ST. JOHN'S

Resilient St. John's Community Climate Plan: Energy Transition

SSG

February 2022

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This project was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

Preliminary Matter

Land Acknowledgements

We respectfully acknowledge the Province of Newfoundland & Labrador, of which the City of St. John's is the capital city, as the ancestral homelands of the Beothuk. Today, these lands are home to a diverse population of Indigenous and other peoples. We also acknowledge, with respect, the diverse histories and cultures of the Mi'kmaq, the Innu, the Inuit, and the Southern Inuit of this Province.

Acknowledgments

Many residents and organizations contributed to the development of this plan throughout the various engagement stages, including public engagement and consultation, membership of the Multi-Stakeholder Sustainability Team, St. John's Environmental and Sustainability Experts Panel, and St. John's Corporate Energy Team. We also thank all the residents and organizations who reached out to staff and council, completed online surveys, hosted do-it-yourself climate change workshops, and attended any virtual sessions or council meetings.

St. John's Environmental and Sustainability Experts Panel

- Kieran Hanley
- Joel Finnis
- Krista Langthorne
- Pablo Navarro
- Joseph Daraio
- Michel Wawrzkow
- Dennis Knight

Multi-Stakeholder Sustainability Team

- Government of Newfoundland and Labrador
- Food First NL
- NAACAP
- Healthy City St. john's
- Bike St. John's
- Newfoundland Federation of Agriculture
- Econext (NEIA)
- Memorial University
- CCNL
- Professional Engineers and Geoscientists Newfoundland & Labrador
- Ducks Unlimited Canada
- Quidi Vidi / Rennies River Development Foundation
- CMHC
- Department of Fisheries and Oceans
- AIM network
- Metrobus
- St. John's Airport (YYT)
- Newfoundland Power
- Home Builders Association
- BOMA NL
- NOIA
- MMSB
- Destination St. John's
- St. John's Board of Trade
- Canadian Home Builders' Association
- Grand Concourse Authority
- MUN Botanical Gardens
- Drive Electric NL
- North Atlantic
- Martin Batterson
- East Coast Trail
- FFAW
- Newfoundland and Labrador Public Health Association
- SWANA

Additionally, we thank First Voice and First Light for supporting an ongoing conversation about the role of this plan and environment and climate action more broadly in the healing process of the Indigenous peoples in the community.

Data Acknowledgements

- Government of Newfoundland and Labrador
- Harris Centre, particularly the Regional Analytics Laboratory (RAnLab)
- Government of Canada, Canada's Changing Climate Report
- Climate Atlas of Canada
- Newfoundland Power

A Note on COVID19

The COVID-19 pandemic significantly changed the way we live, work, and play in our City. The pandemic has had several negative economic and environmental consequences. Many governments, including the Canadian government, are strategizing how economic recovery packages can be used to “build back better” and support an equitable transition to a resilient low-carbon society. It is also in the interest of Municipalities to consider green recovery and support initiatives that help adapt to climate change, reduce greenhouse gas emissions, and increase overall well-being.

Acronyms

BAU	business-as-usual
CO2e	carbon dioxide equivalents
EV	electric vehicles
GHG	greenhouse gas emissions
Kt	kilotonne
t	tonne

Disclaimer

Reasonable skill, care, and diligence has been exercised to assess the information acquired during the preparation of this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains, the information and basis on which it relies, and associated factors are subject to changes that are beyond the control of the authors. The information provided by others is considered to be accurate but has not been verified.

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How to Read this Report

This report summarizes St. John's Community-wide Energy Transition.

St. John's Climate Action Context sets the scene, including information on the 2050 GHG emissions target, the community's energy, and greenhouse gas (GHG) emissions in a business-as-usual scenario, the net-zero GHG emissions transition pathway, and the Transition's overall projected economic impacts.

Sector-by-Sector Transition Pathways lays out the net-zero pathway actions by sector—for transportation, buildings, clean energy, waste, and land use—their key near-term (i.e., first 5 years) implementation strategies and benefits. Targets for each of the actions within the Transition pathway that would lead to a net-zero future can be found in Appendix A. The approach for each of the implementation strategies in this document will be refined through public consultation as they move toward implementation.

Moving Forward outlines the City's unique role in administering and reporting on the Transition, and as a leader in taking on climate action with its own assets. It also includes a discussion on the types of collaboration and innovation that will be needed to bring the Transition to life, as well as the oversight needed to keep it on track and ensure accountability. Finally, this section highlights the need for equitable program design to ensure investments are deployed in a manner that benefits the entire community.

The **Appendices** contain the technical analysis that underpin the Energy Transition. These are referenced throughout this report.

For clarity, the action plans for adaptation and mitigation are being released separately but were developed together, through a holistic approach.

St. John’s Climate Action Context

What is St. John’s Energy Transition?

St. John’s declared a climate emergency in 2019 and committed to a target of net-zero greenhouse gas (GHG) emissions by 2050. This target aligns with dozens of communities across the country, as well as the Provincial and Federal governments (see the Textbox: St. John’s Climate Target in Context). Net zero means reducing as much GHGs as possible, then offsetting the little that remains. All levels of governments are setting targets for net-zero emissions because each has a critical role to play in achieving the GHG reductions needed to address the climate crisis.

Newfoundland and Labrador (NL) released Climate Change Action Plan 2019-2024, which was built on commitments to reduce NL’s GHG emissions by 10% below 1990 levels by 2020,reduce provincial GHG emissions by 30% below 2005 GHG emissions level by 2030, and a commitment to net-zero emissions by the year 2050. Municipalities play the most direct role in their residents' everyday lives and associated energy and GHG emissions—including community buildings; the shape of their streets and public spaces; the route and frequency of transit; and community development and redevelopment standards. Municipalities advocate on behalf of their communities to higher levels of government, to institutions and businesses, and to utilities in order to support and shape local economic development. This Energy Transition (or ‘Transition’) is the evidence-based and community-tailored pathway for how the City of St. John's can use its influence to achieve community-wide net-zero GHGs by 2050.

St. John's Climate Target in Context

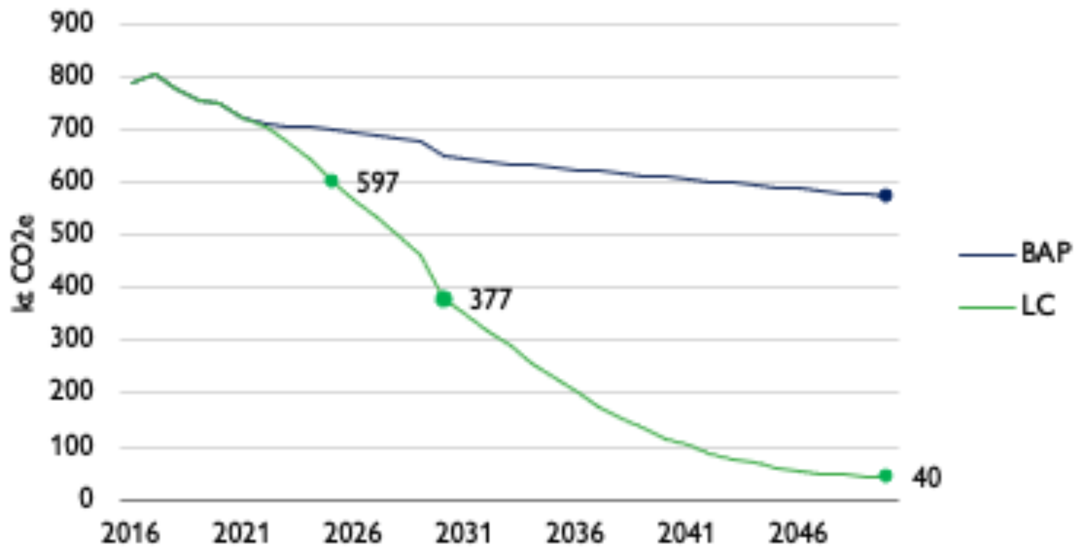
In November 2019, St. John's City Council declared a climate emergency and set a community-wide target of net-zero GHG emissions by 2050. The Province followed suit in May 2020 and committed to reaching net-zero by 2050, followed by the Federal government in July 2021. Hence, St. John's can be considered one of the municipalities that paved the way for climate action in the region, joining the ranks of hundreds of other cities around the globe. St. John's is part of national partnerships like the Partners for Climate Protection, the Global Covenant of Mayors for Climate and Energy, and most recently, the Cities Race to Zero. As of December 2021, 733 cities around the world have joined the global Cities Race to Zero campaign.[1]

Municipalities have the benefit of being nimble and the ability to act more quickly to respond to their community's needs than higher levels of government. They also have unique resources to enable climate action, from operating transit and waste systems to determining land use and setting development standards.

Moving forward, the City can continue to be a climate leader by moving beyond its 2050 point-in-time target to setting an interim target, and annual caps for emissions in every year leading up to 2050. This last action is referred to as a carbon budget and is a best practice for establishing science-based climate action. Every tonne of emissions counts, not just those released in 2050.

Community-wide modeling results show that to achieve net-zero by 2050 (at the latest) St. John's should follow a pathway of emission reductions of approximately 25% by 2025, and 50% by 2030 from the 2016 baseline. This means capping emission to 600 kt COe2 by 2025, 380 kt CO_2e by 2030, and zero by 2050 at the latest.

[1] See: https://unfccc.int/climate-action/race-to-zero-campaign.



The Transition is first and foremost an energy transition away from fossil fuels toward an energy-efficient and renewable energy-powered future. These energy-related GHG emissions represent the bulk of the community's GHG emissions (92% of the total 573 ktCO2e in a 2050 business-as-usual (BAU) scenario, see Figure 1). The Transition also addresses the remaining 8%, which are the community's non-energy GHG emissions (i.e. from organic waste), as well as potential natural carbon sequestration solutions.

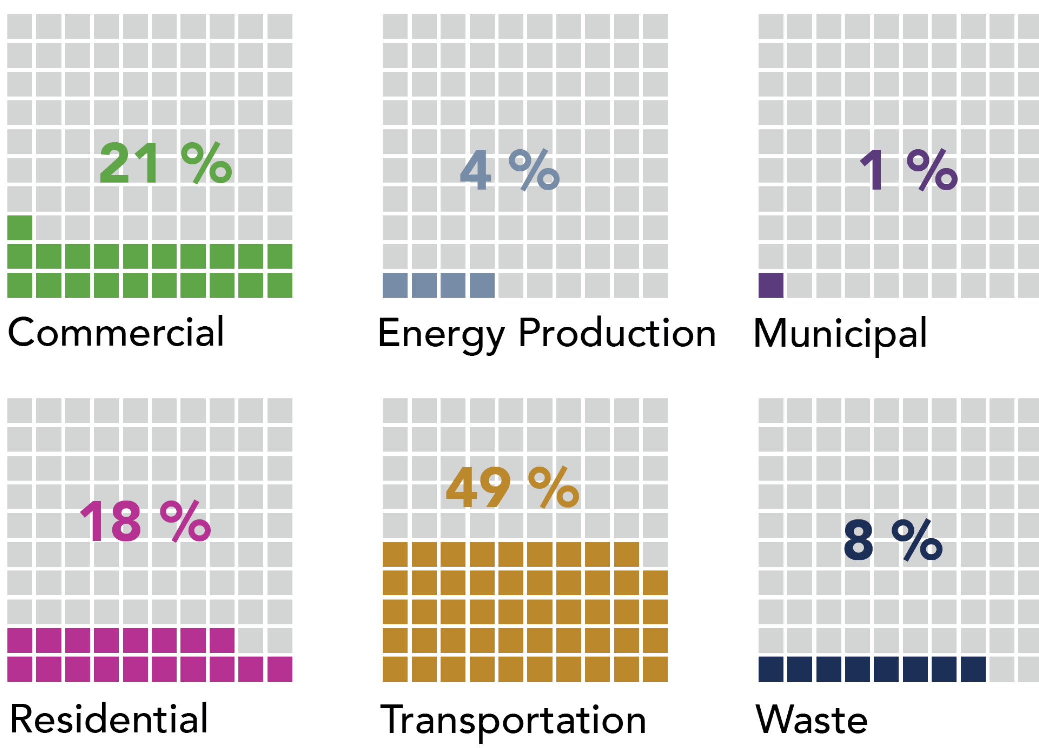


Figure 1. St. John's community greenhouse gas emissions by source in 2020.

Building on Strengths to Overcome Challenges

St. John's has many unique resources that are leveraged in this Energy Transition, namely its creative and resilient residents and business community with a technology and entrepreneurial spirit. It also has a nearly emissions-free central grid supply, many institutions and organizations to partner with, and wind energy potential. However, the most valuable of all are St. John's engaged and committed residents, who are ready to support, oversee, and participate in this Transition.

The Energy Transition leverages these strengths to respond to some of the community's GHG reduction challenges. The largest being the need to address its old, energy-inefficient building stock that relies on inefficient electric baseboard heaters or GHG-intensive fuel oil for heating, while retaining its built and landscape heritage.

Over a third of all households in Newfoundland live in energy poverty, where they spend more than 6% of their after-tax income on energy—that's the second-highest rate in the country.[2] St. John's numbers are similar to the rest of the province, with 34% of households experiencing this level of energy poverty. Additionally, energy poverty is projected to get worse in a BAU scenario due to the projected rise in energy costs (see Figure 2). The Energy Transition's focus on energy efficiency results in a major reduction in the community's energy poverty rates (see Figure 3).

[2] Canadian Urban Sustainability Practitioners, Energy Poverty in Canada: a CUSP Backgrounder (October 2019) online: https://energypoverty.ca/backgrounder.pdf.

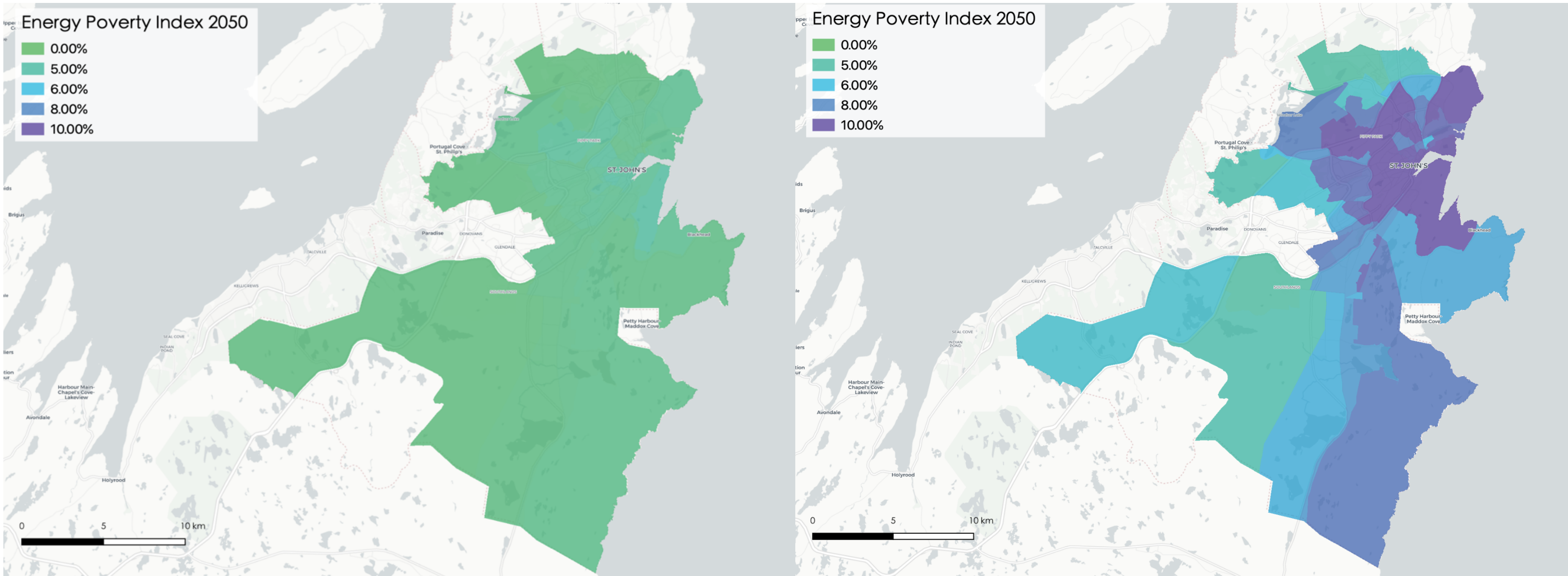


Figure 2. St. John's energy poverty rates by household and by zone in 2020 (left) and in a 2050 BAU scenario (right). An overall rise in energy poverty is forecasted in 2050 due to rising energy costs

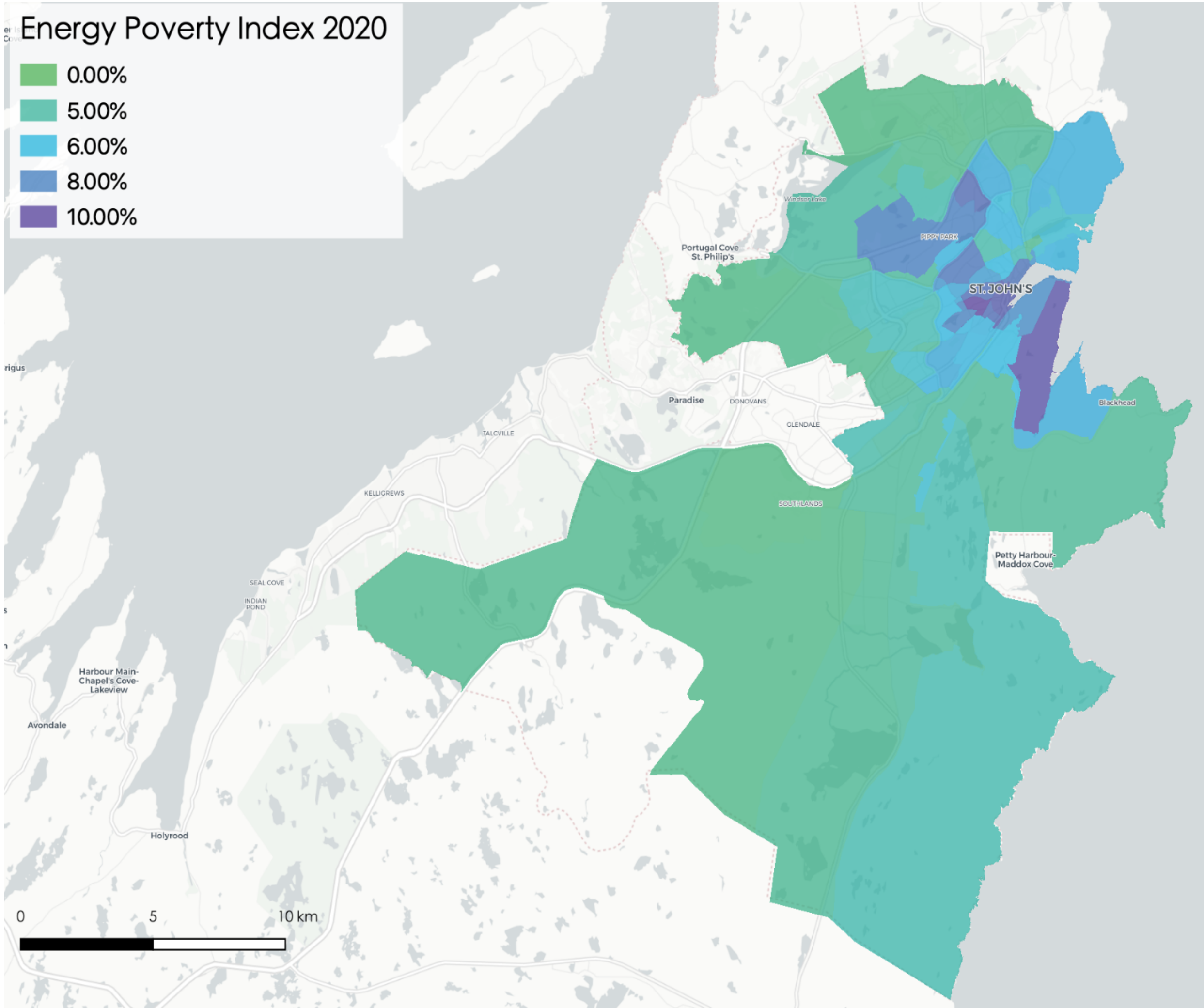


Figure 3. St. John's Energy Transition energy poverty rates by household and by zone in 2050.

This pathway responds to the building stock challenges by prioritizing energy efficiency, then capitalizes on the region's emissions-free electricity resources to heat and power its buildings. It also recognizes the role of intensification to enable transit and active transportation's part in enabling the community to drive less, and when necessary, only via emissions-free vehicles. Embedded carbon in items such as building materials is also acknowledged, and while more difficult to quantify, the pathway includes measures to increase waste diversion and adaptive reuse to repurpose old buildings.

The Toll of Energy Poverty

Households facing energy poverty, or energy insecurity, face difficult choices such as "heat or eat."[3] In particular, energy insecurity disempowers low-income residents such as single parents, the elderly, persons with disabilities, and others with low or fixed incomes.[4] Energy insecurity leads to stress such as food insecurity, utility-related debt, shutoffs, inefficient heating systems, antiquated appliances, and extreme home temperatures with significant health impacts.[5] This is only exacerbated when combined with the higher expense of vehicle ownership than that of active or public transportation. In an energy poverty context, children may experience nutritional deficiencies, higher risks of burns from non-conventional heating sources, poor indoor air quality, high risks for cognitive and developmental behaviour deficiencies, and increased incidences of carbon monoxide poisoning.[6] Subsequent impacts include parents being unable to work in order to look after children, missed school days, and lost productivity.

The mass deep energy retrofit and vehicle electrification programs proposed by the pathway represent a major economic growth opportunity that will reduce household energy costs, create local green jobs, and provide a substantial return on investment. Additionally, land use considerations in the pathway aim to reduce personal vehicle trips by fostering public and active transportation.

[3] Cook, J. T., Frank, D. A., Casey, P. H., Rose-Jacobs, R., Black, M. M., Chilton, M., ... Cutts, D. B. (2008). A brief indicator of household energy security: Associations with food security, child health, and child development in US infants and toddlers. PEDIATRICS, 122(4), e867–e875. https://doi.org/10.1542/peds.2008-0286

[4] Hernández, D. (2013). Energy insecurity: A framework for understanding energy, the built environment, and health among vulnerable populations in the context of climate change. American Journal of Public Health, 103(4), e32–e34. https://doi.org/10.2105/AJPH.2012.301179

[5] Hernández, D., & Bird, S. (2010). Energy burden and the need for integrated low-income housing and energy policy. Poverty & Public Policy, 2(4), 5–25. https://doi.org/10.2202/1944-2858.1095

[6] Ibid.

Available financial data indicates the Transition will cost about $205 million per year, with a 33% return on investment. It will produce 38,600 person-years of employment (1,400 full time jobs), and save households about 50% on their energy costs, which could then be used to afford quality food, education, recreation. (see the Textbox: Valuing the Transition).

The City is committed to ensuring an equitable Transition, meaning that it is implemented in a manner that allows all residents to have access to its many benefits. This particularly includes access for low-income residents and small businesses to energy efficiency improvements, active transportation infrastructure, emissions-free transit, and good-quality green jobs. The Transition stands to benefit many residents experiencing energy poverty and underemployment or the risk of underemployment due to the energy transition. Making these potential benefits a reality will require much more than the City Corporation taking action; the entire community will need to work together.

