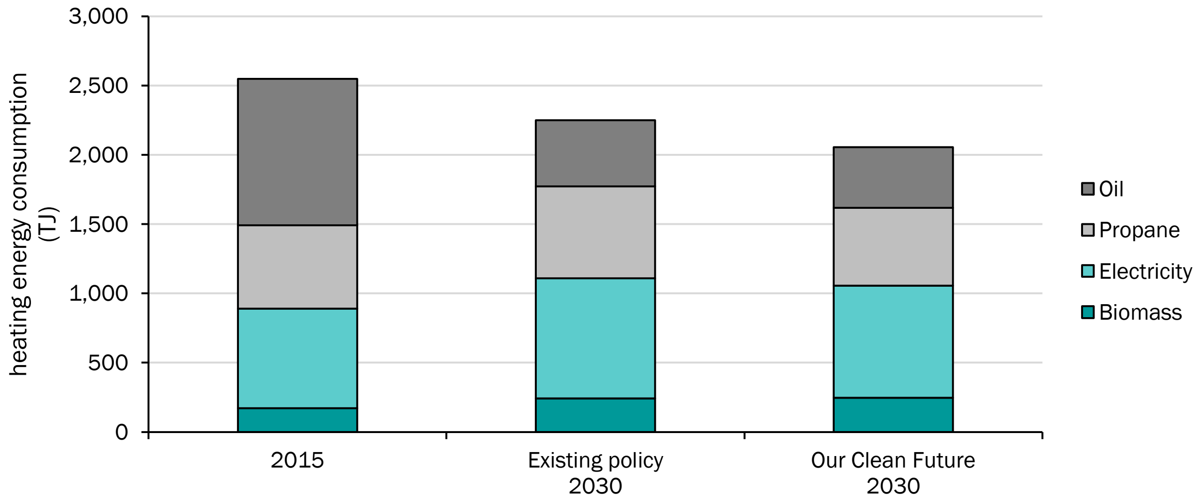
Decarbonizing electricity generation is important not only for reducing emissions from this sector itself, but also because electrification – switching from fossil fuels to clean electricity – is one of the most important actions for reducing emissions from buildings, transport and industry in Yukon.

[33] Forecasted electricity demand growth is based on assumptions about overall economic growth in Yukon, energy prices (including the cost of producing electricity in Yukon), technological change, and territorial and federal policies. Efforts were made to align assumptions with those used by the Yukon Energy Corporation where possible, though forecast differences remain because of the use of different modeling frameworks. Despite differences between the forecasts, this analysis demonstrates the effectiveness of new policies at ensuring a low carbon electricity supply in Yukon.

5.3.2. Heating

Our Clean Future accelerates improvements in the emissions intensity of buildings by increasing building thermal efficiency (reducing total energy demand) and encouraging greater adoption of near zero carbon heating equipment like heat pumps and biomass furnaces. These trends are already occurring in the existing policy forecast, as shown in Figure 20 and discussed in Section 4.3. *Our Clean Future* further reduces heating energy consumption (from 2249 TJ to 2056 TJ in 2030) and boosts the share of renewable heating energy consumption to over half.

Figure 20: Heating energy consumption under *Our Clean Future*

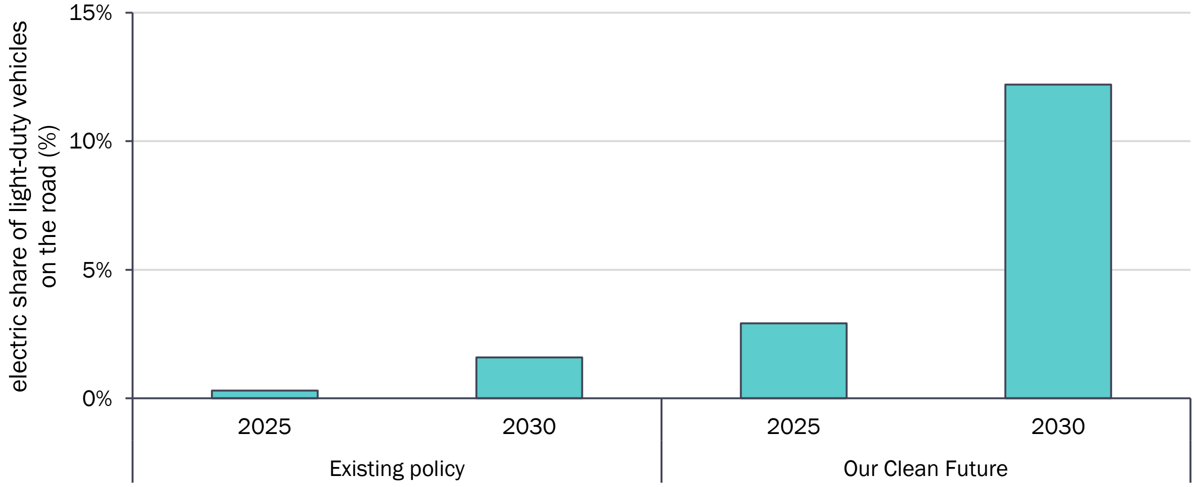


Source: Navius forecast using gTech. Includes energy used for space conditioning and water heating.

5.3.3. On- and off-road transport

Our Clean Future decreases greenhouse gas emissions from on- and off-road driving by boosting the adoption of electric vehicles and blending biofuels into the remaining gasoline and diesel pools. As shown in Figure 21, in the existing policy forecast, electric vehicles (including battery electric and plug-in hybrid electric) account for 2% of light-duty vehicles on the road in 2030. *Our Clean Future* causes the share of electric vehicles to increase further, to 12% in 2030. This increase is due to the zero-emissions vehicle standard, which requires that automakers sell a growing share of these vehicles in Yukon over time. While hydrogen-powered vehicles would also qualify for compliance under this policy, this technology was not included in the modeling due to the technology's less advanced state of commercial development.

Figure 21: Plug-in electric light-duty vehicles on the road

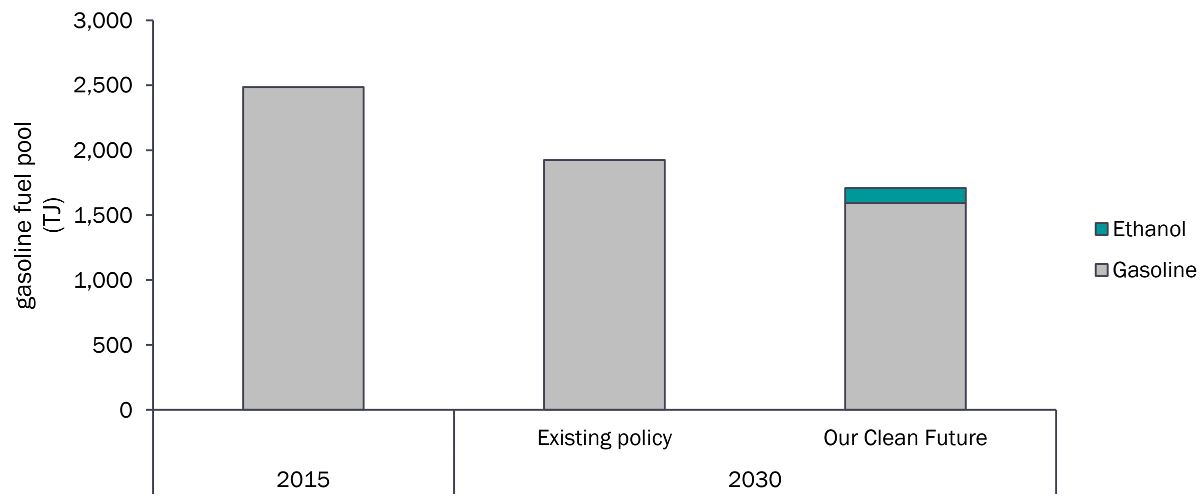


Source: Navius forecast using gTech.

By increasing the number of electric vehicles on the road, *Our Clean Future* decreases demand for gasoline. Gasoline pool demand is expected to drop in the existing policy forecast, driven by federal fuel economy regulations. *Our Clean Future* further reduces gasoline pool demand, to 1594 TJ in 2030 (down from 1926 TJ in the existing policy forecast), as shown in Figure 22.