Valuing the Transition

When defensible data was available, each action included in the Energy Transition was assessed to determine its financial value in comparison to a BAU scenario. This value is derived from a combination of the action's costs (i.e. capital and operational) and benefits (i.e. avoided cost of carbon, energy, and maintenance, as well as revenue), with a discount value of 3% to account for the time value of money. Each action's value was then divided by the cumulative reduction of GHG it represents. This value is also known as the action's marginal abatement cost.

The marginal abatement cost is a useful tool for climate action decision-makers but should not be considered in a vacuum. Expensive actions may be necessary to enable for some of the affordable and even cost saving actions. Furthermore, addressing all emissions will be necessary to achieve net-zero by 2050. The financial analysis shows the Transition, as a whole, is cost-effective and overall a good economic policy for St. John's, with an average $167 in savings per GHG tonne reduced. This quickly adds up, over 28 years, to an overall return of nearly $1.8 billion dollars, or a 33% return on a $5.5 billion dollar investment. The majority of the financial benefit is due to the $7 billion avoided energy and carbon costs, as well as maintenance savings associated with the energy efficiency improvements and fuel switching included in this plan.

The Energy Transition will be funded by many different sources, including the City, other levels of government, the private sector, and individual residents. Where necessary, these investments will be enabled through innovative financing solutions and incentives. Equitable program design will ensure all residents and businesses have access to the savings.

Finally, many critical benefits of the transition and risks of not transitioning are NOT included in the financial analysis. This is because it includes aspects that are difficult to quantify, such as, improving public health, enhancing energy security, decreasing social inequity, etc. Furthermore, not taking any action involves risks including stranded assets or missing out on economic opportunities presented by the local, national, and global low-carbon transition which are impossible to quantify.

See Appendix B for more financial and economic impact analysis information.

Getting from BAU to Net-Zero

A BAU future will see a decrease in St. John's community-wide emissions by 2050 (see Figure 1); decreasing from about 789 ktCO2e in 2016 to 573 ktCO2e in 2050. This is due to existing policies, regulations, and market trends, most notably the near-decarbonization of the provincial electricity grid as well as federal regulations on transportation fuel efficiency. However, the climate emergency demands much more.

In order to eliminate as many GHG emissions as possible by 2050, a comprehensive series of changes across all sectors will be necessary. To determine an evidence-based and community-informed pathway, the CityInSight spatial energy and emissions model (described in Appendix C) was populated with a series of actions informed by best practices, available technologies, and community insight (actions are detailed in Appendix A). GHG emissions can be reduced by 93% in 2050 when compared to business-as-usual emissions in 2050 (see Figure 4). The majority of the remaining emissions are from organic waste decomposing in the landfill. For now, this remaining carbon gap would need to be addressed in the future via the purchase of offsets. Future revisions of this Energy Transition will have the benefit of considering further policy and technological innovations.

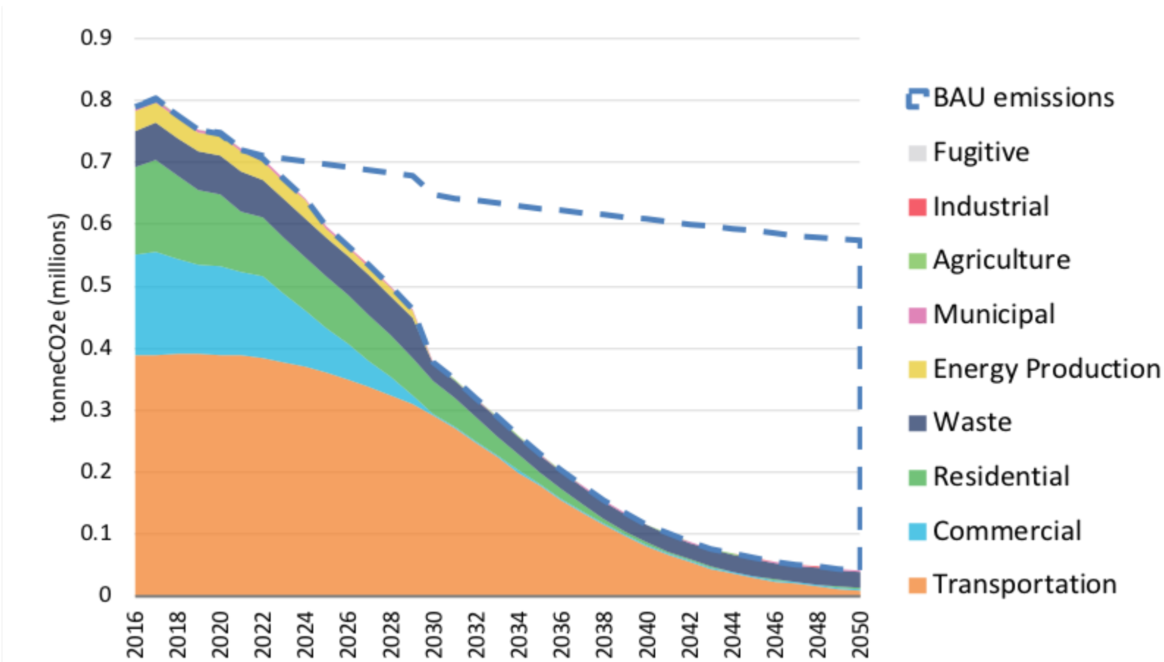


Figure 4. St. John's forecasted greenhouse gas emissions, by sector, in a net-zero scenario, 2016-2050.

Efficiency First, Local Renewable Energy Second

Prioritizing energy efficiency in the St. John's Energy Transition helps reduce the overall cost to society—electricity consumers and the environment. The International Energy Agency promotes energy efficiency as the first fuel in the energy transition, with multiple benefits beyond reduced energy demand, including energy security, home comfort, and the preservation of the existing built environment.[7]

Energy efficiency saves costs in many ways. Despite NL having abundant hydro energy available to St. John's, maximizing energy efficiency will eliminate costly additional electricity capacity to support the electrification of homes, businesses, industry, and transportation. Prioritizing efficiency in buildings also entails minimizing the equipment needed to replace existing heating and cooling systems, saving capital costs. Finally, improved energy efficiency has the important benefit of reducing household energy bills, which currently contribute to St. John's having one of the highest energy poverty rates in the country.[8]

In addition to energy efficiency, by increasing the local renewable energy supply, St. John's has the potential to display leadership, create local jobs, generate revenue, and increase the community's energy security.

[7] International Energy Agency. Multiple Benefits of Energy Efficiency (March 2019). Online: www.iea.org/reports/multiple-benefits-of-energy-efficiency.

[8] 'Energy poverty' is considered to exist when a household spends more than 6% of their after-tax income on home energy costs (including transportation fuels). (per Canadian Urban Sustainability Practitioners, Energy Poverty in Canada: a CUSP Backgrounder (October 2019) at 2, online: https://energypoverty.ca/backgrounder.pdf.)

Sector-by-Sector Transition Pathways

The Energy Transition requires dozens of strategic actions across all sectors between now and the year 2050. These actions, detailed in Appendix A, are based on best practices, current available technologies, and community insight. The wedge diagram in Figure 5 provides a visual representation of how much each action or bundle of actions contributes to the Transition from the BAU scenario. Table 1 lists the cumulative emissions reductions achieved by each action or bundle of actions from the BAU by 2050.

Each action is critical to achieving net-zero emissions, even if it only represents a fraction of overall GHG reductions. In some cases, an action facilitates another action (e.g. increased densification allows for more affordable transit and active transportation infrastructure, which in turn enables the reduced need to use personal vehicles for shorter trips). Actions also provide unique sets of co-benefits beyond GHG reductions, such as improved resiliency to climate extremes (e.g. tree planting and naturalization) or improved air quality and noise pollution (e.g. active transportation, as well as electrification of transit, cars, and trucks).

The proceeding sections provide detail on sectoral transition pathways, their decarbonization actions, near-term implementation strategies, GHG reductions, and co-benefits. This is the 30-year energy transition pathway for the community of St. John's. Each section also introduces the 5-year implementation strategies that will catalyze action now to enable for the longer-term pathway. Additional details on each of the implementation strategies (timing, reporting metrics, GHG impact, co-benefits, estimated cost, potential partners and funders) are provided in Appendix D.

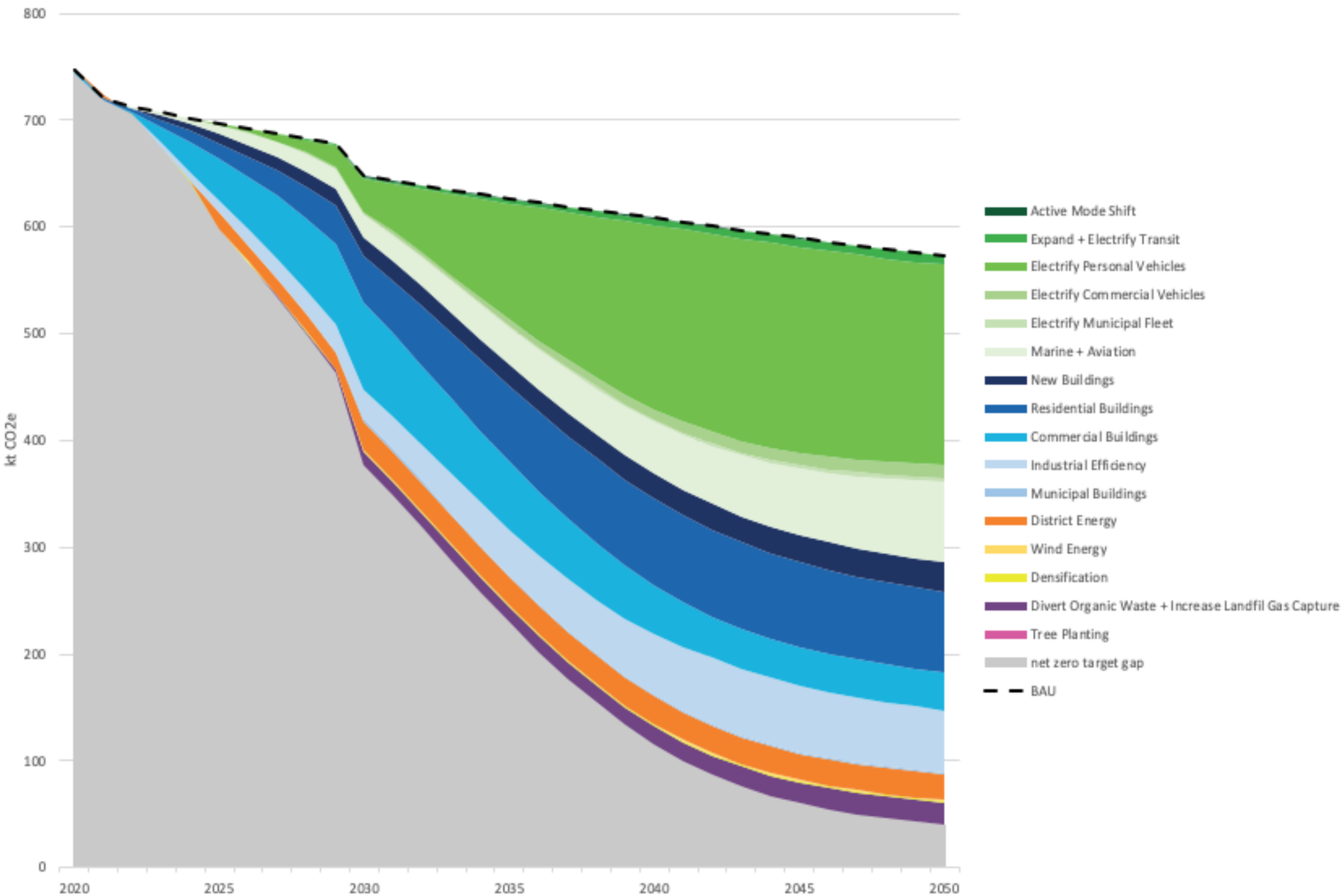


Figure 5. St. John's Energy Transition Pathway, by action, and the associated GHG reductions from 2016-2050.

Table 1. Energy Transition Pathway actions and associated cumulative GHG reductions by 2050.

Energy Transition Pathway Actions	Cumulative	% of Total
	GHG Reductions by 2050	
Expand and electrify transit	121kt CO2e	1.1%
Increase active transportation	14 kt CO2e	0.1%
Electrify personal use vehicles	3,096 kt CO2e	29.7%
Electrify commercial vehicles	178 kt CO2e	1.7%
Municipal fleet electrification	52 kt CO2e	0.5%
Marine efficiency + aviation net-zero	1,100 kt CO2e	10.6%
More efficient, electrically-heated new buildings	548 t kCO2e	5.3%
Mass, deep residential retrofits	1,677 kt CO2e	16.1%
Mass, deep commercial retrofits	1,407 kt CO2e	13.5%
Deep industrial retrofits	1,166 kt CO2e	11.2%
Deep municipal retrofits	44 kt CO2e	0.4%
More efficient, electrically-heated new buildings	548 t kCO2e	5.3%
Decarbonize Memorial University's district energy system	601 kt CO2e	5.8%
Produce local wind energy	11 kt CO2e	0.1%
Increase densification	3.4 kt CO2e	0.5%
Divert organic waste and increase landfill gas capture systems	350 kt CO2e	3.4%
Tree planting	0.25 kt CO2e	0.002%

Overarching Enabling Actions

Before outlining the Transition Pathway for each sector, there are a few overarching actions critical for ensuring the City is enabling community-wide progress toward the Energy Transition's longer-term goals that need to be addressed.

Annual public reporting on action is critical to track progress and enable for a **comprehensive five-year review** on energy use,GHG emissions, and other required updates to the plan . This review is an opportunity to make adjustments that reflect lessons learned, community input, new technologies, and best practices that have arisen over the years.

In addition, it is critical the **City's major spending and policy documents are aligned** with the Energy Transition. This would ensure that the City is taking action by ensuring public dollars and power are working in support of the Energy Transition.

Densification and complete community policies not only help protect green spaces, but they also enable for increased access to transit and active transportation options which reduces the need for other personal vehicle trips. In addition, by maintaining and expanding its tree canopy and green spaces, the City can offset some of its remaining GHG emissions via **natural carbon sequestration**. Maintaining green spaces and expanding the tree canopy will help enhance local air quality and improve the community's resilience to extreme weather.

Walkable communities support community cohesion and healthy living, while ensuring many of the existing natural areas remain undisturbed. **Natural areas** within and around the city, in the era of climate change, are a buffer. They help protect neighbourhoods and communities, as a whole, from changes in climate, and invasive species, while also providing green spaces for important pollinators such as bees and butterflies.

Finally, the Energy Transition will require **skills training and new businesses**. The City will partner with academic institutions to identify the training and research needed to implement the Energy Transition. In addition, the City will help provide a supportive environment for small start-ups seeking to work in the growing green economy.

Table 2. Key overarching Energy Transition actions and implementation strategies.

Pathway Action	Implementation Strategy
1.1 Integrate climate considerations into city-wide development policies	**Policy:** Ensure that climate considerations are fully integrated into St. John's Municipal Plan, subsequent neighbourhood-level plans, and included in updates of other strategies.
1.2 Continue to provide annual GHG and energy use reporting (for City and broader community)	**Program:** Public, annual reporting on progress of action, and at least a 5-year community-wide GHG and energy use reporting.
1.3 Develop and implement a climate lens for all City budget decisions	**Policy:** Develop a climate policy lens to guide City budget decisions **Program:** Annual reporting on corporate GHGs and energy use
1.4 Undertake regular reviews and updates of RSJ	**Initiative:** Establish a 5-year update to RSJ
1.5 Natural area protection and enhancement	**Program:** Continue and expand urban tree planting and naturalization programs **Program:** Continue to naturalize greenspaces, and protect wetlands and waterway buffers
1.6 Business and industry working groups	**Initiative:** Establish a working group with local industries to develop strategies to meet climate goals
1.7 Partnership with academic institutions and entrepreneurship incubators for pilot project and training	**Initiative:** Work with academic institutions and entrepreneurship incubators to identify opportunities for innovation, training, and development

Affordable, Efficient Buildings for All

BAU Energy + Emissions Profile

Residential and commercial buildings are St. John's second-largest source of emissions today and into 2050 in a BAU scenario. They represent 35% of the community's emissions, or 204 kt CO_2e, in 2050. Despite the sector's relatively high share of low-emissions electricity use (about

60% today), a small share of buildings still rely on high-carbon fuel oil (about 18%) and propane (about 9%).

Taking Action Now

The following table outlines the key near-term (2022-2025) implementation strategies that will initiate the transformation of buildings (i.e. homes and businesses) in St. John's. These actions build on existing work at the City and in the community and are informed by community input and global best practices.

These implementation strategies address St. John's building sector BAU energy use and emissions sources, and help achieve the sector's long-term Energy Transition goals and associated co-benefits.

Table 4. Buildings decarbonization actions and implementation strategies.

<table>
<tr><th>Pathway Action</th><th>Implementation Strategy</th></tr>
<tr><td>2.1 All new buildings are net-zero by 2030</td><td>Policy: Establish new Sustainable Development Guideline</td></tr>
<tr><td>2.2 Mass deep retrofits to existing homes and buildings, followed by switching to electric heat pumps and water heaters, achieving net-zero or net-zero ready</td><td rowspan="2">Program: Develop a deep retrofit program for all buildings

Initiative: Pilot a neighbourhood retrofit

Initiative: Pilot a low-income housing retrofit

Initiative: Pilot a rental property retrofit

Leading by example/Infrastructure: Retrofit municipal buildings to net zero or net zero ready</td></tr>
<tr><td>2.3 Heat pumps and electric water heaters in all buildings</td></tr>
<tr><td>2.4 Convene a roundtable to address energy poverty</td><td>Initiative: Convene a roundtable to address energy poverty</td></tr>
</table>

About the Transition Pathway

The transition pathway for St. John's buildings starts with a **mass deep retrofit program**, first to improve building envelopes, then to make the switch to air-source heat pumps. These heat pumps are more than twice as efficient as electric baseboard heaters and are even more efficient than fuel oil boilers. This means that heat pumps supply the same amount of heat as electric baseboards and fuel oil burners, but use considerably less energy. Currently, electric baseboard heating represents about 70% of St. John's home heating systems.

To ensure effective and equitable **retrofit program design**, consultations will be needed with residents, businesses, other levels of government, industry, service providers, and public interest groups. Program design will then be tested and refined via pilot programs. Broader deployment of the retrofit program will require the development of appropriate incentive/financing solutions and public-private collaboration and innovation.

New buildings built today will likely still be standing in 2050. Long-term infrastructure decisions need to be aligned with a net-zero future, as retrofitting buildings at a later date is a more costly proposition. Early considerations of adaptive re-use may also support waste reduction and embedded carbon in construction materials into the future. The City can help ensure this by establishing a comprehensive and clear green development guideline.

Local training institutions will need to ensure that technicians are being trained and retrained to fill all the **new jobs** that will be created to deliver retrofits and build to net-zero.

Co-Benefits

The mass deep retrofit program is critical to the Transition's projected decrease in household energy costs (including vehicle fuel) by over 50%. The City is committed to deploying residential retrofits in a manner that supports low-income households. This will help reduce energy poverty, encourage building improvements, respect heritage, and enable households to afford other household necessities. Furthermore, envelope retrofits have the added benefit of improving resident comfort and health.

Investment in retrofits are also the biggest potential job creator of the Transition, estimated to create over 1,350 person-years of employment for each year from 2022 to 2050.

Transportation Transformation

BAU Energy + Emissions Profile

Transportation is St. John's single largest source of GHG emissions out to 2050 in a business-as-usual (BAU) scenario, representing 52% of the community's emissions. Despite significant increases in vehicle fuel efficiency and incremental electric vehicle adoption, gasoline- and diesel-fuelled cars and trucks on the roads in 2050 are projected to emit 215 kt CO_2e. Marine and aviation emissions associated with the community are expected to be 81 kt CO_2e in 2050.

Taking Action Now

The following table outlines the key near-term (2022-2025) implementation strategies that will initiate the transformation of the transportation sector in St. John's. These actions build on existing work at the City and in the community and are informed by community input and global best practices.

These implementation strategies address St. John's transportation sector BAU energy use and emissions sources, and help achieve the sector's long-term Energy Transition goals and associated co-benefits.

Table 3. Transportation decarbonization actions and implementation strategies.

Pathway Action	Implementation Strategy
3.1 Electrify personal, municipal, and commercial vehicles	**Infrastructure**: Partner on the deployment of electric vehicle charging stations **Initiative**: Work with local car dealerships to improve access to EVs **Initiative**: Develop an EV education program **Initiative**: Convene a commercial fleet decarbonization working group **Leading by Exampl**e: Purchase electric vehicles for the municipal fleet
3.2 Expand and electrify transit	**Program**: Conduct a feasibility study and pilot project for electric buses in St. John's on select routes **Initiative**: Implement the ridership growth strategies identified in the Transit Review Study, 2019 **Initiative**: Update transit study, when appropriate, to identify transit needs and further increase ridership and route coverage across the city
3.3 Improve and expand walking and cycling infrastructure	**Initiative**: Engage with the public and ramp up implementation of the Bike St. John's Master Plan **Initiative**: Initiate a review of walking infrastructure needs in the city

About the Transition Pathway

The transition pathway for St. John's transportation sector prioritizes efficiency by **increasing the number of trips taken by foot, bike, and e-bus,** and then, replacing remaining vehicles with electric vehicles (EVs). Since the number of car trips are reduced, and because EVs are significantly more efficient than combustion engine vehicles, cars and light trucks are projected to use nearly 70% less energy by 2050 in the Energy Transition.

Fossil fuel-free alternatives for heavy trucks in Newfoundland are not fully tested and for the time being are only partially addressed via electrification in this Transition. Some combustion engine heavy trucks are assumed to still be on the roads in 2050 in the Energy Transition. Future iterations of the Transition may consider an expanded heavy-truck electrification, sustainable green hydrogen, or compressed renewable natural gas, as these technologies become available in NL.

The municipality plays a critical role as a first mover in **electrifying its fleet and transit.** It also plays a central role in facilitating increased public and active transportation, by expanding and improving transit networks as well as infrastructure for walking, cycling, and riding scooters.

In order to encourage the adoption of electric vehicles, the municipality and private sector will need to work collaboratively to **expand EV charging infrastructure**, and increase local support for and the availability of EVs.

As for the **marine and aviation transition,** both industries have committed to significant efficiency targets, and the latter has committed to net zero by 2050.

The efforts in this sector can be furthered significantly through co-benefits of land-use actions captured in the **non-energy emissions** sector. Reduction of vehicular trips, and replacing them with transit, walking, or cycling, reduces the overall energy demand. Land use decisions that maximize the availability of non-vehicular trips will improve the quality of life, and build stronger communities.

Co-Benefits

Transitioning the transportation sector will help significantly improve local air quality and noise pollution. Walking and cycling on a safe network of on-street and environmentally- sensitive paths and trails will also help residents stay active and connected with their community. This will enable easier access to amenities such as shops, doctor's offices, schools, workplaces, parks and restaurants. Moreover, if implemented equitably, these public services can be designed to serve those most in need, ensuring that all residents can use affordable, safe and healthy transportation solutions.

Clean Energy for Resilience

BAU Energy + Emissions Profile

A BAU scenario projects that St. John's energy use profile will stay relatively constant out to 2050, subject to some reductions in gasoline and diesel (-29% by 2050), and a minor increase in electricity use (8% by 2050, see Figure 6). These changes are primarily due to overall improvements in efficiency standards, in particular improved federal vehicle fuel efficiency standards and the expected uptake of electric vehicles, as well as population growth (14% by 2050).