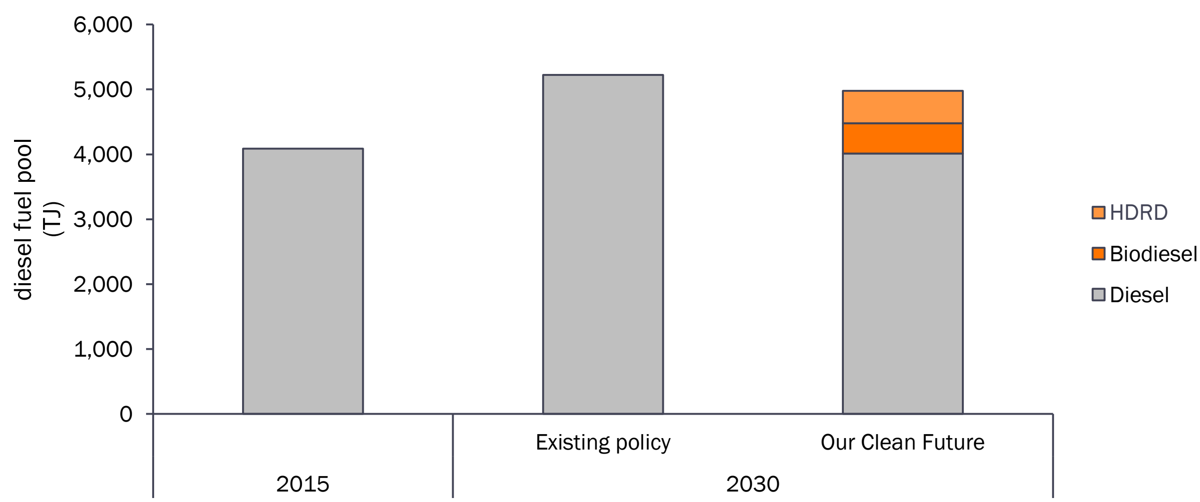
Our Clean Future also increases the amount of biofuel that is blended into the remaining fuel pools, reducing emissions from on- and off-road vehicles with an internal combustion engine (please see Figure 21 and Figure 22). As described in Section 5.1, the gasoline and diesel fuel standards require that renewable fuels account for 20% of the diesel pool and 10% of the gasoline pool by 2025 (by volume). Based on the cost of biofuel production pathways, the forecast suggests that compliance would be achieved by blending (1) biodiesel and hydrogenation-derived renewable diesel (HDRD) into the diesel pool and (2) ethanol into the gasoline pool.

Figure 22: Gasoline pool demand



Source: Navius forecast using gTech.

Figure 23: Diesel pool demand



Source: Navius forecast using gTech.

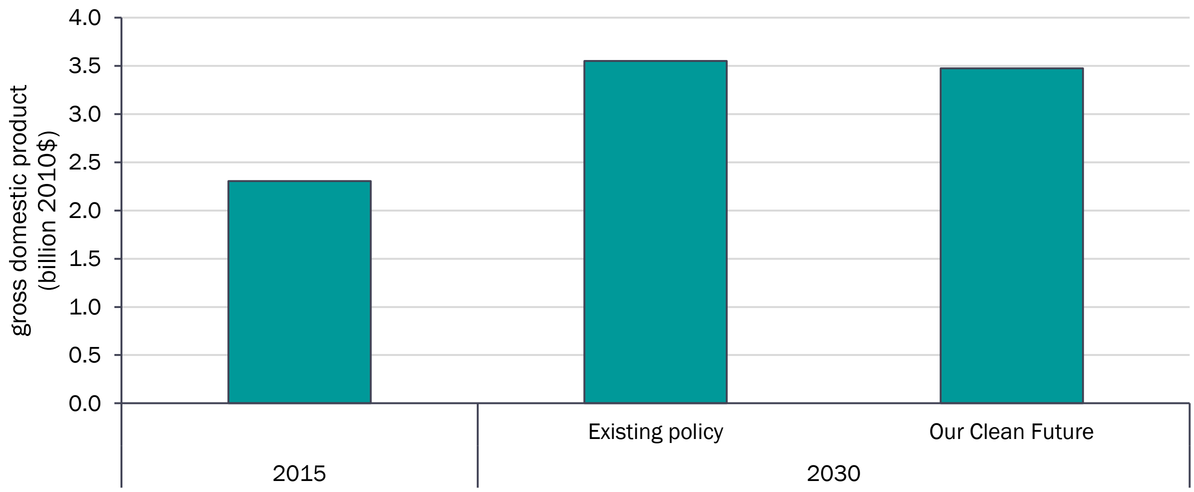
5.4. Economic impacts

5.4.1. GDP

Yukon's economy continues to grow under key greenhouse gas reduction policies in *Our Clean Future*. In the existing policy forecast, the territorial economy is assumed to grow at an average annual rate of 2.5% through 2030. As shown in Figure 24, this means that GDP increases from $2.30 billion in 2015 (2010$) to $3.55 billion in 2030. With the key greenhouse gas reduction policies in *Our Clean Future*, the rate of GDP growth is lower (2.3% annually), resulting in 2030 GDP of $3.47 billion. Yet, the economy still grows under *Our Clean Future,* and by 2030 it is 1.5 times larger than today.

This assessment does not account for policies in *Our Clean Future* that were not modelled, including climate change adaptation policies, or the benefits of avoided climate change on the economy,

Figure 24: Impact on GDP



Source: Navius forecast using gTech.

5.4.2. The clean energy economy

A key objective for *Our Clean Future* is to encourage the transition towards a green economy. A clean energy economy, as defined in Section 3.5, would produce many of the same goods and services as today's while emitting fewer greenhouse gas emissions.

Before discussing the effect of *Our Clean Future* on Yukon's clean energy economy, it is important to highlight that most investment and consumption in Yukon is unrelated to energy consumption or greenhouse gas emissions. For example, in the existing policy forecast:

- Industry investment in 2030 is $834 million (2020$).[34] Of this total, about $42 million relates to energy (e.g., engines for heavy-duty vehicles, building heating systems), with the remaining $792 million not directly related to energy (e.g., software development services, furniture).
- Likewise, energy-related "investments" by households represent a fraction of total household consumption[35]. In 2030, total household consumption is estimated to reach $2.1 billion (2020$). Of this amount, about $37 million relates to energy (e.g., building insulation and furnaces), with the remaining $2.0 billion not directly related to energy (e.g. kitchen renovations, health care, Netflix subscriptions).

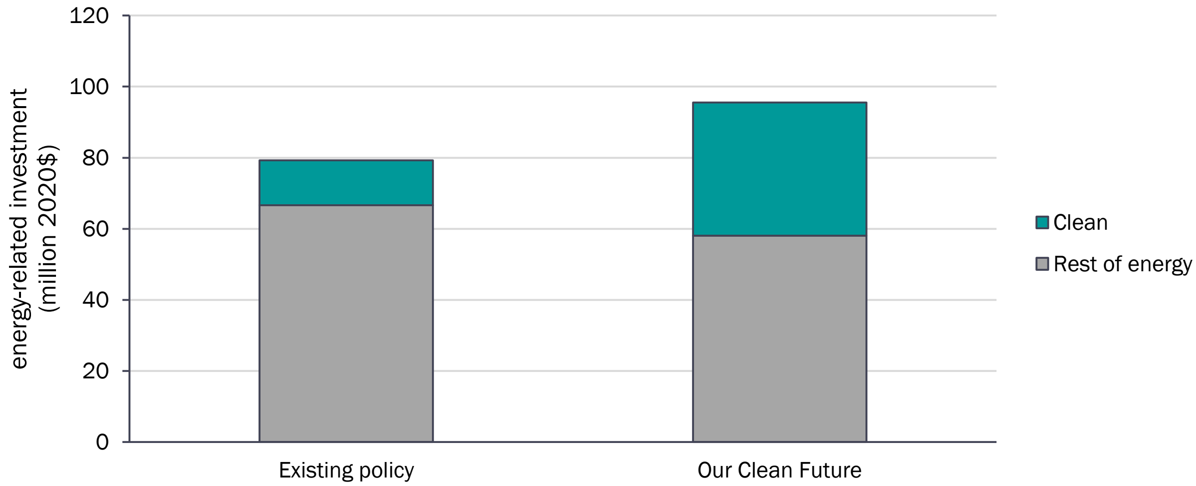
Within energy-related investment, *Our Clean Future* leads to a shift towards a cleaner economy (please see Figure 25). The policies nearly triple clean energy investment (including energy-related investments by households) from $13 million under existing policies to $37 million under *Our Clean Future*. The increase in investment is concentrated in renewable electricity supply, electric vehicles and buildings. This shift is partially offset by less investment in the "rest of energy", which declines from $67 million to $58 million due to less investment in conventional energy technologies, such as oil furnaces and internal combustion vehicles. However, the territory experiences a total increase in energy-related investment of $16 million.