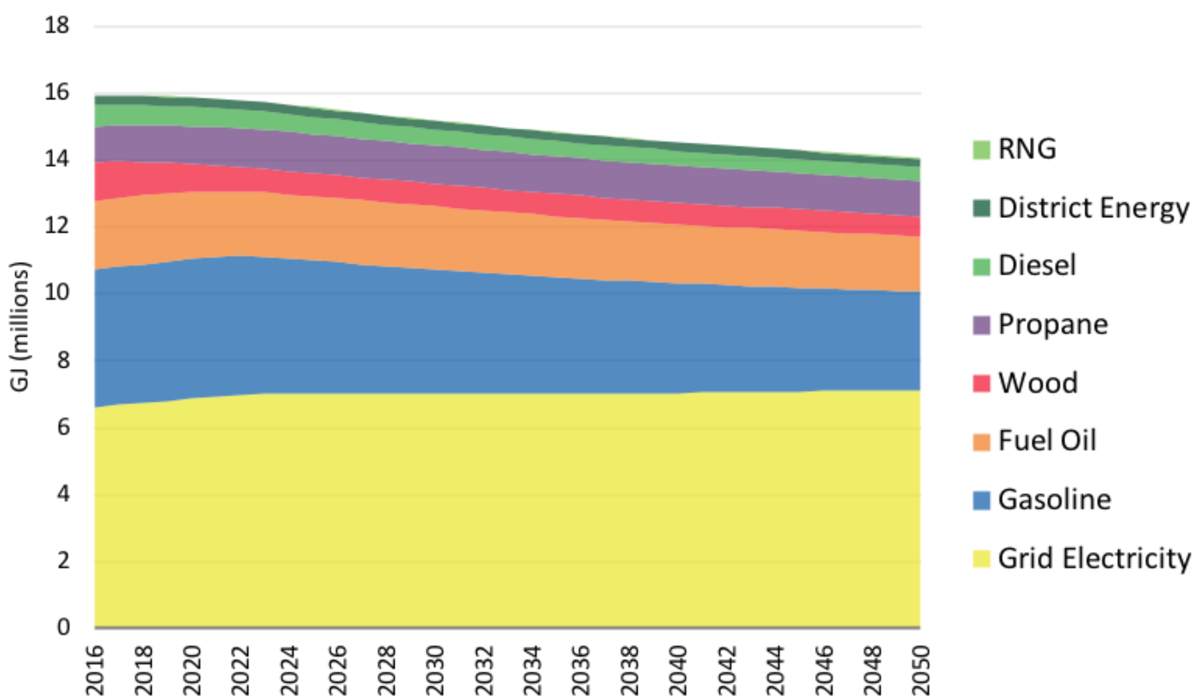


Figure 6. St. John's community energy use, by fuel, in a BAU scenario, 2016-2050.

St. John's energy profile is unique and opportune in its large share of nearly emissions-free electricity, almost exclusively from hydroelectric generation as of 2022. Though electricity is estimated to provide about 50% of the community's energy use by 2050 in a BAU scenario, it is estimated to produce only a small fraction of the community's greenhouse gas emissions (see Figures 6 and 7).

Apart from the carbon-neutral biogas (shown as RNG in Figure 6) that is currently re-used at the Riverhead wastewater treatment plant, the remaining half of the community's energy supply remains fossil-fuelled in a BAU scenario (see Figure 5). Cars and trucks are the primary consumers of fossil fuels, followed closely by fuel oil, a major source of building heating. The shared Memorial University of Newfoundland (MUN)/Eastern Health district energy system is also expected to remain powered by fuel oil boilers in a BAU scenario.

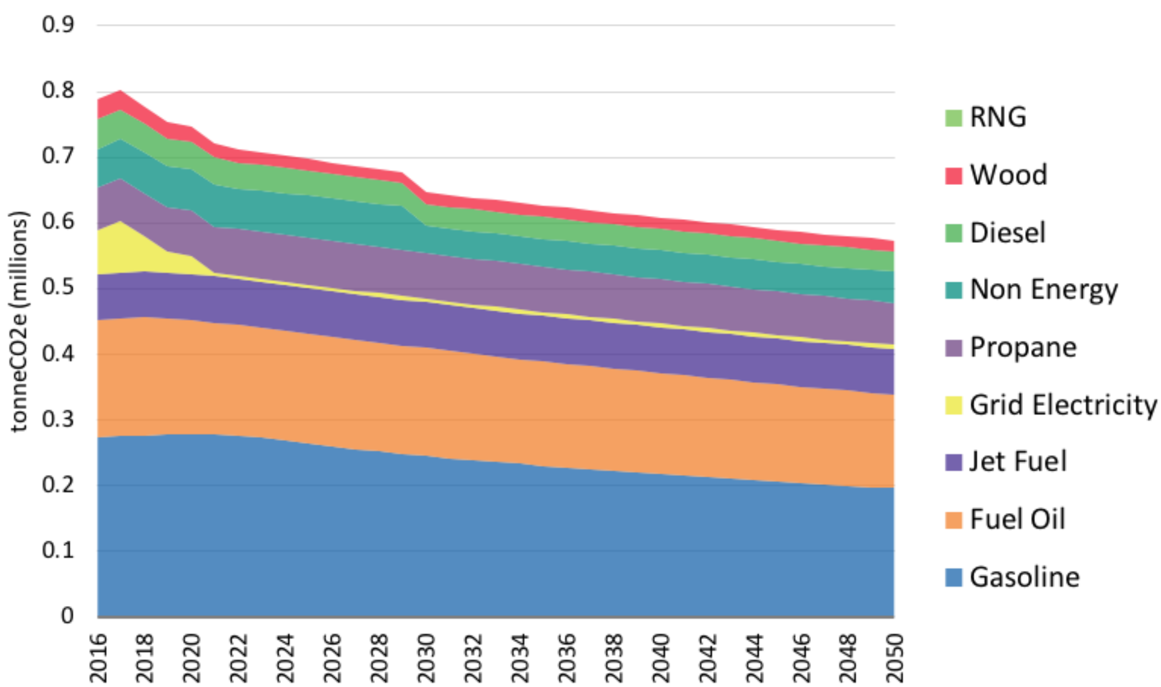


Figure 7. St. John's community GHG emissions, by fuel, in a BAU scenario, 2016-2050.

Taking Action Now

The following table outlines the key near-term (2022-2025) implementation strategies that will initiate the transformation of the energy system in St. John's. These actions build on existing work at the City and in the community and are informed by community input and global best practices.

These implementation strategies address St. John's energy system BAU energy use and emissions sources, and help achieve the sector's long-term Energy Transition goals and associated co-benefits.

Table 5. Energy system decarbonization actions and implementation strategies.

Action	Implementation Strategy
4.1 Partnership with MUN to decarbonize the District Energy system	**Initiative:** Collaborate with MUN/EH to decarbonize the DE system
4.2 Install wind farms to supplement the provincial electricity grid	**Policy:** Support the implementation of the renewable energy policies in the Envision St. John's Municipal Plan **Initiative**: Renewable Energy Co-operative (REC) public education campaign & search for local leads
4.3 Expand landfill gas capture	**Infrastructure**: Expand the landfill gas capture system and explore collaborative frameworks for its feasible reuse
4.4 Ensure the electricity system is planning to manage new demand and new supply mix	**Initiative:** Commission an hourly analysis of electricity demand and capacity to ensure a stable, reliable electricity grid for a net-zero future

About the Transition Pathway

In addition to nearly-emissions-free central grid electricity, in its Energy Transition to a net-zero future, St. John's capitalizes on several other local, abundant emissions-free resources, namely:

- ambient energy from the air (a major energy input for electric air source heat pumps that will heat and cool St. John's homes and businesses);
- avoided energy use from efficient building envelopes;
- avoided energy use from efficient electric versus combustion engine motors (gasoline or diesel);
- avoided energy use from reduced personal use vehicle trips; and
- wind energy.

The combination of these resources results in a massive energy demand reduction for the community by 2050: a 53% reduction from BAU and a 58% reduction from 2016 energy demand levels. The City is supportive of renewable energy generation to meet future demands; however, ambitious energy efficiency is more cost effective, can be implemented in the short-term, and generally provides added co-benefits to residents.

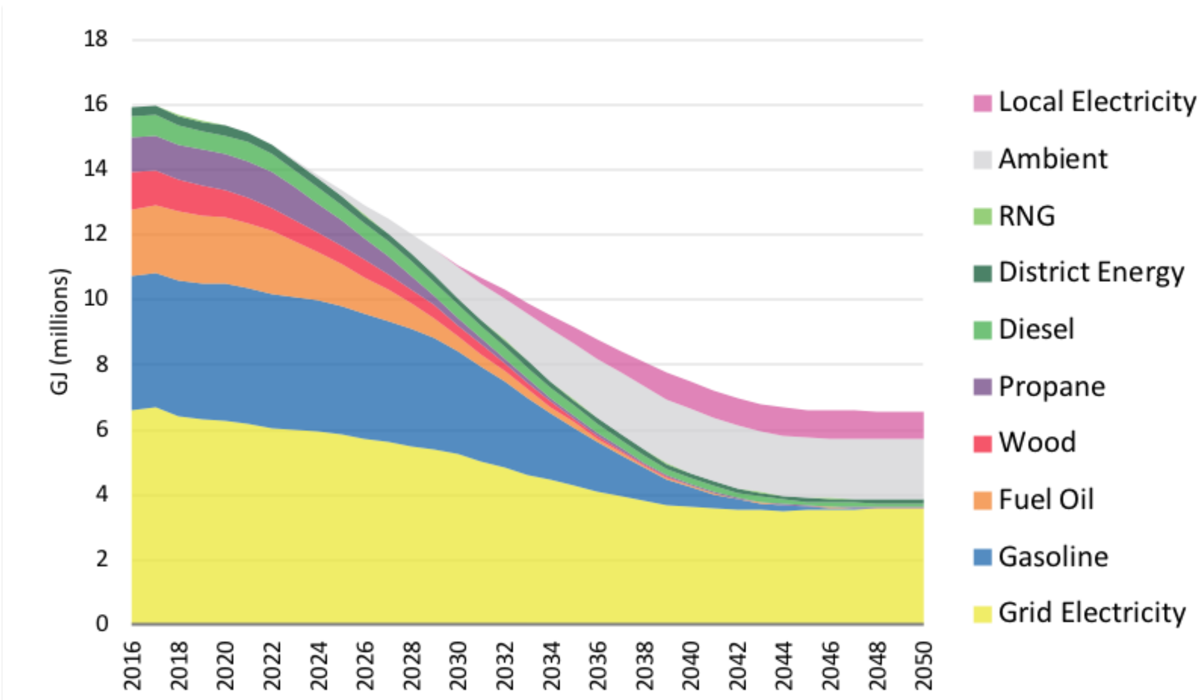


Figure 8. Community energy use, by fuel, in a net-zero scenario, 2016-2050.

The City will also be exploring the potential **beneficial use of methane gas** that will be increasingly captured at its landfill, similar to the beneficial use of methane collected at the Riverhead wastewater treatment plant. Landfill gas could be used to heat neighbouring buildings, generate local electricity, fuel a district energy system, or fuel vehicles.

To deploy the significant energy efficiency improvements included in the Transition and add local clean energy to the grid, the City will need to **coordinate with the Province, Newfoundland Power, and Newfoundland and Labrador System Operator** to ensure the electrical system is prepared for the changing demand and supply mix.

A**dding zero-emissions electricity from wind generation** may not immediately make financial sense in a location with clean grid electricity. However, by adding wind generation to the grid in St. John's, the city will diversify its electricity supply and support the Province's vision in the Maximizing our Renewable Future Plan. This diversification will also increase the resilience of the city in the event of disruptions to electricity distribution or generation.

Co-Benefits

The benefits of reducing overall energy demand and diversifying some of the community's electricity supply include: decreased household energy costs, increased energy system resilience (from electricity price increases and any potential disruption to the onshore electricity supply), and local economic development (for more on co-benefits, see the section 'Efficiency First, Local Renewable Energy Second' above).

Non-Energy Emissions: Low-Waste Future

BAU Energy + Emissions Profile

The current 7% of St. John's GHG emissions resulting from non-energy sources are due to the decomposition of organic waste at the Robin Hood Bay Landfill. This methane produced here is partially captured by the landfill's gas capture system, as they can only be installed in inactive areas of the landfill. The 59 kt CO_2e presently emitted are projected to decrease slightly to 47 kt CO_2e by 2050 in a BAU scenario. This is primarily due to planned expansion of the landfill gas capture systems from a 60% to 70% capture rate in 2030.

Although methane from the landfill reflects a small share of the community's emissions, it is critical in the short term. Over the next 100 years, methane's climate change impact is considered to be 34 times more potent than carbon dioxide (i.e. 1 tonne of CH_4 = 34 tonnes of CO_2e)[9]. In comparison to the next 20 years, methane's climate change impact is much more consequential, during which it is 86 times as potent as carbon dioxide (i.e. 1 tonne of CH_4 = 86 tonnes of CO_2e). For this reason, it is vital the City continues and expands on its waste diversion and methane capture practices. The benefit of landfill gas collection expansion to the climate is significant, even if the City simply continues to flare the methane being captured at its landfill as carbon dioxide (versus capturing the gas for beneficial reuse).

Other non-energy emissions sources and pathway actions, while seemingly small, have significant co-benefits that enable the actions in other sectors, the residents' overall health and

[9] Standardized GHG accounting and reporting standards require that methane's global warming potential be measured on a 100-year time horizon.

well-being, and climate adaptation (i.e., intensification, naturalization, conservation, tree planting).

Taking Action Now

The following table outlines the key near-term (2022-2025) implementation strategies that will transform non-energy sources (i.e. waste management in St. John's). These actions build on existing work at the City and in the community and are informed by community input and global best practices.

These implementation strategies address St. John's BAU non-energy emissions sources and help achieve the long-term Energy Transition goals and associated co-benefits.

Table 6. Waste decarbonization actions and implementation strategies.

Pathway Action	Implementation Strategy
5.1 Public education to reduce overall waste production, and improve waste diversion	**Program:** Develop and deliver educational programming about waste reduction, and waste sorting
5.2 Support the development of a circular economy	**Initiative:** Convene a working group to identify opportunities for building a local industry for repair and reuse including community composting and building materials reuse such as: ● undertaking a review of existing guidance (e.g., Guide to Community Gardens in the City of St. John's) to incorporate neighbourhood level community composting on city-owned land. ● identifying barriers and opportunities for building materials reuse. ● exploring the development of a food waste and resource flow map to identify food waste-to-value opportunities for innovation.

About the Transition Pathway

The Energy Transition requires the timely introduction of an **organic waste diversion program** along with an **expansion of the landfill gas capture system** to address legacy organic waste emissions. The **inclusion of circular economy principles** in the economy will support the City's diversion and material reuse efforts, while also encouraging new businesses to design out waste from their products and services.

Organic waste takes up to 50 years to completely decompose and stop producing methane.[10] Beneficial use of the energy provided from decomposing organic waste can take the form of compost or biogas. Since St. John's operates a regional service, financial support and collaboration from the Provincial and Federal government are essential to realize the decarbonization of this sector. The latter can be an important source of carbon neutral energy for St. John's, and is discussed in the prior section on Clean Energy for Resilience; it will need to be seriously considered via a feasibility study.

Co-Benefits

Incorporating circular economy principles would support work toward the eventual elimination of waste while encouraging innovation in the local economy. For example, diverting organic waste from the landfill has the added benefit of providing a useful resource for the community, either as rich compost or as biogas.

The Path Forward

The Role of the City

Declaring a climate emergency, setting GHG emissions targets, and developing this Transition Strategy are necessary first steps. Once passed, the City will need to move to action as soon as possible. Though directly responsible for a fraction of the community's emissions, the Municipality plays a critical leadership role in the Energy Transition.

1. Being a first mover

The City will show leadership by ensuring that all its Council-approved spending decisions are aligned with a resilient, net-zero future, starting as soon as possible. The City will achieve this by adopting a climate lens that ensures the City remains within its annual cap on emissions, with surpluses and deficits applied to the following year.

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[10] "Landfill Gas Primer - An Overview for Environmental Health Professionals" online at Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services: www.atsdr.cdc.gov/hac/landfill/html/ch2.html.

2. Providing public education, progress reporting, and periodic reviews

The City will continue to be the central source of public education about the Energy Transition, providing annual public reporting on the City's corporate GHG emissions and progress metrics for key community-wide programs. This data will help the community provide essential oversight and inform the Strategy's 5-year reviews.

3. Enabling and coordinating community action

The City will also help coordinate community action by establishing enabling policies and regulations, convening potential partners, and supporting proposals to various levels of government, as well as by lobbying higher levels of government for new funding and supporting policies. In addition, the City will support community action by coordinating private sector working groups to share resources and best practices.

4. Leading certain key programs, with an equity and local economic development lens

There are certain community decarbonization programs that the City will lead, partnering with the private sector where appropriate. For example, the City's sustainable development guideline will be led by the City, and the City will play a role in mass retrofit residential and commercial retrofit programs.

In leading community decarbonization programs, the City is committed to do so with an equity and local economic development lens. This will promote community accessibility to programs and services, notwithstanding income or other circumstances. It will ensure the City's Energy Transition addresses energy poverty in St. John's and maximizes local business participation.

The Role of the Community

1. Learn, participate, and shape

The community's role in the Energy Transition is to become informed about, participate in, and shape programs. The community will review their options and prepare to take advantage of Energy Transition programs as they become available. The community can help shape St.

John's Energy Transition by participating in Energy Transition committees or working groups; attending public information meetings and asking questions or making suggestions; or reaching out to their Councilors–among many other options.

To keep abreast of opportunities to do so, residents can register for updates from the City at: https://stjohns.ca/

https://twitter.com/SustainStJohns

https://www.facebook.com/SustainableStJohns

2. Organizations as partners and leaders

The Energy Transition is a large undertaking for any single organization to lead. There are significant opportunities for businesses, institutions, associations, and community groups to step up as Energy Transition program delivery partners or leaders. They can do so by bidding for public projects or by accessing public funding. Organizations can also learn about their own emissions and set organizational net-zero targets. Finally, organizations can lobby higher levels of government for support in their emissions reductions efforts. The City may be able to assist these efforts by:

- providing letters of support (sometimes required to access funding),
- sharing know-how to build capacity,
- convening working groups, and
- generally keeping communication channels open and transparent.

Growth of the Green Economy

The Energy Transition will not only save money on household and business energy costs, it will also create many local economic development opportunities for St. John's. In particular, the massive building retrofit and heating system switch will require a small army of service providers and businesses to undertake the required energy audits, finance and administer the projects, undertake the envelope improvements, and provide and service the equipment. Economic modelling suggests the investments in mass deep retrofits across the community's building stock will result in more than 1,350 full time job equivalents by 2050. In total, the Transition is projected to produce a net increase of 1,400 jobs across all of its programs.

The Energy Transition is a community investment plan that will result in many new jobs and also a transition of skills in existing jobs. For example, the electrification of vehicles will require a transition from skills that are currently focused on servicing combustion engine vehicles to batteries. The transition to air source heat pumps as a primary source of heating for buildings will require technicians accustomed to installing electric baseboards or fuel oil boilers to retool. And so on.

To fill these new jobs and business opportunities, the City will work with local colleges, technical training institutions, and universities to ensure their course offerings and research programs reflect the evolving economy. The City is committed to ensuring training and retraining programs are made accessible to those whose jobs will be affected by the transition or that are experiencing under-employment.

See **Appendix C** for more details on the Transition's economic impacts.

APPENDICES

A. Business-as-Usual and Net-Zero Scenario Modelling Assumptions and Results

B. Economic and Financial Analysis

C. Modelling Scope, Method, and Process

D. Implementation Strategy

Appendix A: BAU and Net-Zero Scenario Modelling Assumptions and Results

November 2021

About this document

This report was developed by SSG as a technical resource to support and inform the development of the City of St. John's Energy Transition. This report details the key energy use and greenhouse gas (GHG) assumptions used to model St. John's 2016 to 2050 business-as-usual (BAU) and net-zero energy and emissions scenario (NZS), as well as the model results.

A separate document, the Data, Methods and Assumption Manual, details the model used to produce the results outlined in this document.

Disclaimer

Reasonable skill, care, and diligence have been exercised to assess information acquired during the preparation of this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains and upon which it relies are subject to changes that are beyond the control of the authors. The information provided by others is believed to be accurate but has not been verified.

This analysis includes high-level estimates of energy and use and emissions that should not be relied upon for design or other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document.

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Summary of BAU and NZS Actions

Table 1. Summary of business-as-usual (BAU) and net-zero scenario (NZS) assumptions modelled for the City of St. John's Energy Transition.

Category		BAU Assumption	Net-Zero Action	Source
POPULATION				
a.	Population	Increases by 14% by 2050 from 2016 total	Same as BAU	City
BUILDINGS				
New buildings growth				
1	Building growth projections	Focus 5% of new development in intensification zones, per 5-year period, the remainder should continue according to current population placement	Focus 10% of new development in intensification zones, the remainder should continue according to current population placement.	City
New buildings energy performance				
2	Residential	In line with the 2012 NBC, held constant to 2050	All new buildings are substantially more efficient and electric by 2030 (NZER equivalent). Efficiency improvements are modelled as follows: NBC (small buildings & houses):	**BAU**: St. John's Building By-Law, s.46. **NZS:** Current model National Building Code and National Energy Building Code 2020 (delayed until at least December 2021) proposes buildings be net-zero ready by 2030.
3	Multi-residential			
4	Commercial & Institutional	none		

5	Industrial		2022: 2015 NBC s.9.36 2024: 10% better 2026: 20% better 2030: 40% better NEBC 2020 (commercial & industrial): 2022: NEBC 2020 2024: 25% better 2026: 50% better 2030: 60% better	Net Zero Energy Ready (NZER) is a highly energy efficient building that minimizes energy use such that on-site or community renewables or energy from a clean grid can be used to reach NZE.
6	Municipal	none		
Existing buildings energy performance				
7	Residential	Existing building stock efficiency increases at 1%/year 2016-2050.	Achieve 50% thermal savings and 50% electrical savings in 100% of all existing dwellings by 2045. (modelled before any fuel switching)	**BAU:** Pembina, Pathway Study on Existing Residential Buildings in Ottawa, 2019 (at 22). **NZS:** The Newfoundland and Labrador Conservation Potential Study (2020-2034) estimates about 30% electricity savings are possible in the residential sector by 2034. Studies undertaken by the US National Renewable Energy Laboratory and the Rocky Mountain Institute indicate that retrofits achieving far more than 50% in energy savings are possible, and that the deeper and more systemic the retrofits, the more affordable they become.
8	Multi-residential			
9	Commercial & Institutional			
10	Municipal			

11	Industrial	none		Increasing government funding is making technical potential more economical. Existing building retrofits are considered a key priority from the public engagement (March 2021, What We Heard PPT presentation).
End use				
12	Space heating	Fuel shares for end use unchanged; held from 2016-2050.	100% of buildings' space heating needs are met by electric heat pump systems by 2050. (No new oil fuel heating systems can be installed from 2030 onwards)	**NZS:** To ensure net-zero by 2050, no fossil-fuelled heating systems can be purchased that might still be in use by 2050. In addition, air source heat pumps offer the most efficient use of energy for cooling and heating.
13	Water heating			
14	Space cooling			
ENERGY GENERATION				
Low- or zero-carbon energy generation (community scale)				
15	Rooftop Solar PV	To hold constant out to 2050 at 0 MW	n/a	Public survey showed interest; however, wind has greater potential for grid supply in the area. Small projects for cost-avoidance may occur where feasible through net-metering.
16	Ground mount solar		n/a	
17	Biogas	Riverhead Anaerobic Digester and re-use of biogas, expected to increase to 11,697.6 GJ in 2030, then hold constant.	n/a	St. John's Energy and Greenhouse Gas Inventory (2018) at Table 32.

18	Wind	To hold constant out to 2050 at 0 MW	30 wind turbines	**NZS:** Public survey showed interest in local renewable energy projects. A large wind project is currently under development in central Nova-Scotia (2,800 hectares, 34 wind turbines, 3 MW each--Vaughn, NS). This project is a best practice and an example for the City to follow. The consultant recommends that the City and its partners undertake a further study to identify maximum wind potential and strategic siting.
19	District Energy Generation	Memorial University / Health Science Centre diesel DE system to remain unchanged	Replace existing fuel oil boilers with electric boilers (from 2030 onwards)	**BAU:** Currently Memorial University university and the Health Science Center relies on 4 high temperature hot water oil boilers, 2 are back up. **NZS:** Electric are not as efficient as many of the best practices that are available for district energy systems (e.g., ambient geothermal with ground source heat pump back up; or, RNG-powered boilers or CHP), without a detailed study to determine sufficiency of back-up energy supply, electric boilers have been modelled. The consultant recommends that a detailed study be undertaken before committing to electric boilers.
TRANSPORTATION				
Transit				

20	Expanded transit	2018 ridership to stay constant out to 2050, despite the significant decline in 2020-2021 due to Covid.	30% increase ridership by 2030 50% increase ridership by 2040 2% per year (from baseline) per year after that.	Identified as a priority from public engagement. St. John's Transportation Commission (Metrobus).
21	Electrify transit system	No current plans	Electrify transit system by 2045, starting in 2025 all new buses are electric	St. John's Transportation Commission (Metrobus).
Active Transportation				
22	Mode share	Hold constant in all zones, except for intensification zones, where the active transportation share increases moderately out to 2050. Overall sustainable mode share increases from an average of 13% to 15%.	Increase modeshare by 50% for short trips (<2km walking <10 km for biking), linearly, starting in 2022 by 2050	**BAU:** City (Very low sustainable mode share target from the Direction Note to the Committee of the Whole on Sustainable Mode Share Targets, November 4, 2020.) Consistent with Mode Share Target Council Decision (November 2020)
Private/personal use				
23	Electrify municipal fleet	No change to municipal fleets.	100% EV by 2045	Corporate Climate Plan (adopted May 2021)
24	Electrify personal vehicles	10% new sales by 2034, continue increase at 1% a year until 2050, reaching 26% of new sales by 2050	100% new sales EV by 2035	**BAU**: Dunsky, Newfoundland Conservation Potential Study (2020-2034), Appendix 2, Table F- 39: Adoption Under Baseline Scenario. (Reaching 10% of new

25	Electrify commercial vehicles	11% new sales by 2034, continue increase at 1% a year until 2050, reaching 28% of new sales by 2050	100% new sales EV by 2035; other than heavy trucks, which reach 25% new sales being electric by 2035, then stays constant	personal vehicle sales and 11% of commercial vehicles sales by 2034.) Identified as a priority from public engagement Aligned with the new federal target of 100% of vehicle sales to be EV by 2035 (assuming a 13-year vehicle life cycle).
MARINE & AVIATION				
26	Marine	Based on share of local employment	Reduce GHG use intensity by 50%	BAU: Statistics Canada, Provincial Marine Fuel Use for Newfoundland, Table: 25-10-0029-01 (2017 data, as 2016 was suppressed) NZS: International Marine Organization commitment, halving emissions by 2050 as compared to a 2008 baseline.
27	Aviation	Based on population	100% net zero by 2050	**BAU:** Statistics Canada, Provincial Aviation Fuel Use for Newfoundland, Table: 25-10-0029-01 (formerly CANSIM 128-0016) (2017 data, as 2016 was suppressed) **NZS**: Air Canada committed to be 100% Net-Zero by 2050; International Civil Aviation Organization has also begun to track net-zero aligned commitments by airlines and airports.
WASTE				
28	Waste diversion	To hold constant	Divert 95% of organic waste from landfill by 2040 to composting facility	City

29	Landfill gas capture	Robin Hood Bay: landfill gas capture system currently captures an estimated 60% of methane emissions, to increase by 5% by 2022, and another 5% by 2030.	to increase to 80% by 2040	**NZS:** the consultant recommends that the City and its partners undertake a feasibility study on the potential to divert organic waste to a central anaerobic digester and refinery, so that it may be used as a local source of fuel, potentially for a district energy system.
30	Industrial efficiencies (including wastewater treatment)	No change.	Increase by 50% by 2050 (linearly, starting in 2023)	**NZS:** Newfoundland Achievable Conservation Potential Study; Ontario Achievable Potential Study.
TREE PLANTING				
31	Tree Planting	none included	8.24 t CO_2 reduced annually to 2050, from 11.3 hectares of urban reforestation (2021-2023)	**NZS: City** tree planting project – "Carbon Sequestration Naturalization" (Approved by City Council Nov. 2020). Additional naturalization and fuel switching of turf maintenance equipment supports the effort to reach NZ.

Community Energy and Emissions

Table 2. Community energy use and emissions, per capita, in 2016 and in 2050 in a business-as-usual and in a net-zero scenario.

	2016	2050 BAU	2050 NZS	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Per capita energy (GJ/cap)	127,728	99,020	46,203	-64%	-53%
Per capita emissions (tCO2eJ/cap)	6.3	4.0	0.3	-95%	-93%

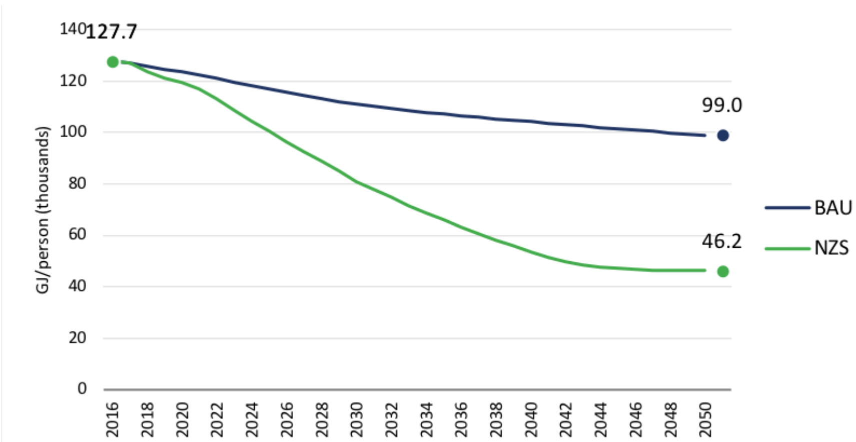


Figure 1. Energy use per capita in a business-as-usual and in a net-zero scenario, 2016-2050.

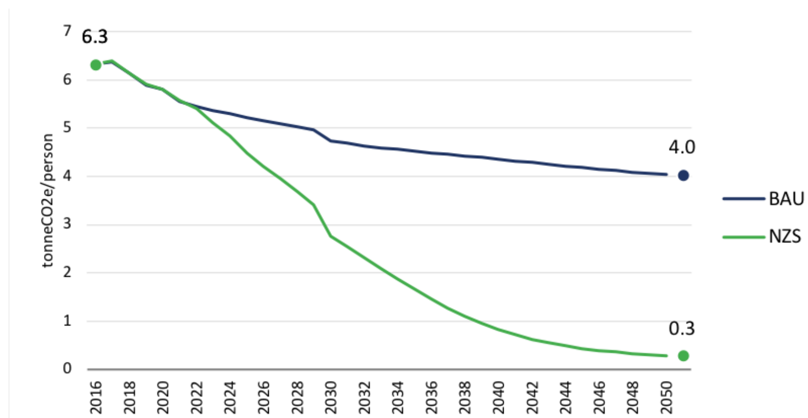


Figure 2. Greenhouse gas emissions per capita in a business-as-usual and in a net-zero scenario, 2016-2050.

Table 3. Community energy use, by fuel, in 2016 and in 2050 in a business-as-usual and in a net-zero scenario.

Energy by fuel (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Ambient	0	0	0	0	1,843,677	28%	100%	100%
Diesel	628,279	4%	424,451	3%	103,010	2%	-84%	-76%
District Energy	288,025	2%	237,347	2%	119,943	2%	-58%	-49%
Fuel Oil	2,047,977	13%	1,640,875	12%	15,260	0.2%	-99%	-99.9%
Gasoline	4,120,829	26%	2,947,728	21%	4,037	0.1%	-100%	100%
Grid Electricity	6,617,928	42%	7,120,629	51%	3,585,153	55%	-46%	-50%
Local Electricity	0%	0%	0%	0%	856,398	13%	100%	100%
Propane	1,052,276	7%	1,056,078	8%	26,441	0.4%	-97%	-19%
RNG	11,478	0%	11,572	0%	7,715	0.1%	-33%	-33%
Wood	1,167,207	7%	623,884	4%	0	0%	-100%	-100%
Total	15,934,000	100%	14,062,563	100%	6,561,634	100%	-59%	-53%

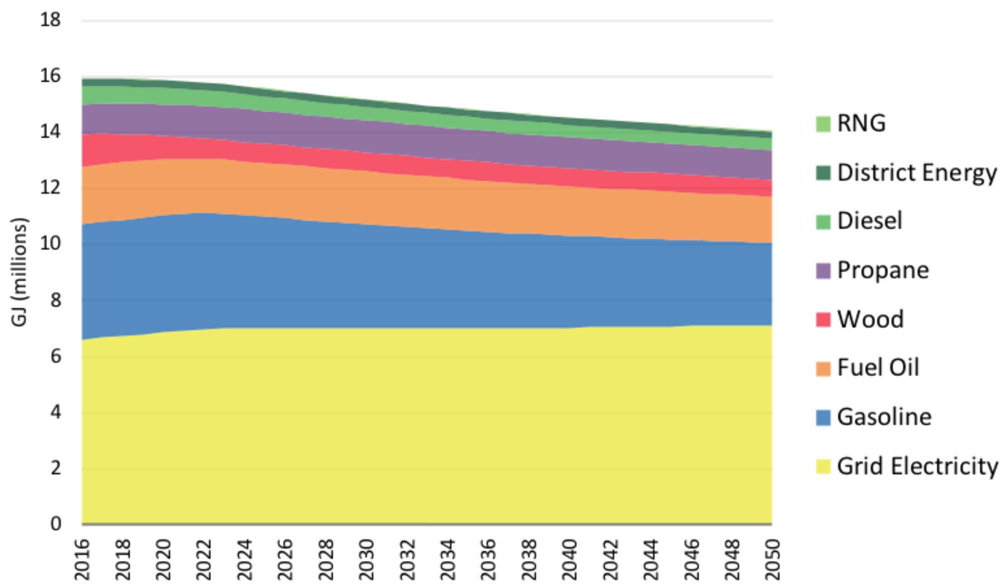


Figure 3. Community energy use by fuel in a business-as-usual scenario, 2016-2050.

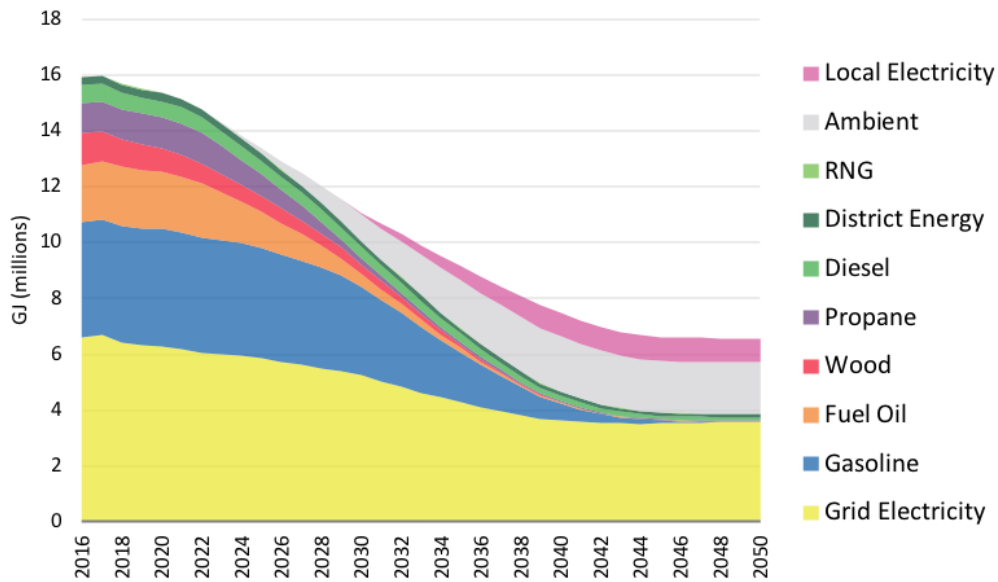


Figure 4. Community energy use by fuel in a net-zero scenario, 2016-2050.

Table 4. Community energy use, by sector, in 2016 and in 2050 in a business-as-usual and in a net-zero scenario.

Energy by fuel (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Agriculture	7,538	0%	10,043	0%	6,695	0%	-11%	-33%
Commercial	5,071,507	32%	4,693,371	33%	1,470,246	22%	-71%	-69%
Industrial	35,882	0%	36,489	0%	22,442	0%	-37%	-38%
Municipal	265,029	2%	324,624	2%	176,479	3%	-33%	-46%
Residential	5,811,293	36%	5,348,128	38%	3,337,774	51%	-43%	-38%
Transportation	4,742,750	30%	3,649,909	26%	1,547,997	24%	-67%	-58%
Total	15,934,000	100%	14,062,563	100%	6,561,634	100%	-59%	-53%

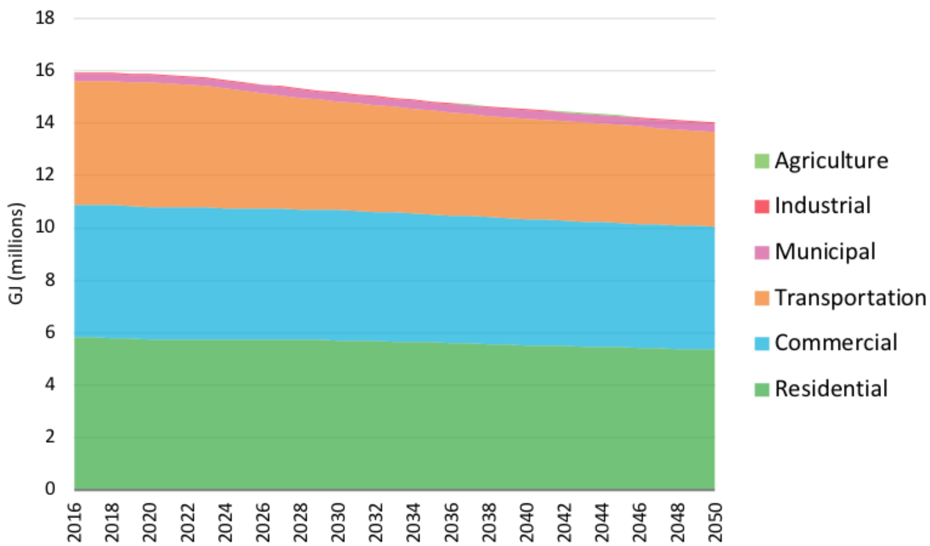


Figure 5. Community energy use by sector in a business-as-usual scenario, 2016-2050.

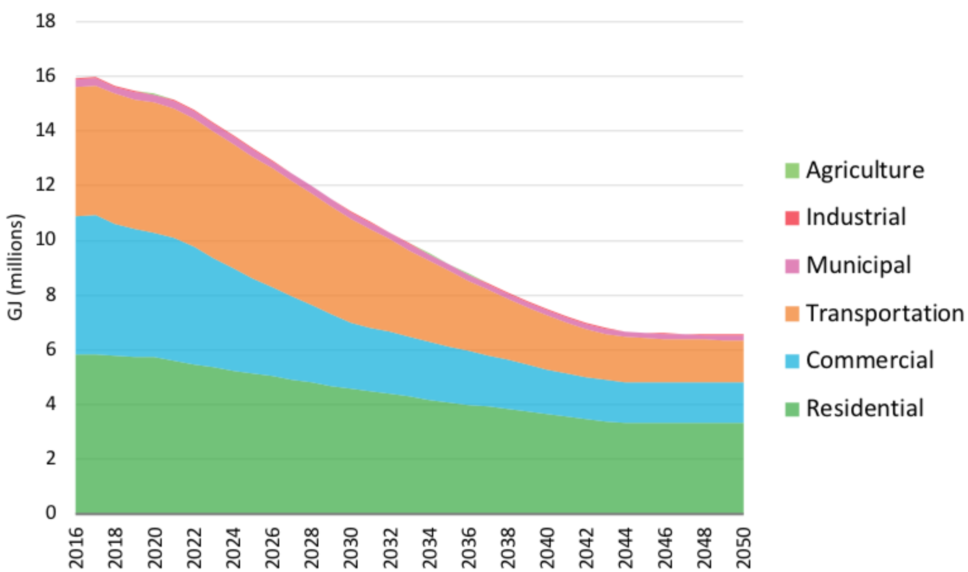


Figure 6. Community energy use by sector in a net-zero scenario, 2016-2050.

Table 5. Community greenhouse gas emissions, by sector, in 2016 and in 2050 in a business-as-usual and in a net-zero scenario.

Emissions by sector (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Agriculture	537	0%	715	0%	477	1%	-11%	-33%
Commercial	161,651	20%	107,175	19%	2,409	6%	-99%	-98%
Energy Production	31,533	4%	25,966	5%	95	0%	-100%	-100%
Fugitive	14	0%	14	0%	9	0%	-33%	-38%
Industrial	351	0%	133	0%	72	0%	-79%	-46%
Municipal	5,806	1%	3,827	1%	1,180	3%	-80%	-69%
Residential	141,273	18%	92,133	16%	952	2%	-99%	-99%
Transportation	389,384	49%	296,754	52%	8,627	21%	-98%	-97%
Waste	58,867	7%	46,590	8%	26,391	66%	-55%	-43%
Total	789,417	100%	573,307	100%	40,213	100%	-95%	-93%

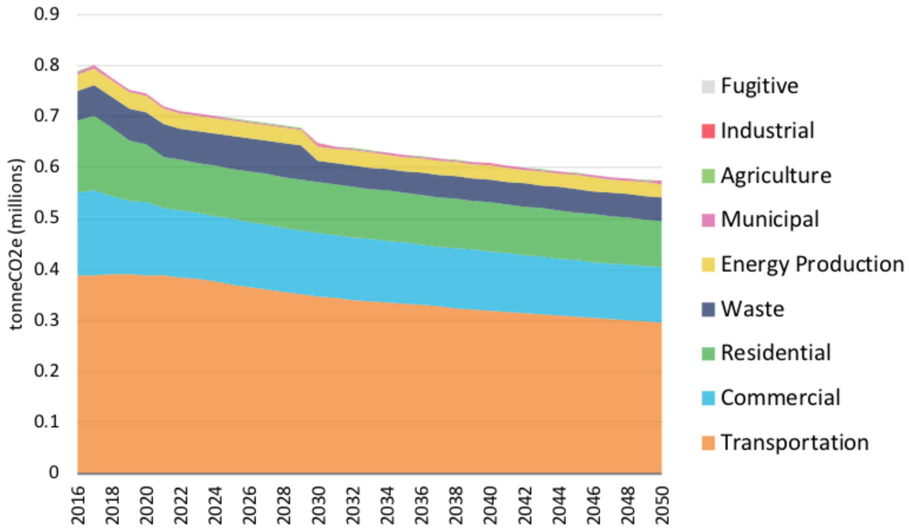


Figure 6. Community greenhouse gas emissions by sector in a business-as-usual scenario, 2016-2050.

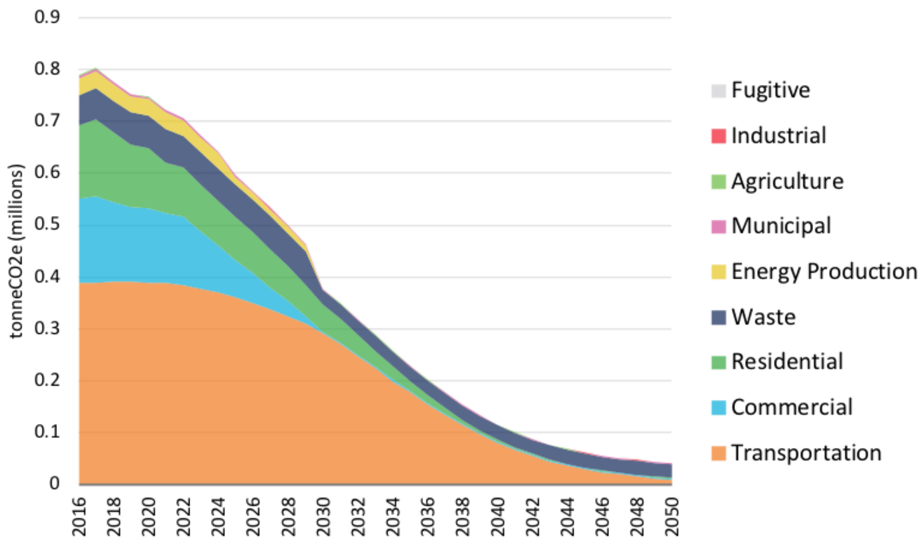


Figure 7. Community greenhouse gas emissions by sector in a net-zero scenario, 2016-2050.

Table 6. Community greenhouse gas emissions by fuel in 2016 and in 2050 in a business-as-usual and in a net-zero scenario.

Emissions by source (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Diesel	46,148	6%	31,491	5%	7,913	20%	-83%	-75%
Fuel Oil	177,213	22%	142,672	25%	1,087	3%	-99%	-99%
Gasoline	274,028	35%	196,017	34%	269	1%	-100%	-100%
Grid Electricity	68,044	9%	5,620	1%	2,924	7%	-96%	-48%
Jet Fuel	69,734	9%	69,734	12%	0	0%	-100%	-100%
Non-energy	58,881	7%	46,604	8%	26,401	66%	-55%	-43%
Propane	64,360	8%	64,593	11%	1,617	4%	-97%	-97%
Wood	3	0%	3	0%	2	0%	-33%	-33%
Total	789,417	100%	573,307	100%	40,213	100%	-95%	-93%

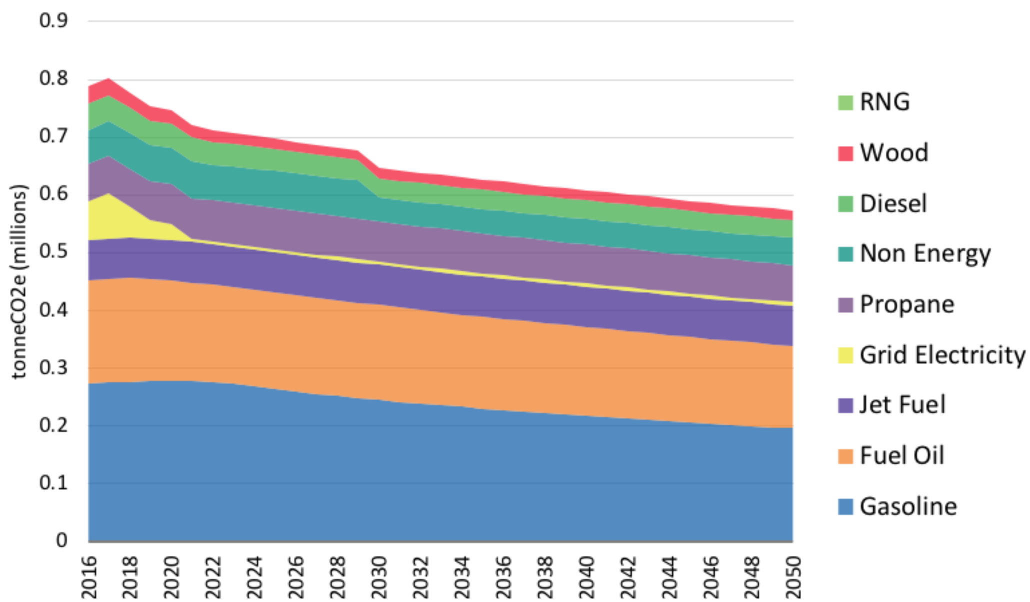


Figure 8. Community greenhouse gas emissions by fuel in a business-as-usual scenario, 2016-2050.