---

[34] Excluding residential construction.

[35] As mentioned in Section 3.5, household consumption of energy-related technologies is reported as investment.

Figure 25: Total energy-related investment in 2030

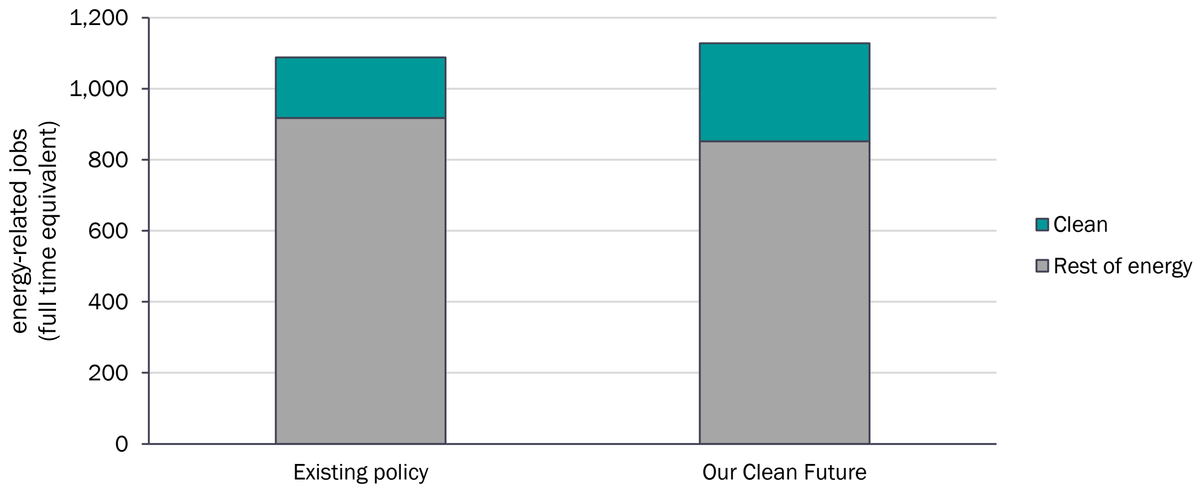


Includes household consumption of energy-related technologies. Source: Navius forecast using gTech.

Similar to investment, jobs in energy-related sectors account for a small portion of total employment. In 2030, energy-related jobs account for about 4% of all jobs in the territory under the new policy forecast.

Our Clean Future also results in a shift toward clean energy jobs, as shown in Figure 26. The implementation of *Our Clean Future* increases clean energy employment by 106 jobs in 2030. These jobs include those related to the construction of low carbon buildings, the generation of renewable electricity and using electric vehicles to provide transport services. This increase is partially offset by a decline in the rest of energy by 80, but total employment in the energy-related sector increases by about 49 jobs compared to the existing policy forecast.

Figure 26: Impact on energy-related jobs in 2030



Source: Navius forecast using gTech.