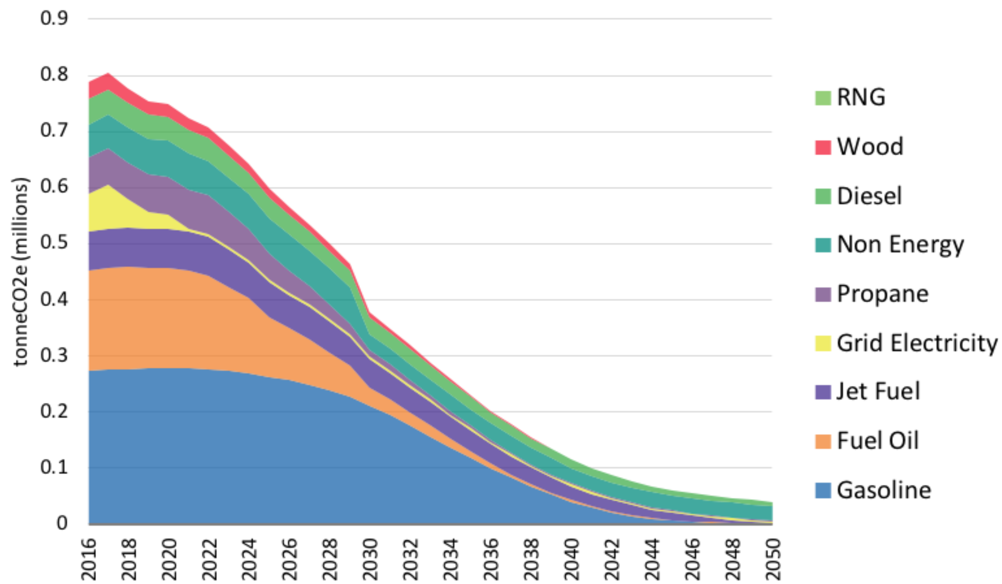


Figure 9. Community greenhouse gas emissions by fuel in a net-zero scenario, 2016-2050.

Buildings Energy and Emissions

Table 7. Buildings energy use in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by fuel.

Energy by end use (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Industrial Processes	138,736	1%	173,046	2%	117,101	2%	-16%	-32%
Lighting	714,956	6%	769,070	7%	404,589	8%	-43%	-47%
Major Appliances	363,034	3%	419,242	4%	287,172	6%	-21%	-32%
Plug Load	1,690,499	15%	1,759,888	17%	959,741	19%	-43%	-45%
Space Cooling	233,115	2%	452,153	4%	64,271	1%	-72%	-86%
Space Heating	7,020,732	63%	5,773,626	55%	2,860,857	57%	-59%	-50%
Water Heating	1,030,177	9%	1,065,628	10%	319,907	6%	-69%	-70%
Total	11,191,249	100%	10,412,655	100%	5,013,637	100%	-55%	-52%

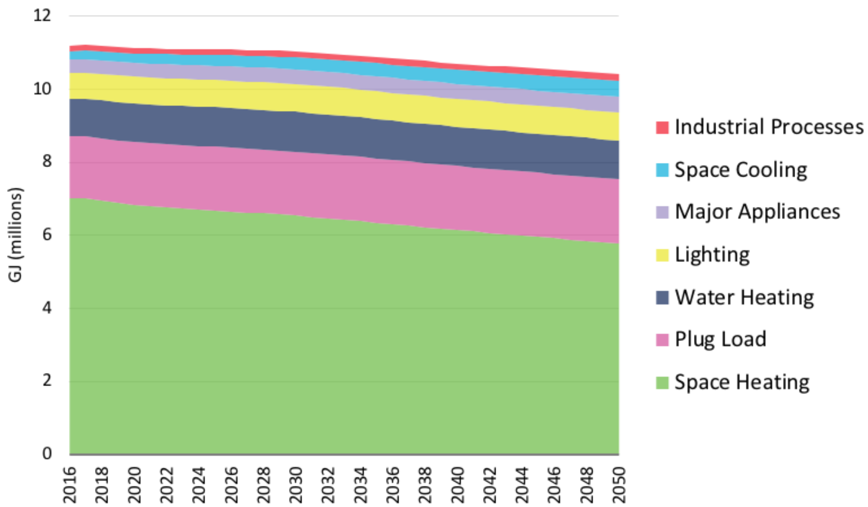


Figure 10. Building energy use by end use in a business-as-usual scenario, 2016-2050.

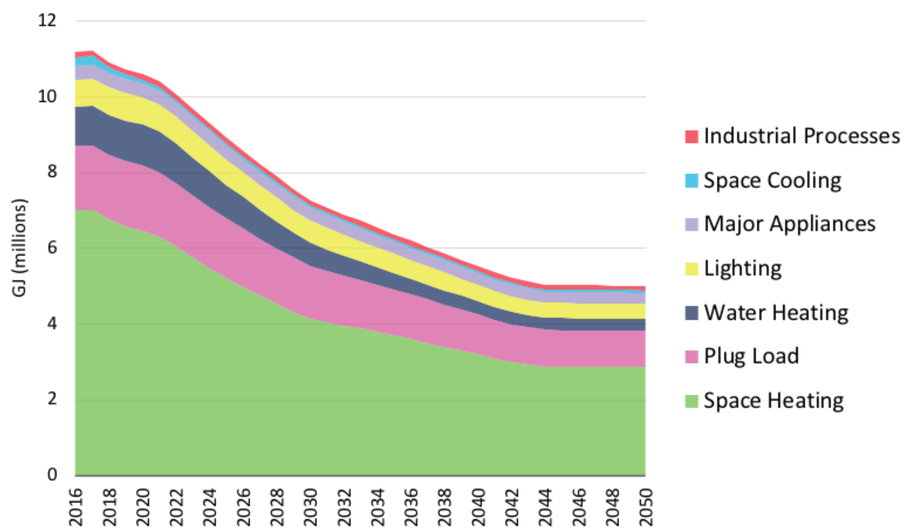


Figure 11. Building energy use by end use in a net-zero scenario, 2016-2050.

Table 8. Buildings energy use in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by fuel.

Energy by fuel (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Ambient	0	0%	0	0%	1,843,677	37%	100%	100%
Diesel	7,538	0%	10,043	0%	6,695	0%	-11%	-33%
District Energy	288,025	3%	237,347	2%	119,943	2%	-58%	-49%
Fuel Oil	2,047,977	18%	1,640,875	16%	15,260	0%	-99%	-99%
Grid Electricity	6,616,748	59%	6,832,858	66%	2,416,636	48%	-63%	-65%
Local Electricity	0	0%	1,056,078	10%	577,270	12%	100%	-45%
Propane	1,052,276	9%	11,572	0%	26,441	1%	-97%	128%
RNG	11,478	0%	623,884	6%	7,715	0%	-33%	-99%
Wood	1,167,207	10%	10,412,655	100%	0	0%	-100%	-100%
Total	11,191,249	100%	10,043	0%	5,013,637	100%	-55%	-52%

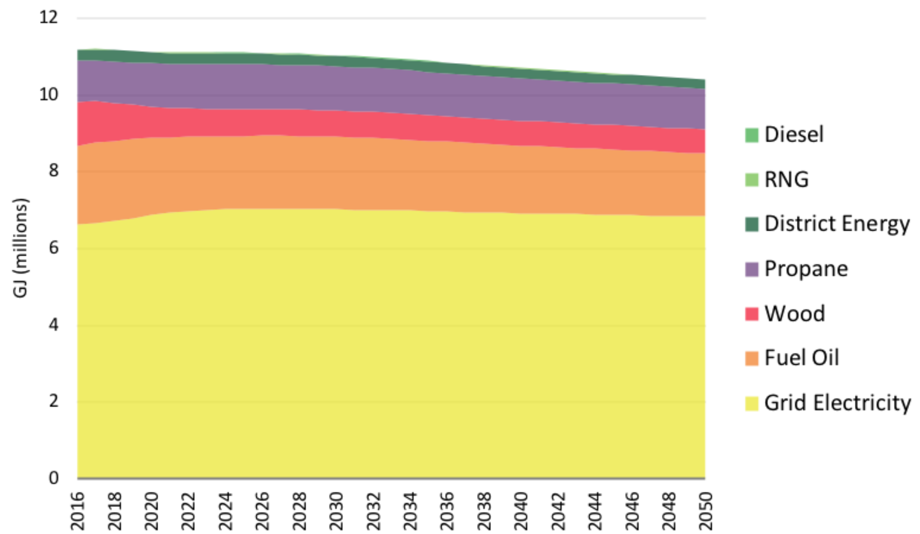


Figure 12. Building energy use by end use in a business-as-usual scenario, 2016-2050.

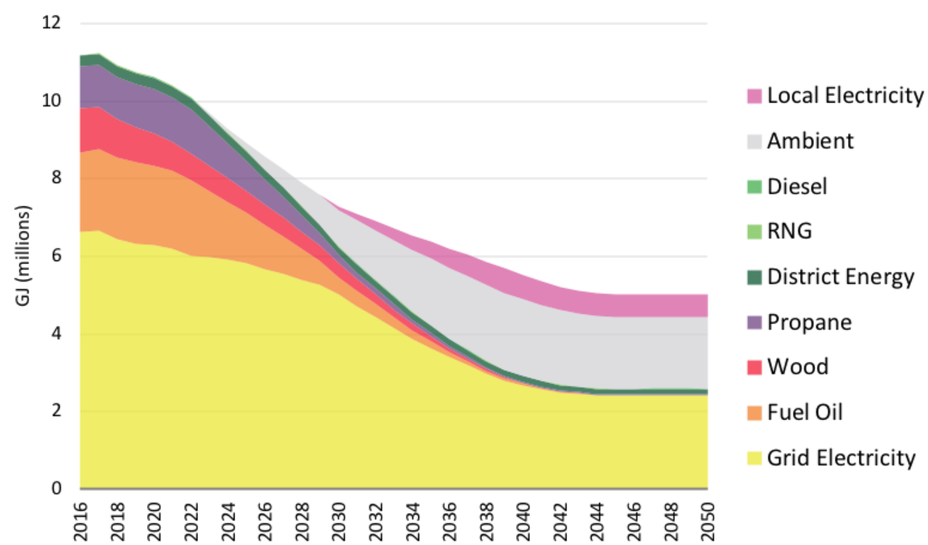


Figure 13. Building energy use by end use in a net-zero scenario, 2016-2050.

Table 9. Buildings greenhouse gas emissions in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by end use.

Emissions by end use (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Industrial Processes	2,879	1%	2,468	1%	1,633	32%	-43%	-34%
Lighting	7,351	2%	607	0%	258	5%	-96%	-58%
Major Appliances	3,733	1%	331	0%	183	4%	-95%	-45%
Plug Load	19,876	6%	4,417	2%	2,160	42%	-89%	-51%
Space Cooling	2,397	1%	357	0%	41	1%	-98%	-89%
Space Heating	236,716	76%	161,846	79%	582	11%	-100%	-100%
Water Heating	36,668	12%	33,959	17%	234	5%	-99%	-99%
Total	309,618	100%	203,984	100%	5,090	100%	-98%	-98%

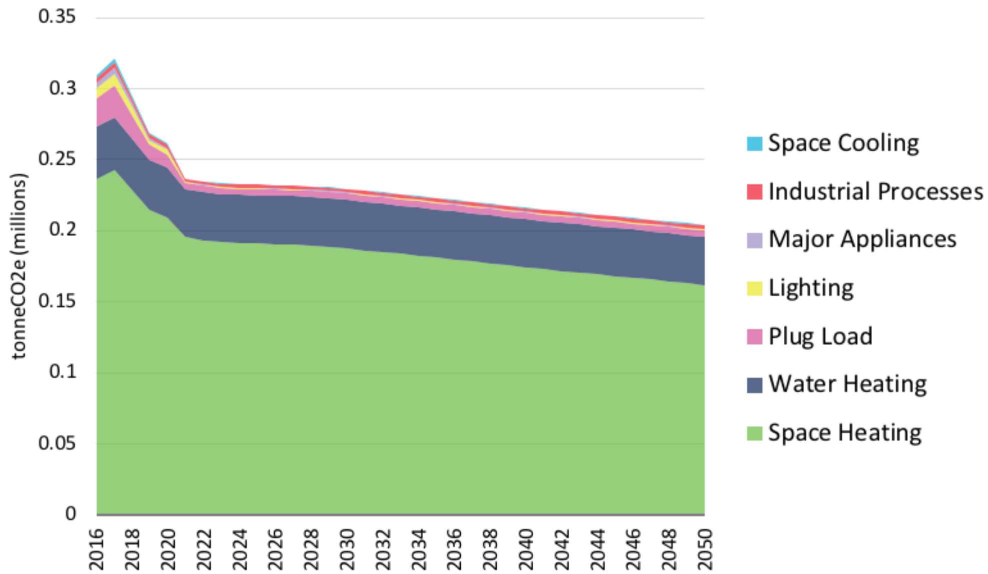


Figure 14. Building greenhouse gas emissions by end use in a net-zero scenario, 2016-2050.

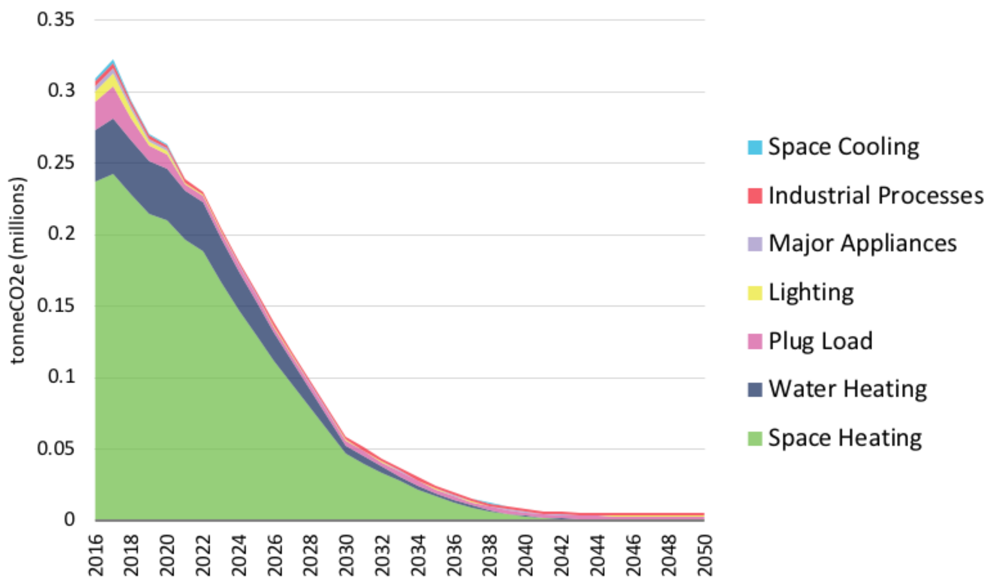


Figure 15. Building greenhouse gas emissions by end use in a net-zero scenario, 2016-2050.

Table 10. Buildings greenhouse gas emissions in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by fuel.

Emissions by fuel (tCO_2e)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Diesel	537	0%	715	0%	477	9%	-11%	-33%
Fuel Oil	145,679	47%	116,706	57%	1,087	21%	-99%	-99%
Grid Electricity	68,031	22%	5,393	3%	1,907	37%	-97%	-65%
Propane	64,360	21%	64,593	32%	1,617	32%	-97%	-97%
RNG	3	0%	3	0%	2	0%	-33%	-33%
Wood	31,008	10%	16,574	8%	0	0%	-100%	-100%
Total	**309,618**	**100%**	**203,984**	**100%**	**5,090**	**100%**	**-98%**	**-98%**

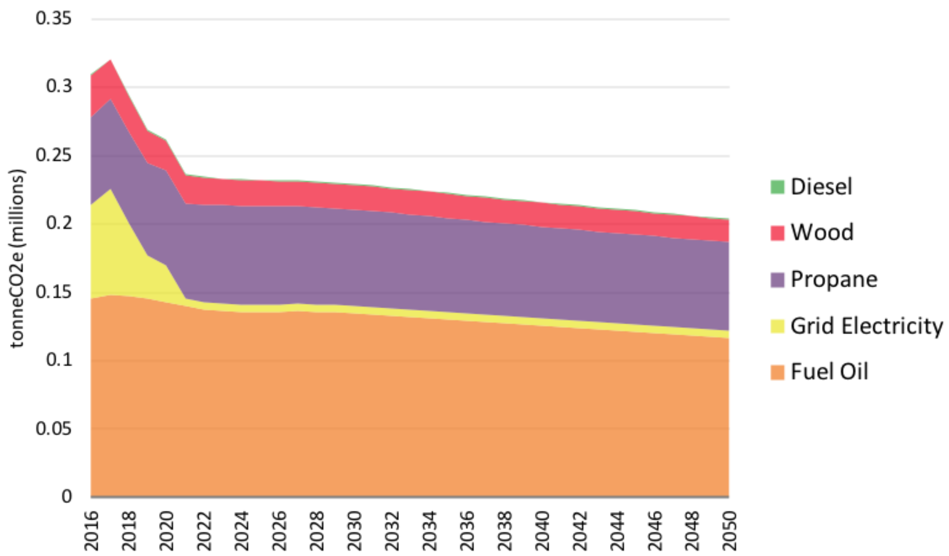


Figure 16. Building greenhouse gas emissions by fuel in a business-as-usual, 2016-2050.

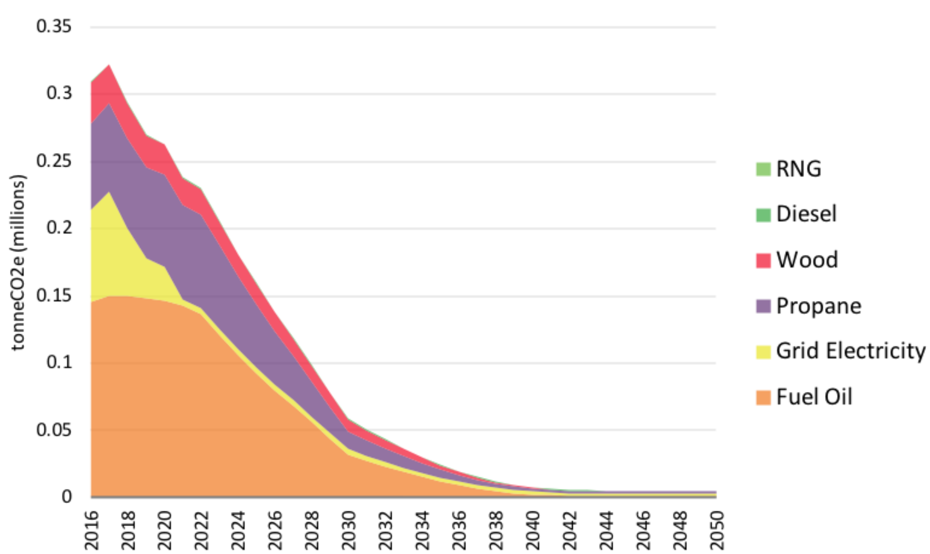


Figure 17. Building greenhouse gas emissions by fuel in a net-zero scenario, 2016-2050.

Transportation Energy and Emissions

Table 11. Transportation energy use in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by fuel.

Energy by fuel (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/- 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Diesel	472,741	10%	266,408	8%	22,315	2%	-95%	-92%
Gas	4,120,829	90%	2,947,728	84%	4,037	0%	-100%	-100%
Grid electricity	1,180	0%	287,772	8%	1,134,385	79%	960,53%	294%
Local electricity	4,594,750	100%	3,501,909	100%	270,975	19%	100%	100%
Total	472,741	10%	266,408	8%	1,431,711	100%	-69%	-59%

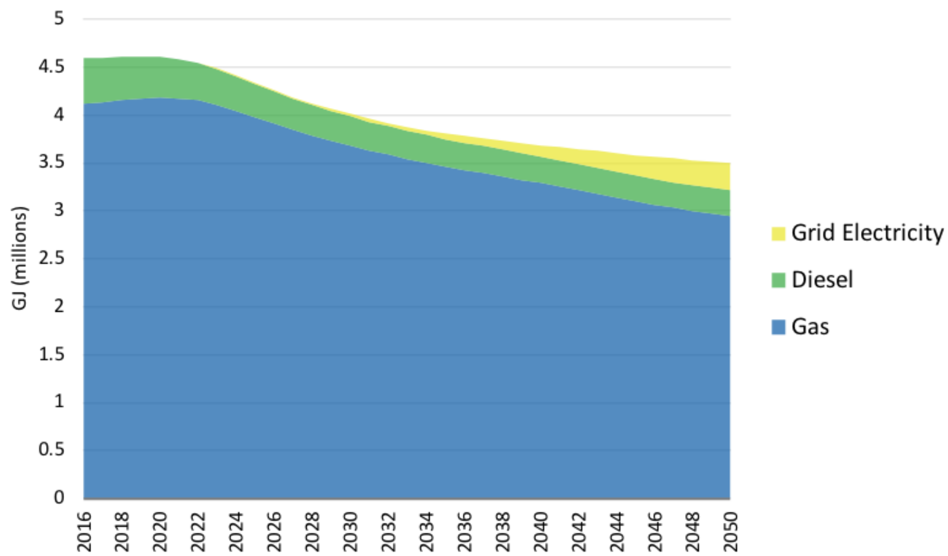


Figure 18. Transportation energy use by fuel in a business-as-usual scenario, 2016-2050.

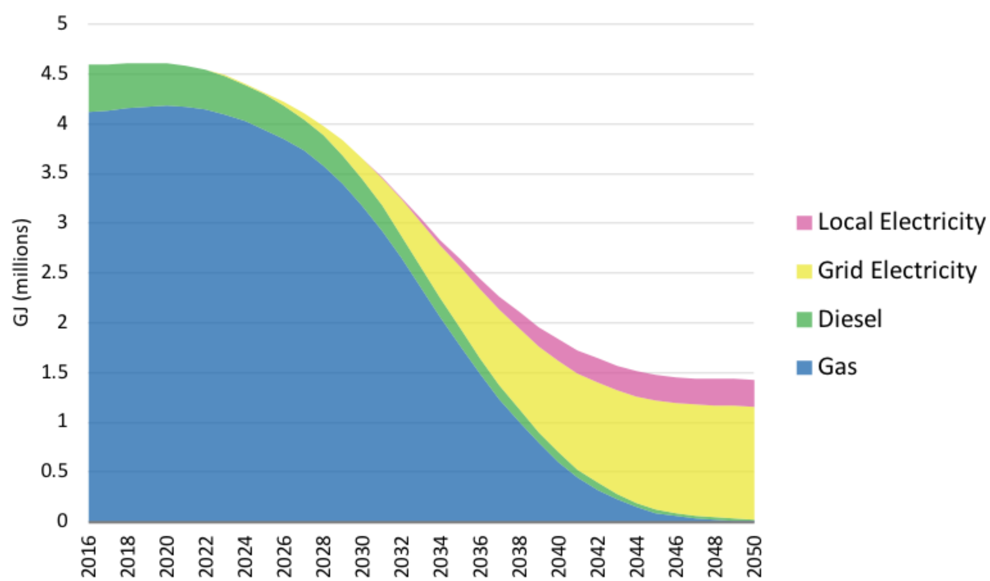


Figure 19. Transportation energy use by fuel in a net-zero scenario, 2016-2050.

Table 11. Transportation energy use in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by vehicle type.

Energy by vehicle (GJ)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/ 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Car	3,298,242	72%	1,161,231	33%	467,351	33%	-86%	-60%
Heavy truck	146,173	3%	103,196	3%	42,384	3%	-71%	-59%
Light truck	1,067,866	23%	2,155,013	62%	894,655	62%	-16%	-58%
Urban bus	82,469	2%	82,469	2%	27,322	2%	-67%	-67%
Total	4,594,750	100%	3,501,909	100%	1,431,711	100%	-69%	-59%

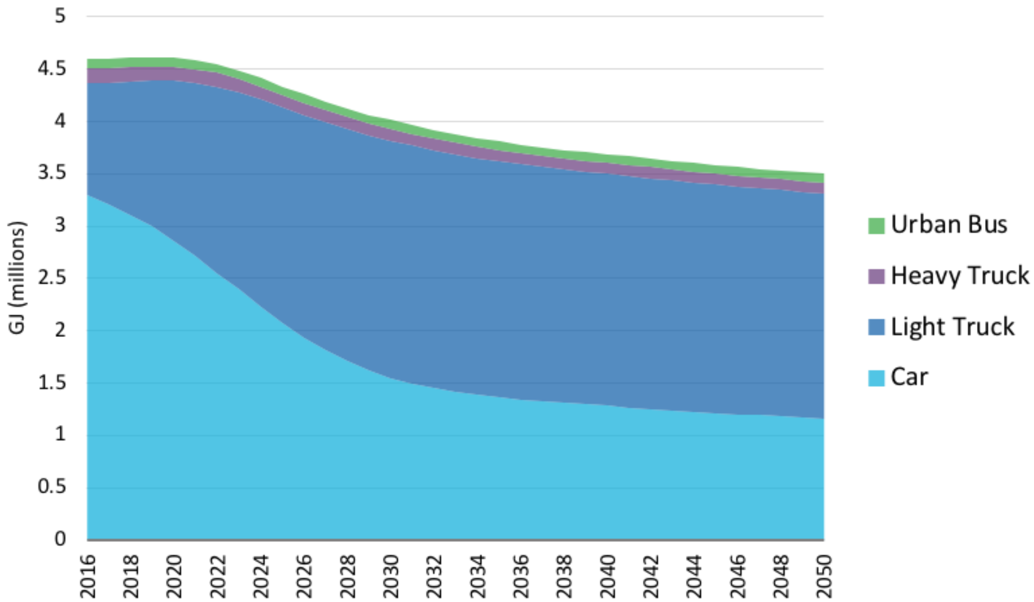


Figure 20. Transportation energy use by vehicle type in a business-as-usual scenario, 2016-2050.

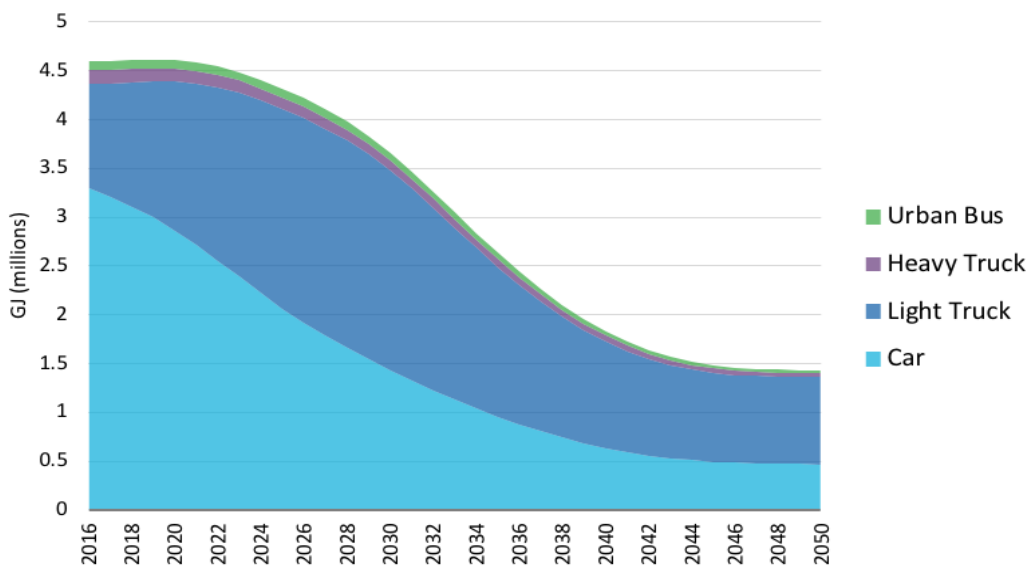


Figure 21. Transportation energy use by vehicle type in a net-zero scenario, 2016-2050.

Table 12. Transportation greenhouse gas emissions in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by fuel.

Emissions by source (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/ 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Diesel	45,611	12%	30,776	10%	7,436	86%	-84%	-76%
Gasoline	274,028	70%	196,017	66%	269	3%	-100%	-100%
Grid electricity	12	0%	227	0%	922	11%	7,503%	306%
Jet fuel	69,734	18%	69,734	23%	0	0%	-100%	-100%
Total	389,384	100%	296,754	100%	8,627	100%	-98%	-97%

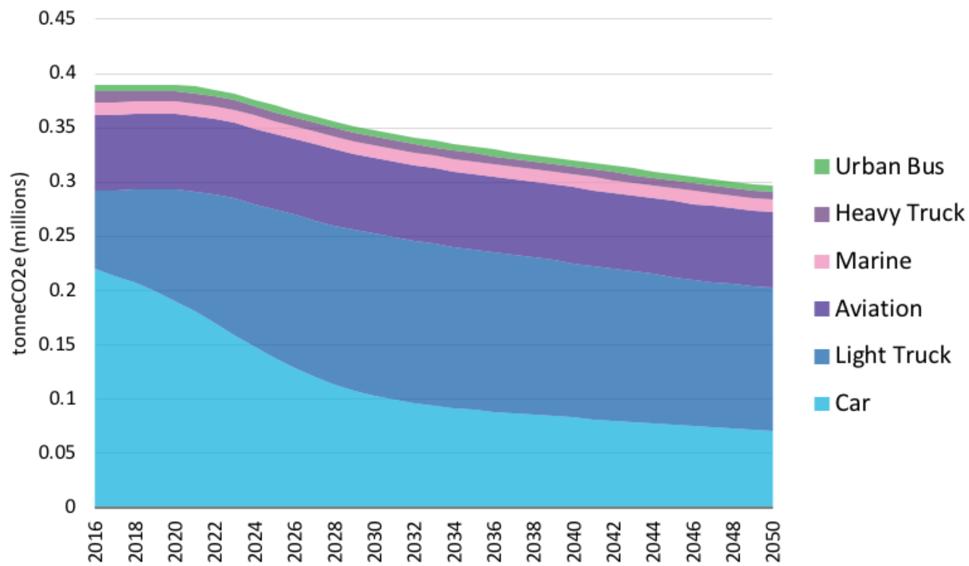


Figure 22. Transportation greenhouse gas emissions, by vehicle type, in a business-as-usual scenario, 2016 to 2050.

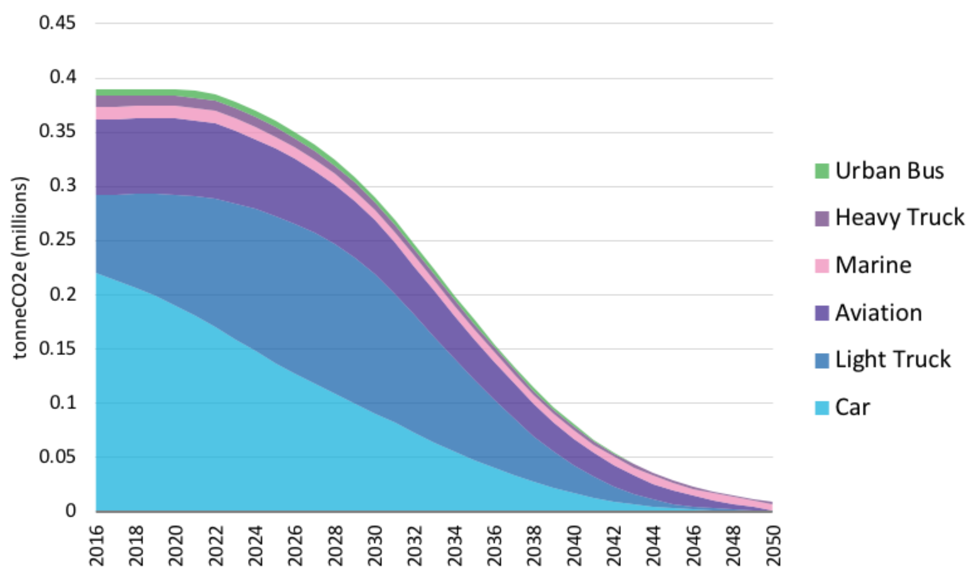


Figure 23. Transportation greenhouse gas emissions, by vehicle type, in a net-zero scenario, 2016 to 2050.

Table 13. Transportation greenhouse gas emissions in 2016 and in 2050 in a business-as-usual and in a net-zero scenario, by vehicle type.

Emissions by vehicle (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/ 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Aviation	69,734	18%	69,734	23%	0	0%	-100%	100%
Car	219,829	56%	71,019	24%	370	4%	-100%	-99%
Heavy truck	10,440	3%	7,134	2%	1,603	19%	-85%	-78%
Light truck	71,782	18%	131,275	44%	770	9%	-99%	-99%
Marine	11,681	3%	11,681	4%	5,868	68%	-50%	-50%
Urban bus	5,919	2%	5,911	2%	17	0%	-100%	-100%
Total	389,384	100%	296,754	100%	8,627	100%	-98%	-97%

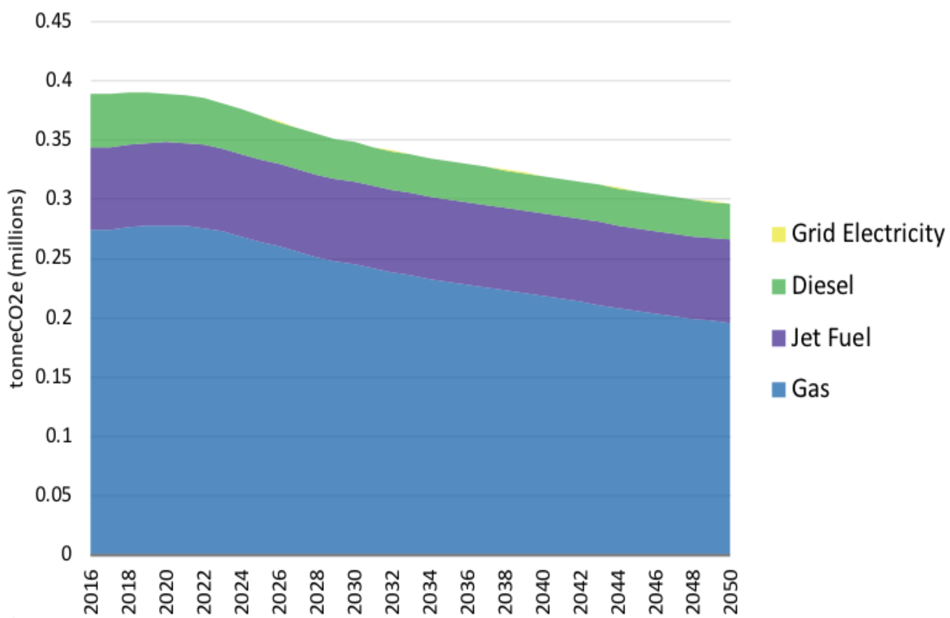


Figure 24. Transportation greenhouse gas emissions, by fuel, in a business-as-usual scenario, 2016 to 2050.

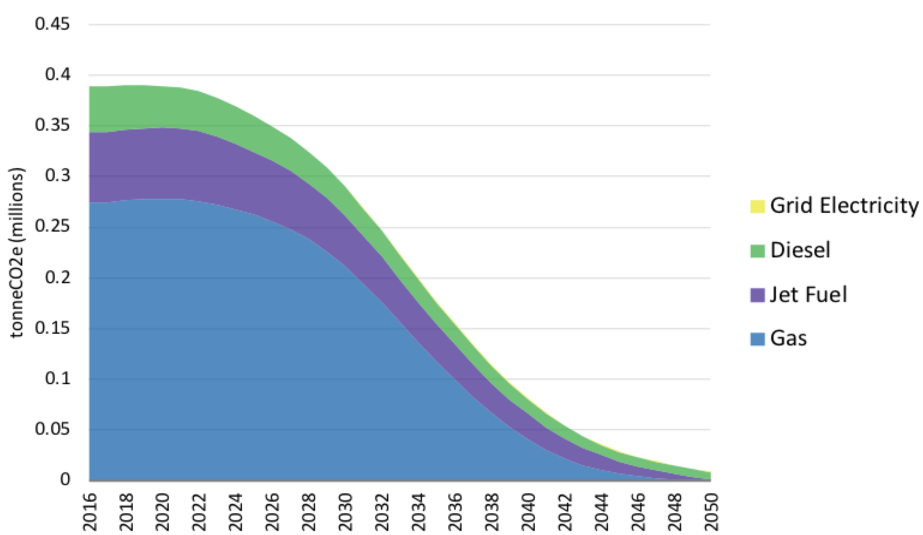
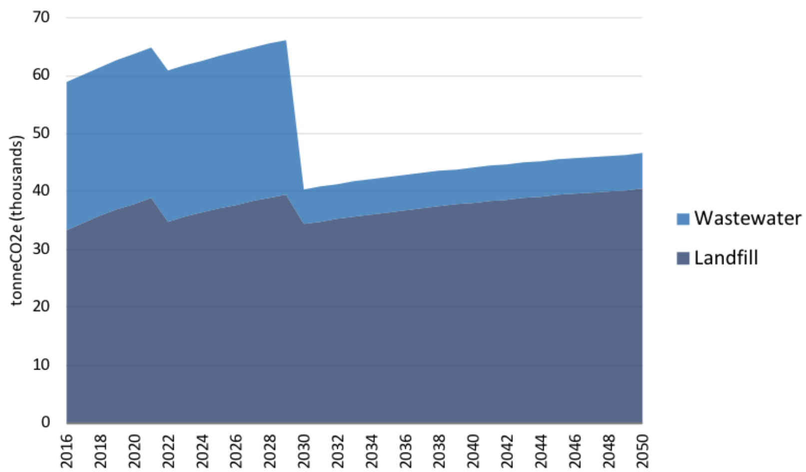


Figure 25. Transportation greenhouse gas emissions, by fuel, in a net-zero scenario, 2016 to 2050.

Waste Emissions

Table 14. Waste greenhouse gas emissions, by waste type in 2016 and in 2050 in a business-as-usual and in a net-zero scenario.

Emissions by source (tCO2e)	2016	share 2016	2050 (BAU)	share 2050	2050 NZS	share 2050	% +/ 2016-2050 NZS	% +/- 2050 BAU-2050 NZS
Biological (compost)	0	0%	0	0%	2,185	8%	100%	100%
Landfill	33,354	57%	40,440	87%	18,056	68%	-46%	-55%
Wastewater	25,514	43%	6,150	13%	6,150	23%	-76%	0%
Total	58,867	100%	46,590	100%	26,391	100%	-55%	-43%



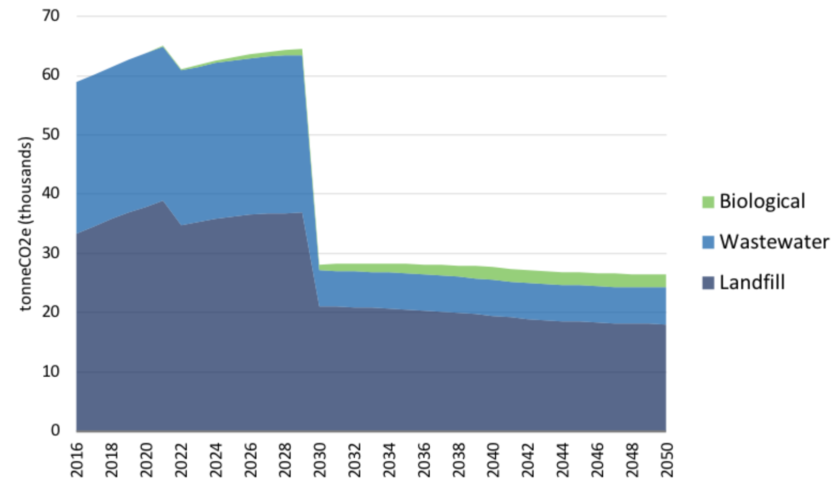


Figure 26. Waste emissions, by waste type, in a business-as-usual and net-zero scenario, 2016 to 2050.

Appendix B: St. John's Energy Transition Economic and Financial Analysis

October 2021

Purpose of this Document

This document provides a summary of the projected costs, revenues, and savings represented by the City of St. John's Energy Transition, on the whole and on an action-by-action basis. It also provides an overview of some of the Energy Transition's broader economic impacts, such as on jobs and household energy costs.

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DISCLAIMER

Reasonable skill, care, and diligence have been exercised to assess the information acquired during the preparation of this analysis, but no guarantees or warranties are made regarding the accuracy or completeness of this information. This document, the information it contains, the information and basis on which it relies, and the associated factors are subject to changes that are beyond the control of the author. The information provided by others is believed to be accurate but has not been verified.

This analysis includes strategic-level estimates of capital investments and related revenues, energy savings, and avoided costs of carbon represented by the proposed Energy Transition. The intent of this analysis is to help inform project stakeholders about the potential costs and savings represented by the Energy Transition in relation to the modelled reference scenario. It should not be relied upon for other purposes without verification. The authors do not accept responsibility for the use of this analysis for any purpose other than that stated above and do not accept responsibility to any third party for the use, in whole or in part, of the contents of this document.

This analysis applies to the City of St. John's and cannot be applied to other jurisdictions without further analysis. Any use by the City of St. John's, its sub-consultants or any third party, or any reliance on or decisions based on this document, is the responsibility of the user or third party.

Acronyms

BAP	business-as-planned
GHG	greenhouse gas
NPV	net present value
NZS	net zero scenario
MAC	marginal abatement cost
MACC	marginal abatement cost curve
PV	present value

Units

CO2e	carbon dioxide equivalents
kWh	kilowatt hour

Overview

The following table highlights the key findings from the financial analysis of the net-zero scenario modelled for the City of St. John's Energy Transition. Further details about what is captured in each financial estimate are provided in the body of the report, as indicated in the right-hand column.

Table 1. Summary of high-level financial analysis of St. John's' Energy Transition.

Financial estimate	Key results	Where to find further details
The net benefit of the Energy Transition investments, 2022-2089	*≈ $1.788 billion, NPV.*	NPV, Figure 4
Total incremental capital investment, 2022-2050	*≈ $5.46 billion NPV.*	NPV and MAC Values
Total savings (avoided energy maintenance and carbon costs), 2022-2089[11]	*≈ $7.00 billion, NPV.*	Cash Flow Analysis
Total revenue, 2022-2089	*≈ 246 million, NPV.*	Cash Flow Analysis
Average cost to reduce each tonne of GHG	*≈ $167 in savings, NPV.*	Table 3
Top 5 most cost-effective GHG-reduction actions ($/ tonne CO2e)	1. *Large scale wind ≈ $5,466 in savings* 2. *New residential buildings ≈ $940 in savings* 3. *Transit expansion & electrification ≈ $836 in savings* 4. *Municipal fleet electrification: ≈ $588 in savings* 5. *New commercial & industrial buildings: ≈$572 in savings*	Table 3
Household savings on energy, average in 2050	*≈ $4,324*	Pt. 2, Cost Savings for Households

[11] While the capital investments in the Energy Transition all occur by 2050, the savings and revenue from many of those investments continue well beyond 2050 and are tracked in this analysis to the year 2089.

What Is and Is Not Included

The following five categories of costs and savings are included in this financial analysis:

1. capital costs,
2. maintenance costs,
3. revenues,
4. energy costs/savings, and
5. carbon cost savings.

Neither are the operating costs associated with actions (e.g., administration, education, or marketing costs) or the avoided costs of additional central electricity capacity included in the financial analysis.

Where defensible cost and savings are not identified for particular actions, they are excluded from the financial analysis. As a result, the following Energy Transition actions are not included in this financial analysis:

- active transportation mode share increase,
- organics waste diversion,
- marine fuel efficiency, and
- aviation fuel net-zero by 2050.

Part 1. Key Financial Analysis Concepts

The direct financial impacts of St. John's' Energy Transition provide important context for local decision-makers. However, it is important to note that the direct financial impacts are a secondary motivation for undertaking actions that reduce greenhouse gas (GHG) emissions. First and foremost, GHG reductions are a critical response to the global climate emergency. In addition, most measures included in the Energy Transition provide social goods to the community, such as net job creation and positive health outcomes. These benefits are only marginally captured in this financial analysis via the cost of carbon.

Key concepts that are used to analyze the financial impacts of the Energy Transition are summarized below.

Costs Are Relative to the BAP

This financial analysis tracks projected costs and savings associated with net-zero measures that are above and beyond the assumed "reference" costs under a business-as-planned (BAP) scenario, which is a projection of current plans and policies.

Discount Rate

The discount rate is the baseline growth value an investor places on their investment dollar. A project is considered financially beneficial by an investor if it generates a real rate of return equal to or greater than their discount rate.

An investor's discount rate varies with the type of project, the duration of investment, risk, and the scarcity of capital.

The social discount rate is the discount rate applied for comparing the value to society of investments made for the common good. As such, it is inherently uncertain and difficult to determine. Some argue that in the evaluation of climate change mitigation investments a very low or even zero discount rate should be applied. In this project, we evaluate investments in a net-zero future with a 3% discount rate.[12]

Net Present Value

The net present value (NPV) of an investment is the difference between the present value (PV) of the future stream of savings and revenue generated by the investment and the capital investment.

$$NPV = (PV\ savings + PV\ revenue) - PV\ capital\ investment$$

Five aggregate categories are used to track the financial performance of the net-zero actions in this analysis: capital expenditures, energy savings (or additional costs), carbon cost savings (assuming the carbon price reaches $170/tonne CO2e in 2050 and is held constant thereafter),

---

[12] 3% is the social discount rate recommended by the Treasury Board of Canada (Treasury Board of Canada Secretariat, Canadian Cost-Benefit Analysis Guide Regulatory Proposals, 2007, at 38). A social discount rate is recommended for instances where:

- A regulatory proposal primarily affects private consumption of goods and services
- A regulatory proposal's impacts occur over the long term (50 years or more)

(Treasury Board of Canada, 'Policy on Cost-Benefit Analysis', policy effective as of September 2018, online: www.canada.ca/en/government/system/laws/developing-improving-federal-regulations/requirements-developing-managing-reviewing-regulations/guidelines-tools/policy-cost-benefit-analysis.html).

operation and maintenance savings, and revenue generation (associated with renewable energy production facilities and some transit actions).