5.5. Uncertainty

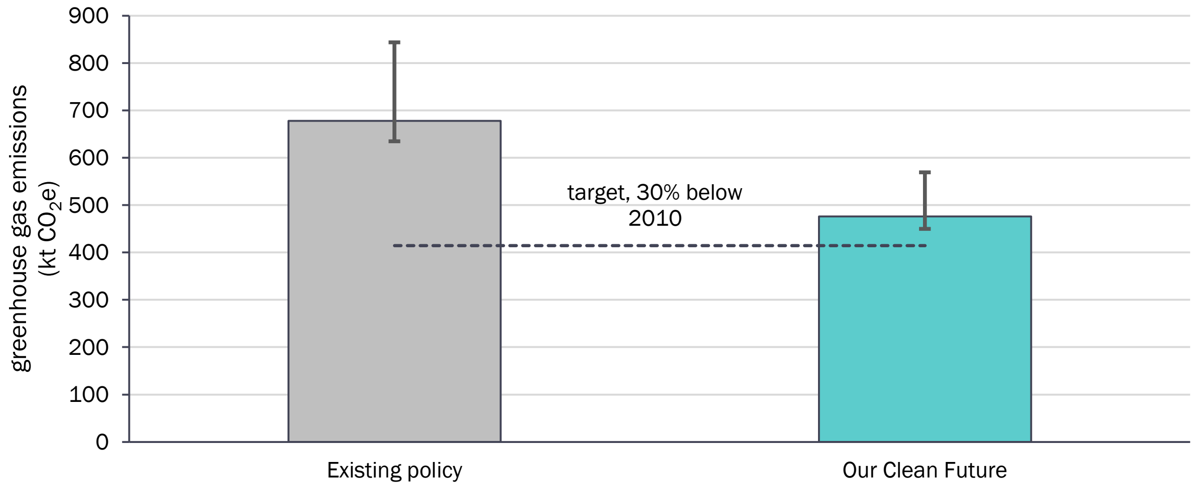
Yukon's future greenhouse gas emissions are uncertain and are influenced by a variety of factors, many of which are outside of Yukon's control.

For example, Figure 27 shows the impact of varying levels of economic growth on Yukon's non-mining emissions in 2030. It demonstrates that (1) *Our Clean Future* will get Yukon closer to its 2030 greenhouse gas targets but also that (2) the remaining gap to the target is uncertain, ranging from 36 kt to 155 kt.

Yukon's greenhouse gas emissions are also influenced by the emissions intensity of economic activity. In addition to territorial policy, emissions intensity depends on other factors, such as whether federal policy is tightened or relaxed (e.g., fuel economy standards for new vehicles), future energy prices (e.g., oil prices affect the relative attractiveness of many low carbon technologies in the North) and the pace of technological change (e.g., the cost and performance of cold weather heat pumps).

The implication of this uncertainty is that achieving Yukon's greenhouse gas target requires assessing progress along the way, updating greenhouse gas projections based on new information and modifying policies if necessary. Uncertainty analysis can also help by identifying policies that perform well under a range of future developments.

Figure 27: Non-mining greenhouse gas emissions in 2030



Source: Navius forecast using gTech.

Appendix A: Covered sectors, fuels and end-uses in gTech

Table 13: Covered sectors

Sector name	NAICS code
Soybean farming	11111
Oilseed (except soybean) farming	11112
Wheat farming	11114
Corn farming	11115
Other farming	Rest of 1111
Animal production and aquaculture	112
Forestry and logging	113
Fishing, hunting and trapping	114
Agriculture services	115
Natural gas extraction (conventional)	211113
Natural gas extraction (tight)	
Natural gas extraction (shale)	
Light oil extraction	
Heavy oil extraction	
Oil sands in-situ	211114
Oil sands mining	
Bitumen upgrading (integrated)	
Bitumen upgrading (merchant)	
Coal mining	2121
Metal mining	2122
Non-metallic mineral mining and quarrying	2123
Oil and gas services	213111 to 213118
Mining services	213119
Fossil-fuel electric power generation	221111
Hydro-electric and other renewable electric power generation	221112 and 221119
Nuclear electric power generation	221113
Electric power transmission, control and distribution	22112
Natural gas distribution	222
Construction	23
Food manufacturing	311
Beverage and tobacco manufacturing	312