What is NOT included are administrative costs associated with implementing programs, as well as any energy system infrastructure upgrades that may be required. Similarly, the broader social costs that are avoided from mitigating climate change are not included in the financial analysis.

Abatement Cost

The abatement cost of an action is the estimated cost for that action to reduce one tonne of greenhouse gas emissions (GHG) and is calculated by dividing the action's net present value (NPV) by the total GHG emissions it reduces (tCO2e) over its lifetime. For example, if a project has a NPV of $1,000 and generates 10 tCO2e of savings, its abatement cost is $100 per tCO2e reduced.

Amortization

The costs of major capital investments are typically spread over a period of time (e.g., a mortgage on a house commonly has a 25-year mortgage period). Amortization refers to the process of paying off capital expenditures (debt) through regular principal and interest payments over time. In this analysis, we have applied a 25-year amortization rate to all investments. This period has been selected as it is the average amortization period for home mortgages in Canada, and the majority of the investments included in the plan are similar infrastructure investments.

Energy and Carbon Cost Projections

Energy cost projections are key underlying assumptions in this financial analysis. Our projections were derived from:

- the US Energy Information Administration (propane); and
- the Canadian Energy Regulator (formerly National Energy Board) for all other fuels.

In Newfoundland, electricity costs are projected to increase more rapidly than fuel oil, gasoline, or propane. However, current Federal regulation sets an escalating cost of carbon, reaching $170 per tonne by 2050, which is included in our financial analysis and helps mitigate this growing differential. The projected cost impact of the Federal Clean Fuel Standard on diesel and gasoline were excluded from this analysis, which results in conservative avoided cost estimates.

In addition to the cost of carbon, energy efficiency helps further mitigate the growing cost differential. Electricity is a more efficient source of energy than combusting fossil fuels, which loses energy in waste heat. In addition, the net-zero scenario modelled for St. John's also prioritizes energy efficiency via actions such as building envelope retrofits and increased transit service, which helps reduce energy costs and exposure to energy price fluctuations.

Because energy cost projections are so important to the financial analysis, they were also included in a sensitivity analysis included at the end of this report.

Part 2. City of St. John's Energy Transition Financial Analysis Results

Abatement Costs

As outlined in Table 2 (below), the Energy Transition investments included in this financial analysis yield a positive financial return that translates to a weighted average benefit of $167 per tonne of CO2e reduced.[13] All measures that have a positive abatement cost (i.e., greater costs than benefits) are highlighted in red, all measures with a negative abatement cost (i.e., greater benefits than costs) are highlighted in green.

The most expensive actions are industrial process retrofits, at $497 per tonne of CO2e avoided. This retrofit action is followed closely by tree planting at $490 per tonne of CO2e avoided. The third most expensive action is the residential retrofits at $335 per tonne of CO2e avoided. The commercial retrofits are more cost-effective primarily because their baseline energy sources are more carbon-intensive than residential energy uses. As a result, the commercial retrofits represent greater carbon reductions, which both increases the denominator of their marginal abatement cost (i.e., their costs are spread over more tonnes of carbon) and the avoided cost of carbon.

[13] This average is weighted in terms of actions that reduce more tonnes of GHGs influence the average more than actions that reduce less tonnes of GHGs, The net present value of the measures includes credit for the avoided costs of carbon ($170/tonne CO2e by 2050); if that credit were excluded, the net savings per tonne of GHG mitigated would be correspondingly lower.

Again, it is important to note that the marginal abatement cost for these actions do not capture the savings from avoided increased energy generation infrastructure (i.e., large scale electricity generation facilities) or the ecosystem services they provide (e.g. in the case of tree planting, stormwater management, biodiversity support) which can be significant.

It is also worth noting that the residential and non-residential retrofit actions represent a bundle of three actions (i.e., envelope improvements, heat pumps, and electric water heaters) that are broken out in italics in the table. Depending on how these retrofit programs are designed will affect their costs and long-term impact on the electricity grid and customer energy bills. In our modelling approach we have prioritized energy efficiency to reduce the pressure on central grid capacity and the sizing of new heating and cooling equipment.

Large scale wind generation has the lowest cost per tonne of GHG reduction, at an estimated savings of over $5,465 per tonne of CO2e avoided. The basis for the assumed profitability of this action is a guaranteed cost per kwh produced, in line with historic wind power purchase agreements on the island (i.e., 0.069 kwh, an average of the Fermeuse and St.Lawrence power purchase agreements). Any potential costs required to connect wind turbines to the grid, prepare the site, and obtain environmental approvals are not included in the marginal abatement cost.

Reviewing the following table action-by-action requires understanding the action's sequencing in the model (i.e., what the action is offsetting), which is not provided here as it would require a complex and lengthy model description. For this reason, what is most important when looking at the following table is the abatement cost for the entire plan, as well as identifying which actions are considered to have a positive versus negative abatement cost. Measures with a *positive* net present value (i.e., where the investment has a positive return of at least 3%) will therefore have a *negative* abatement cost (i.e., they would be worth doing even without consideration of the carbon benefits), whereas measures with a *negative* net present value will have a *positive* abatement cost (i.e., these are measures with returns less than 3%). For example, electrifying personal vehicles has a high net-present value because of the high savings associated with increased efficiency of electric cars combined with the avoided cost of carbon and the fact that the investment costs are projected to decrease.

Table 2. Net present value and marginal abatement costs by action.

Decarbonization Action	Average Annual Emissions Reduction (t CO2e)	Cumulative Emissions Reduction (kt CO2e)	Net Present Value	Marginal Abatement Cost ($ / t CO2 e)
New Residential Buildings	6,679	194	-$182,092,639	-$940
New Non-Residential Buildings[14]	10,241	297	-$169,798,954	-$572
Residential Retrofits	57,823	1,677	$561,812,118	$335
Envelope		*617*	*$1,228,781,879*	*$1,990*
Heat pumps		*899*	*-$537,410,511*	*-$598*
Water heaters		*161*	*-$41,745,488*	*-$260*
Non-Residential Retrofits[15]	88,237	2,559	-$332,080,975	-$130
Envelope		*1,158*	*$509,408,450*	*$440*
Heat pumps		*1,025*	*-$699,697,531*	*-$682*
Water heaters		*376*	*-$29,265,288*	*-$78*
Municipal Retrofits	1,502	44	$7,102,278	$163
Industrial Processes[16]	437	13	$6,295,261	$497
District Energy[17]	22,937	665	-$105,598,859	-$159
Transit Expansion and Electrification	4,178	121	-$101,357,712	-$836
Electrify Municipal Fleet	1,779	52	-$29,928,509	-$580
Electrify Personal Use Vehicles	106,756	3,096	-$1,063,989,651	-$344
Electrify Commercial Use Vehicles	6,127	178	-$53,138,951	-$299
Landfill Gas Capture	7,060	205	$8,270,033	$40

[14] 'Non-Residential' includes commercial and industrial buildings.
[15] *Ibid.*
[16] 'Industrial Processes' includes energy uses other than envelope improvements, e.g., lighting systems, space heating, water heating, motive energy, and process heat.
[17] 'District Energy' here refers to the oil-fuelled heating system at Memorial University.

Wind Generation	396	11	-$62,734,084	-$5,465
Urban Forest Management	9	0.25	$120,999	$490
				AVERAGE -$167

Marginal Abatement Cost Curve

Figure 1 shows the marginal abatement cost curve (MACC) for measures included in the City of St. John's' Energy Transition.

While a MACC illustrates the financial profile of the suite of actions, it is an imperfect indicator. The presentation of the MACC implies that the actions are a menu from which individual actions can be selected. In fact, many of the actions are dependent on each other. For example, the energy use costs increase without retrofits. In addition, in order to achieve the Town's target all the actions need to be undertaken, as soon as possible. Delaying action for any reason, including waiting for technological improvements, will reduce the savings that can be achieved for households and businesses, and the new employment opportunities created.

The MACC provides useful insights that guide implementation planning. It helps answer critical questions, such as:

- Can high-cost and high-savings actions be bundled to achieve greater GHG emissions reductions?
- How can the Town help reduce the costs of the high-cost actions by supporting innovation or by providing subsidies?
- Which actions both save money and reduce the most GHG emissions? These can be considered "big" moves.
- Which actions are likely to be of interest to the private sector, assuming barriers can be removed or supporting policies introduced?

Such insights are illustrated in Figure 2.

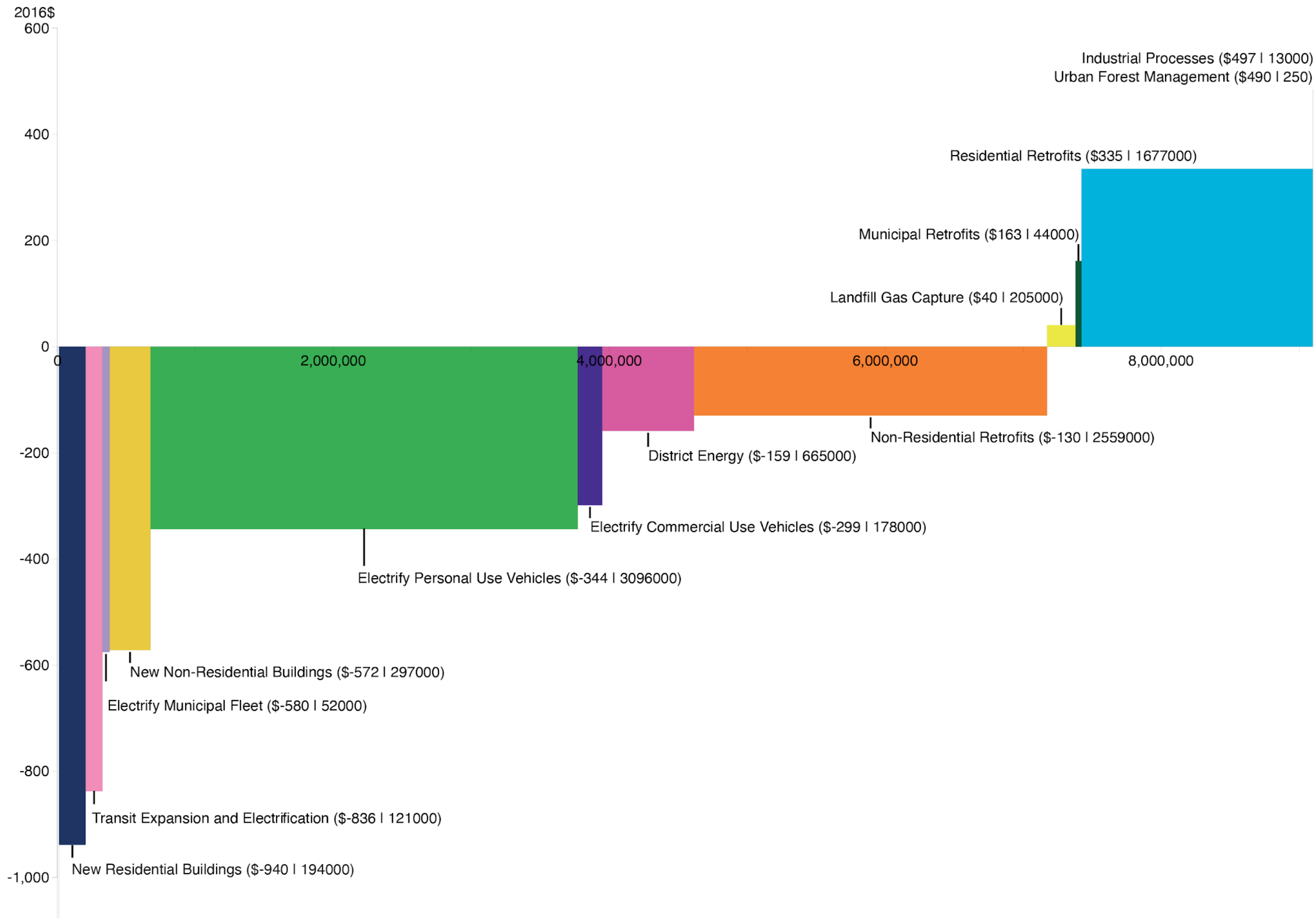

Figure 1. The Marginal Abatement Cost Curve (MACC) for the actions included in the Energy Transition.

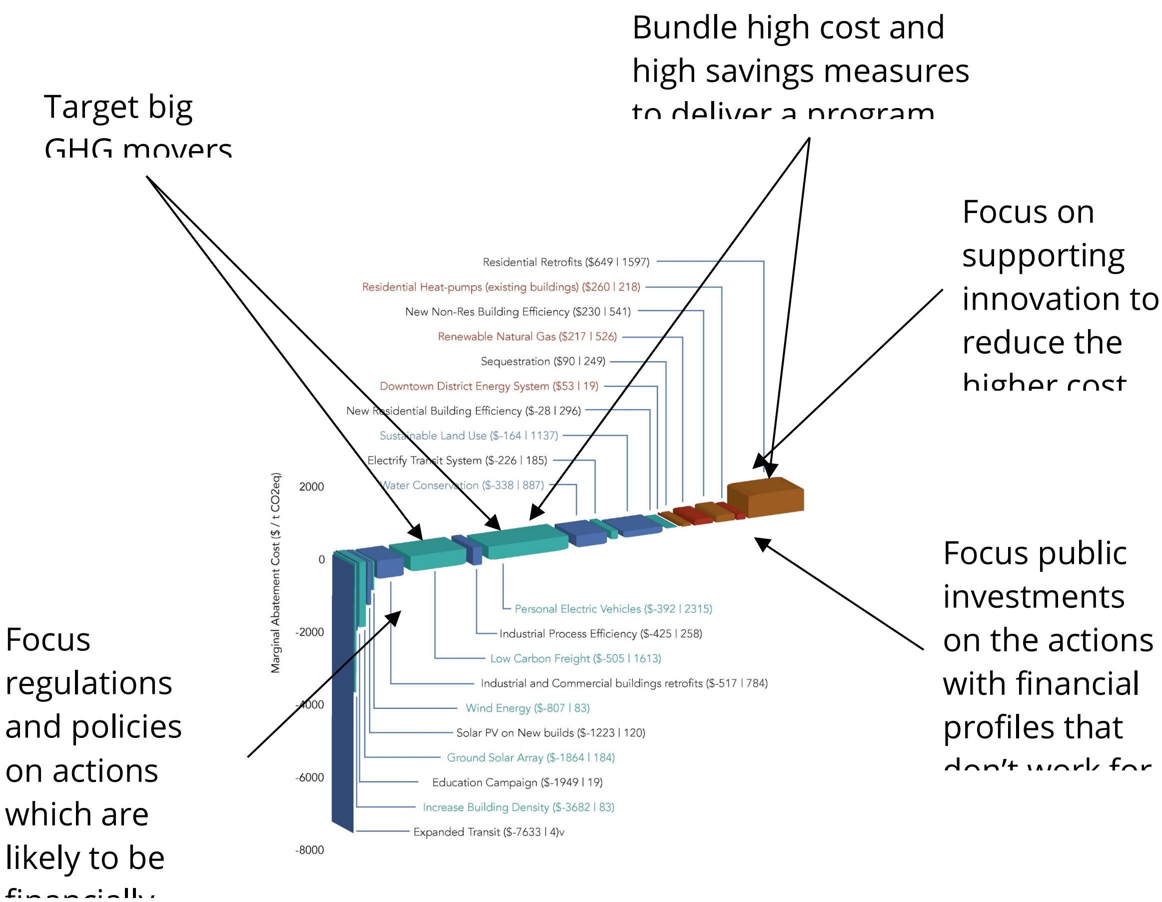

Figure 2. Examples of the strategic uses of a marginal abatement cost curve analysis.

Present and Net Present Values

As noted in the previous section, most of the actions in the net-zero scenario have positive net present values, as does the program of investments as a whole. Figure 3 shows the present value of the major components of the Energy Transition: investments, operations and maintenance savings, fuel and electricity savings, avoided costs of carbon, and revenue from transit and local energy generation. After discounting at 3%, the investments in the program have a present value of $5.5 billion and the savings, avoided cost of carbon, and revenue have a present value of $7.25 billion. The NPV of the whole scenario is $1.788 billion.

Even though capital investment for the plan ends in 2050, the NPV includes the energy, maintenance, carbon costs savings and projected revenue over the full life of the measures, which, in some cases, extends as far as 2089.

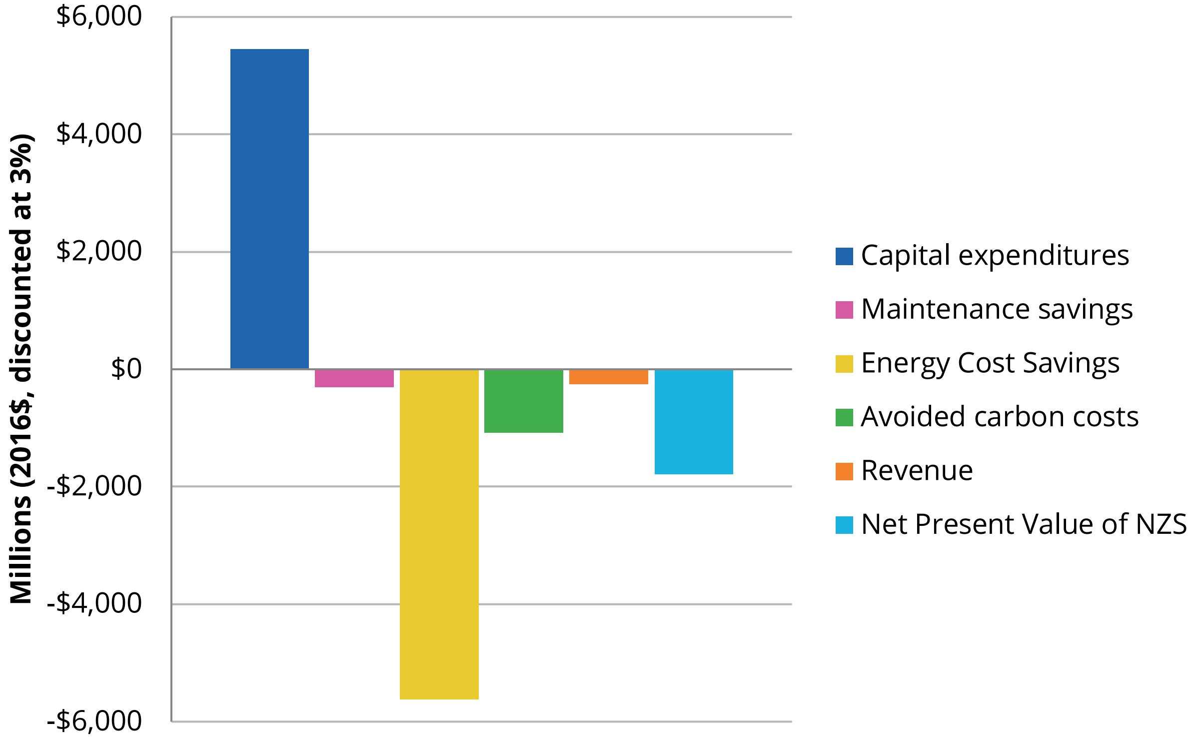

Figure 3. Present values of net-zero scenario costs, and savings, and net present value of the net-zero scenario. Costs are positive in this convention, and revenue and savings are negative.

Cash Flow Analysis

The annual costs, savings, and revenue associated with fully implementing the actions in the Energy Transition are shown in detail in Figure 4 and Table 4, with capital expenditures shown in full in the years in which they are incurred. (Please review the section 'What Is and Is Not Included', above.)

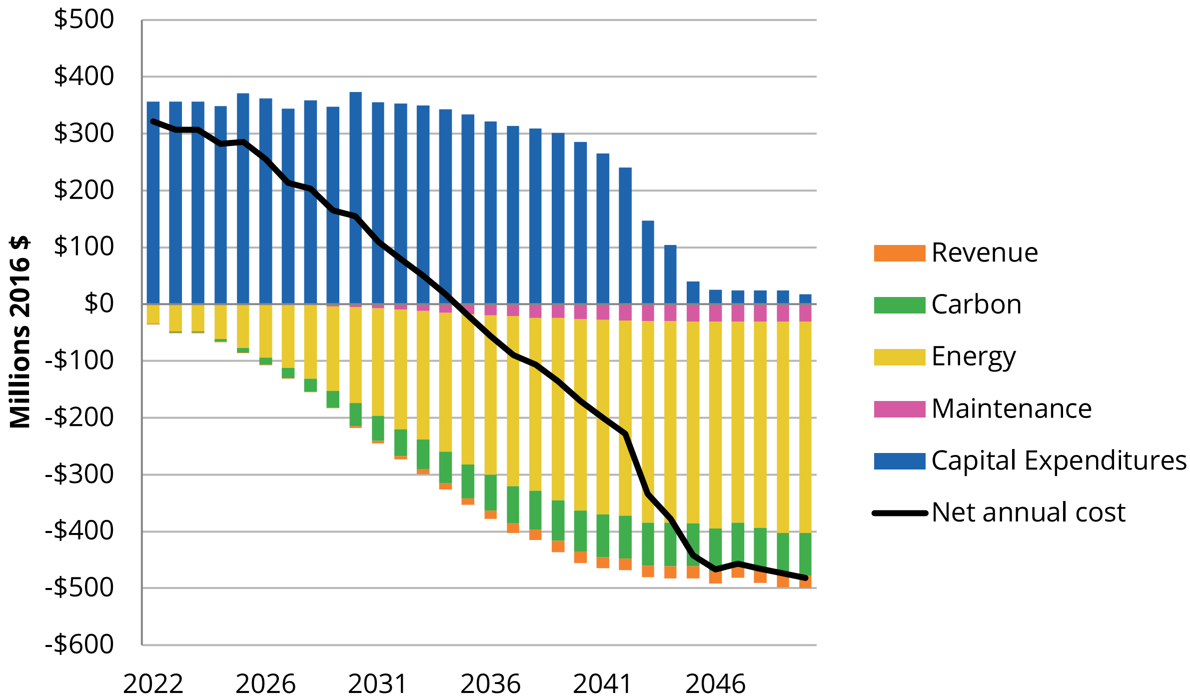

Figure 4. Capital expenditures vs. savings and revenues from the net-zero scenario, 2022-2050.

Table 4. Annual (2030, 2035, 2040, 2045, and 2050) and overall net-zero scenario capital expenditures and savings.

	$ Millions (*negative costs = savings*)					
	2030	2035	2040	2045	2050	Net Present Value
Capital Expenditures	$373	$333	$285	$40	$18	**$5,458**
Maintenance	-$5	-$17	-$27	-$31	-$31	**-$306**
Energy	-$169	-$264	-$337	-$355	-$372	**-$5,617**
Cost of Carbon	-$41	-$60	-$72	-$76	-$75	**-$1,076**
Revenue	-$3	-$12	-$20	-$21	-$22	**-$246**
Net Cost	$155	-$20	-$171	-$442	-$482	**-$1,788**

As is characteristic of net-zero transitions, the capital expenditures in the early years of the transition are significantly greater than the savings and revenues generated, but, by 2035, the annual benefits exceed the annual investments and the cumulative benefits are greater than the cumulative costs.