Sector name	NAICS code
Textile and product mills, clothing manufacturing and leather and allied product manufacturing	313-316
Wood product manufacturing	321
Paper manufacturing	322
Petroleum refining	32411
Coal products manufacturing	Rest of 324
Petrochemical manufacturing	32511
Industrial gas manufacturing	32512
Other basic inorganic chemicals manufacturing	32518
Other basic organic chemicals manufacturing	32519
Biodiesel production from canola seed feedstock	
Biodiesel production from soybean feedstock	
Ethanol production from corn feedstock	
Ethanol production from wheat feedstock	
HDRD (or HRD) production from canola seed feedstock	
Renewable gasoline and diesel production	
Cellulosic ethanol production	
Resin and synthetic rubber manufacturing	3252
Fertilizer manufacturing	32531
Other chemicals manufacturing	Rest of 325
Plastics manufacturing	326
Cement manufacturing	32731
Lime and gypsum manufacturing	3274
Other non-metallic mineral products	Rest of 327
Iron and steel mills and ferro-alloy manufacturing	3311
Electric-arc steel manufacturing	
Steel product manufacturing from purchased steel	3312
Alumina and aluminum production and processing	3313
Other primary metals manufacturing	3314
Foundries	3315
Fabricated metal product manufacturing	332
Machinery manufacturing	333
Computer, electronic product and equipment, appliance and component manufacturing	334 and 335
Transportation equipment manufacturing	336
Other manufacturing	Rest of 31-33
Wholesale and retail trade	41-45
Air transportation	481
Rail transportation	482
Water transportation	483

Sector name	NAICS code
Truck transportation	484
Transit and ground passenger transportation	485
Pipeline transportation of crude oil	4861 and 4869
Pipeline transportation of natural gas	4862
Other transportation, excluding warehousing and storage	4867-492
Landfills	Part of 562
Services	Rest of 51-91

Table 14: Covered fuels

Fuel
Fossil fuels
Coal
Coke oven gas
Coke
Natural gas
Natural gas liquids
Gasoline and diesel
Heavy fuel oil
Still gas
Electricity
Electricity
Renewable fuels (non-transportation)
Spent pulping liquor
Wood
Wood waste (in industry)
Renewable natural gas
Renewable fuels (transportation)
Ethanol produced from corn
Ethanol produced from wheat
Cellulosic ethanol
Biodiesel produced from canola
Biodiesel produced from soy
Hydrogenated renewable diesel (“hdrd”)
Renewable gasoline and diesel from pyrolysis of biomass
Renewable natural gas

Table 15: Covered end-uses

End use
Stationary industrial energy/emissions sources
Fossil-fuel electricity generation
Process heat for industry
Process heat for cement and lime manufacturing
Heat (in remote areas without access to natural gas)
Cogeneration
Compression for natural gas production and pipelines
Large compression for LNG production
Electric motors (in industry)
Other electricity consumption
Transportation
Air travel
Buses
Rail transport
Light rail for personal transport
Marine transport
Light-duty vehicles
Trucking freight
Diesel services (for simulating biodiesel and other renewable diesel options)
Gasoline services (for simulating ethanol options)
Oil and gas fugitives
Formation co2 removal from natural gas processing
Flaring in areas close to natural gas pipelines
Flaring in areas far from natural gas pipelines
Venting and leaks of methane (oil and gas sector)
Industrial process
Mineral product GHG emissions
Aluminum electrolysis
Metallurgical coke consumption in steel production
Hydrogen production for petroleum refining and chemicals manufacturing
Non-fuel consumption of energy in chemicals manufacturing
Nitric acid production
Agriculture
Process CH4 for which no know abatement option is available (enteric fermentation)
Manure management
Agricultural soils
Waste
Landfill gas management

End use
Residential buildings
Single family detached shells
Single family attached shells
Apartment shells
Heat load
Furnaces
Air conditioning
Lighting
Dishwashers
Clothes washers
Clothes dryers
Ranges
Faucet use of hot water
Refrigerators
Freezers
Hot water
Other appliances
Commercial buildings
Food retail shells
Office building shells
Non-food retail shells
Educational shells
Warehouses (shells)
Other commercial shells
Commercial heat load
Commercial hot water
Commercial lighting
Commercial air conditioning
Auxiliary equipment
Auxiliary motors (in commercial buildings)

At Navius, we offer our clients the confidence to make informed decisions related to energy, the economy, and the environment.

We take a collaborative approach to projects, drawing on a unique suite of modeling, research and communication tools to provide impartial analysis and clear advice.