Figure 5 presents the same costs and benefits, but with the capital expenditures amortized over 25 years at 3%. With this approach, which presumably better reflects actual approaches for financing the transition, the annualized capital payments are about equal to the savings and revenue generation from 2024. On an annual basis, the program never has a significant annual deficit; there is a net annual benefit that grows steadily throughout the 2020s. By 2050, the annual net benefit is over $100 million. After 2050 (not shown in Figure 5), the benefits and revenues continue, resulting in continuing growth in the net annual benefit in the post-2050 period.

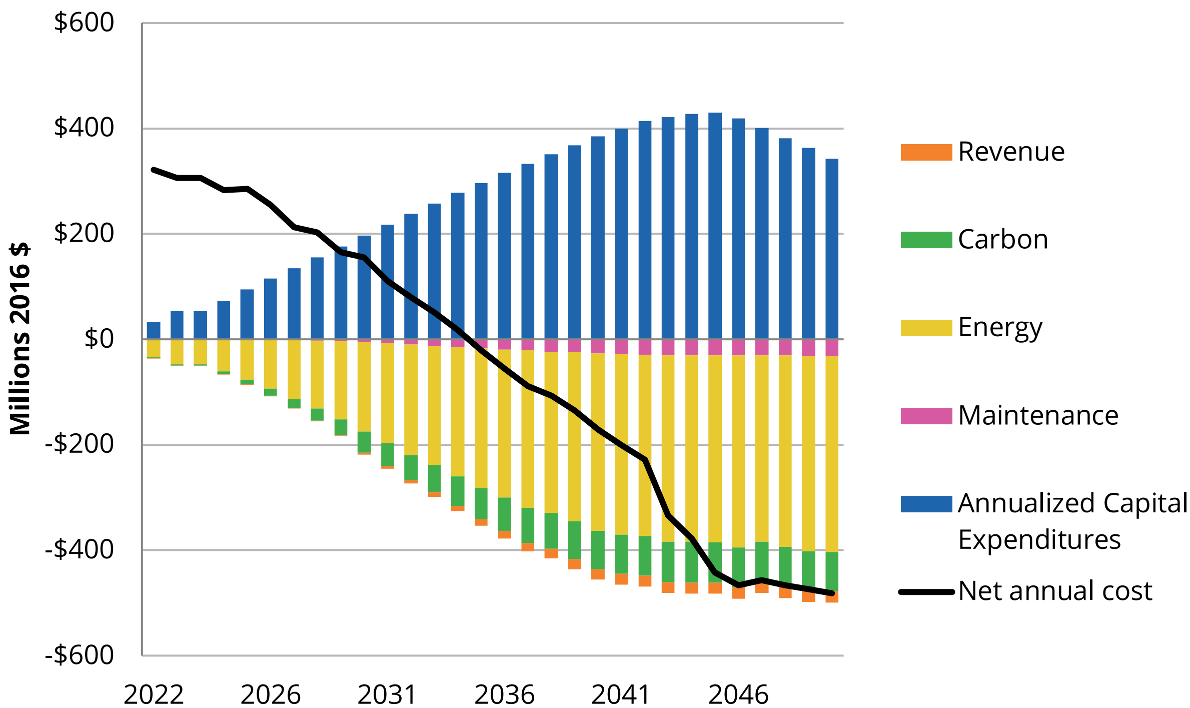

Figure 5. Annualized capital expenditures vs. savings and revenue from the net-zero scenario, 2022-2050.

Cost Savings for Households

According to CUSP (Canadian Urban Sustainability Practitioners) energy poverty is considered to exist when a household spends more than 6% of its after-tax income on energy.[18] Newfoundland and Labrador has some of the highest rates of energy poverty in Canada.[19] In 2016, the average St. John's household spent about 9% of their after tax income on energy—electricity, oil, gasoline, and diesel.[20] Keeping energy costs low, especially for low-income households, is critical for any climate action plan that aims to achieve improved equity, local economic growth, and public buy-in.

Household expenditures on energy are projected to slightly increase in the BAP and decline quite significantly in the net-zero scenario (see Figure 6). In the BAP, household energy expenditures increases are somewhat mitigated because vehicles become more efficient due to national fuel efficiency standards and because of decreased heating requirements as the climate becomes milder due to climate change. They are projected to increase primarily because of the federal price on carbon.

The net-zero scenario involves shifting away from oil and gasoline to electricity, a more costly energy source. The increased cost of electricity, however, is offset by the increased efficiency of homes and electric vehicles, as well as the avoided carbon price.

In the net-zero scenario, an average St. John's household spends $3,250, on fuel and electricity (household energy and transportation expenditures) in 2050—over 50% less than they would have in a BAP scenario ($7,345).

Between 2022 and 2050, the net-zero scenario saves the average St. John's household about $80,667 in gross fuel and electricity expenditures (i.e., not including the cost to undertake the efficiency improvements). Depending on the business, policy and financing strategies used in the implementation of the actions, these savings will be partly offset by the incremental capital expenditures required.

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[18] CUSP, Energy Poverty in Canada: a CUSP Backgrounder (October 2019) online: https://energypoverty.ca/backgrounder.pdf.

[19] Ibid, at Figure 2.

[20] Statistics Canada, 2015 Census, average after-tax income by St. John's household was $77,960 (adjusted for inflation to 2016$ this would translate to $78,817). In 2016 average household energy expenditures were $7,153.

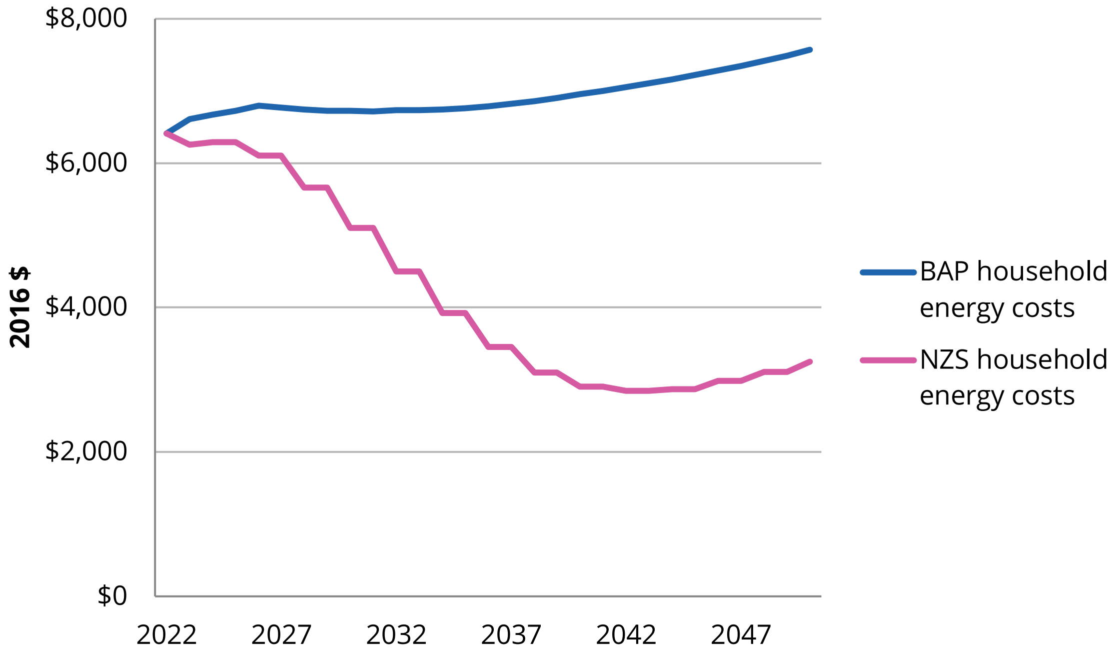

Figure 6. Average annual household energy costs in the net-zero and BAP scenarios, 2022-2050.

New Job Opportunities

Transitioning to a low- or zero-carbon economy is expected to have four categories of impacts on labour markets: additional jobs will be created in emerging sectors, some employment will be shifted (e.g., from fossil fuels to renewables), certain jobs will be reduced or eliminated (e.g., combustion engine vehicle mechanics), and many existing jobs will be transformed and redefined.

According to the direct job multipliers from Census Canada, the Energy Transition will result in a net job increase of an average annual 1,400 full time jobs in St. John's (or 38,600-person years of employment over 28 years). These are primarily due to the investment in retrofits (see the red and blue bar bars in Figure 7), followed by personal use vehicle electrification (in pink) and more energy efficient new residential buildings (in turquoise).

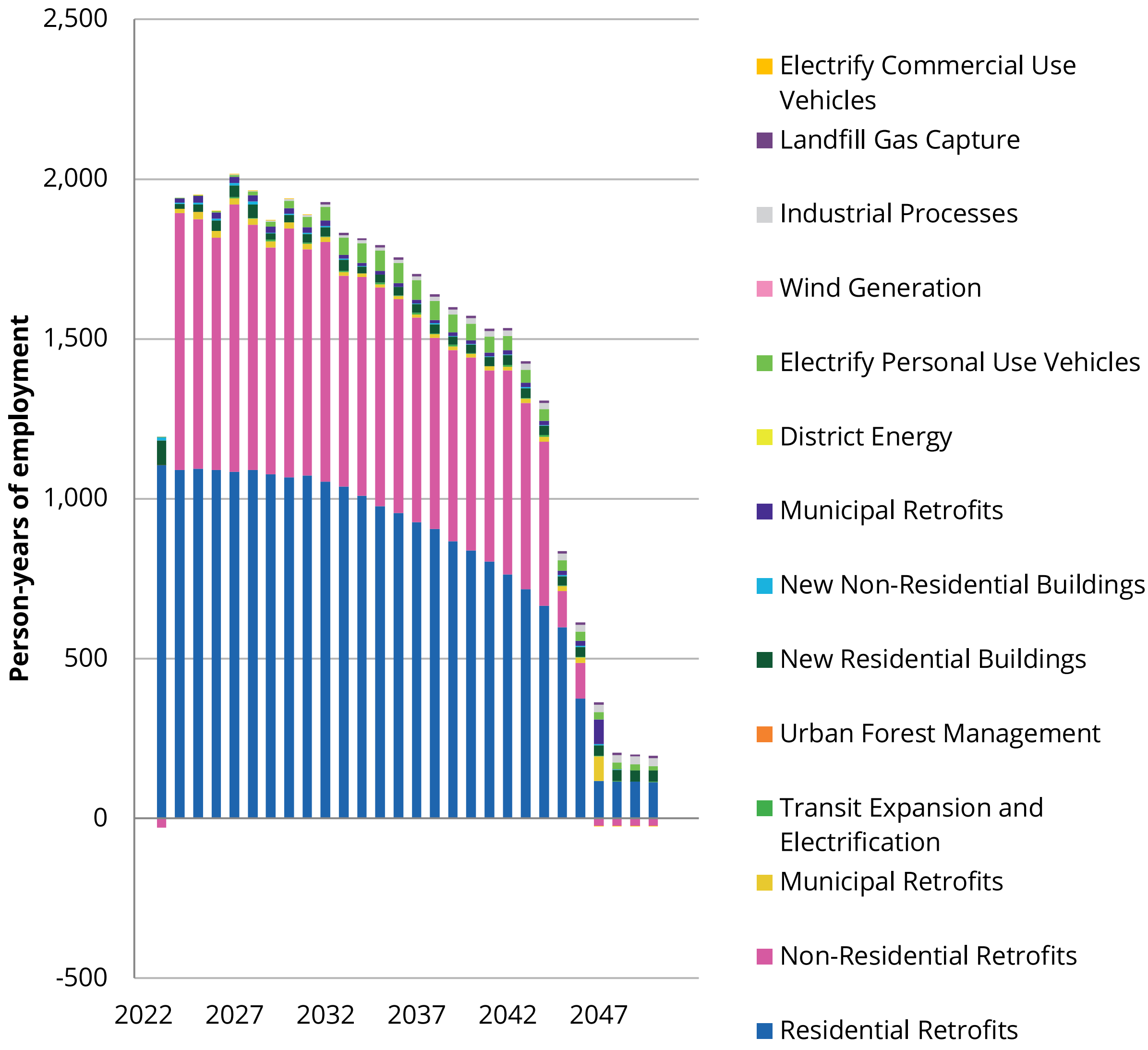

Figure 7. Additional person-years of employment associated with Energy Transition actions.

Sensitivity Analysis

The financial analysis involves several assumptions on building, infrastructure, equipment, and energy costs. A sensitivity analysis was conducted to assess how uncertainties in future costs could affect the overall results. The following chart shows how changing key parameters (i.e., energy costs) in the model will affect the net-zero costs pathway for the City of St. John's.

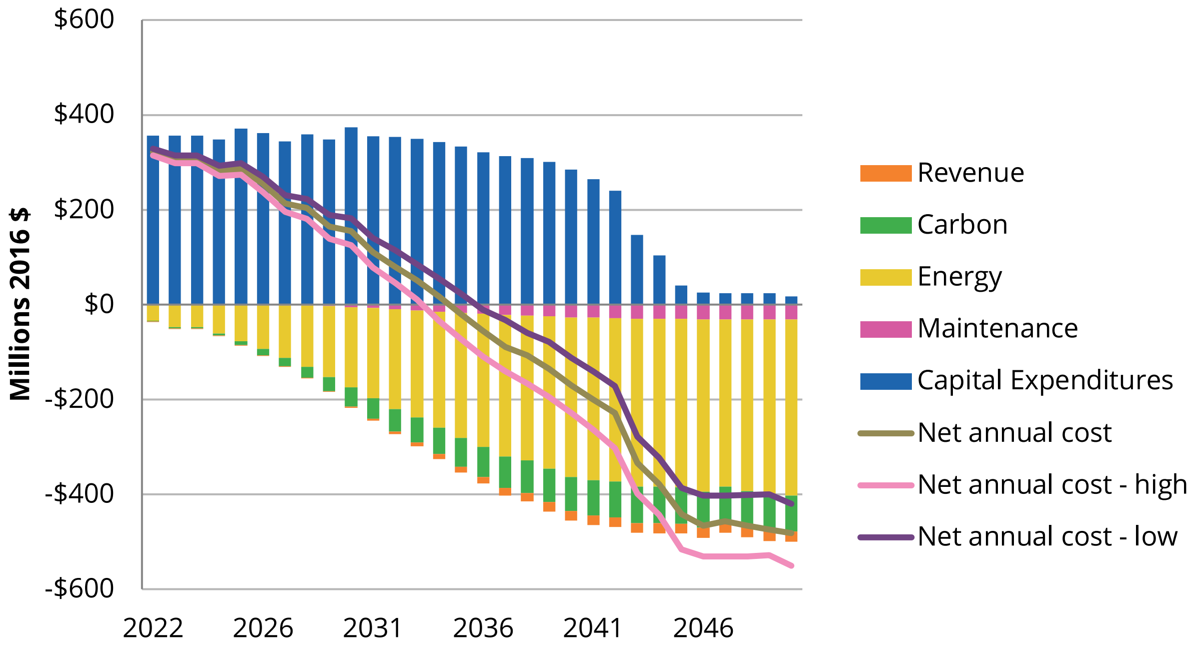

Figure 8. Sensitivity analysis of the energy costs for the Energy Transition investment and returns.

The sensitivity analysis, which is displayed in Figure 8, shows that, when you increase or decrease the overall energy costs by 20%, the net cost of the scenario in 2050 is affected by 13-14% in either direction. A major conclusion that can be drawn by this sensitivity analysis is the important co-benefit of energy efficiency and local energy generation measures in terms of hedging against future energy price increases.

Key Financial Assumptions

Land Use	Capital Investment Assumption
Land use intensification	- Capital costs associated with land-use intensification encompass standard investment in the community, such as new housing developments. - Generally speaking, with more infill development, new infrastructure spending decreases.
Decrease share of single-detached housing	
New Buildings	

New residential buildings with heat pumps	- The cost for new construction of buildings on a $/m^2 is estimated to be:
	  - Single-detached: $1,372 / m^2
	  - Double: $1,372 / m^2
	  - Apt 1-6 storey: $2,072 / m^2
	  - Apt 7-12 storey: $2,207 / m^2
	  - Apt > 12 storey: $2,260 / m^2
	  - Commercial: $2,395/ m^2
	  - Industry: $3,202 / m^2
	- A residential heat pump has a capital cost of approximately $8,500 (non-residential is ~$10,000) and annual operating cost of approximately $160 annually (~$400 annually for non-residential).

New industrial building efficiency	
New commercial building efficiency with heat pumps	
Existing Buildings	

Retrofits of homes and heat pumps	- The average cost of a 50% energy efficiency retrofit is assumed to be:
	  - Residential (per unit): $45,000
	  - Non-Res ($/m2) : $275
	- Industrial upgrades average the following in 2022 and 2050 per GJ/year
	  - Lighting system: $134→ $59
	  - Space heating: $25 → $34
	  - Water Heating: $32 → $49
	  - Motive: $66 → $176
	  - Process heat: $27 → $43

Retrofits of commercial and industrial buildings	
Industrial improvements (process motors/efficiency)	

Renewable Energy	
Wind	- Onshore wind turbines are assumed to cost about $2,336 per kw/year in 2022, their maintenance costs are assumed to be $55 per kw/year.
Transport	
Establish local electric bus service	- Today electric buses cost approximately $630,000, and are expected to cost less than a diesel bus by 2031. A fast charger costs about $140,000, and is assumed to be needed on a 1:20 ratio with electric buses. Electric bus maintenance costs are approximately 30% lower than for diesel buses. - The cost of a personal electric vehicle is approximately $34,000 in 2021 and is expected to decrease to $32,000 by 2030, dropping below the cost of an average combustion engine vehicle by 2025. As of today, maintenance costs for an EV are assumed to be half of those for combustion engine vehicles. - Heavy duty combustion engine vehicles are not expected to reach cost parity with their electric counterparts by 2050.
Electrify municipal fleets	
Electrify personal vehicles	
Net-zero commercial transport activity	
Waste and Wastewater	
Wastewater process efficiency	- Improving wastewater process efficiency will cost an estimated $497 per tonne of GHG reduced.
Landfill gas capture increase	- The landfill gas capture increase is expected to cost $700,000/year from 2022-2050.
Natural Environment and Sequestration	
Tree planting	- Tree planting will cost an average of $23,350/year from 2022-2050.

Appendix C: Modelling Scope, Method, and Process

May 2021

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I. Modelling Scope

Geographic Boundary

The geographic boundary of the modelling assessment is the municipal boundary of the City of St. John's (Figure 1). The model will use the 29 neighbourhoods outlined in Figure 1 to assign energy use and greenhouse gas emissions spatially.

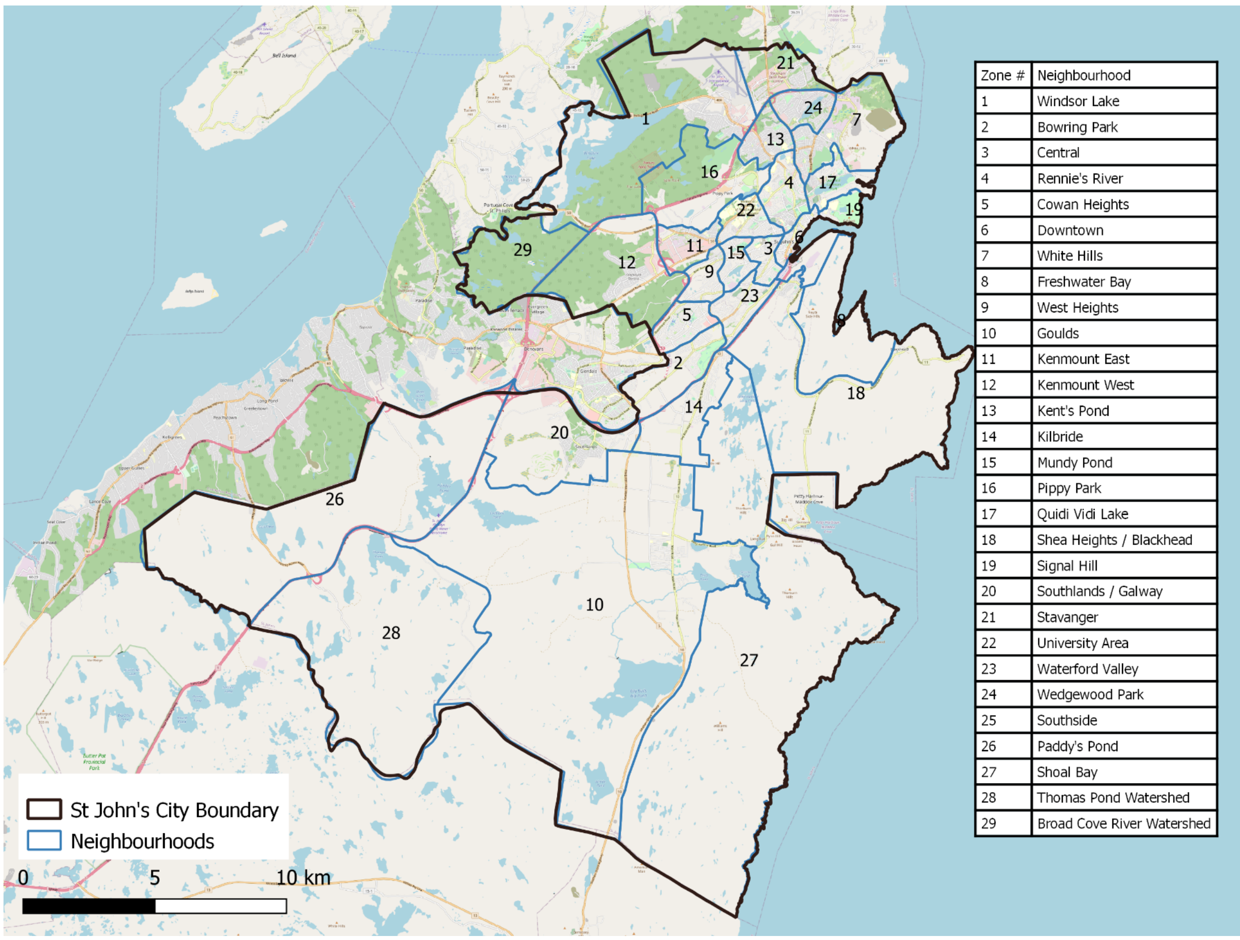

Figure 1. Assessment boundary for the City of St. John's and the 29 neighbourhoods that will be used in the modelling process.

Time Scope

- The assessment will cover the years from 2016 to 2050.

- The year 2016 will be used as the base year within the model. The rationale for using this as the base year is that:
    - The model requires the calibration of a base year system state (initial conditions) using as much observed data as possible in order to develop an internally consistent snapshot of the city.
    - A key data source for the model is census data. At the time of modelling, the most recent census year for which data is available is 2016.

- 1-year increments are modelled from the 2016 base year. 2016 is the first simulation period/year, as it is the most recent Statistics Canada Census year.

- Some 2016 data was not available, and was supplanted by more recent data, most notably the City of St. John's community and corporate energy use and greenhouse gas emissions inventory for 2018, namely:
    - wastewater and water pumping electricity (2018 corporate inventory)
    - wastewater BOD (2018 data from the City's Environmental Services Division, Public Works)
    - fuel oil use by sector (2018 community inventory)
    - Kent vehicle fuel use data (used for calibration, 2018 data in liters)
    - LFG capture rate at Robinhood Bay Landfill (2018 community inventory)
    - methane flared at RiverHead (2018 community inventory)
    - student enrollment (2014, 2016, 2018 for private institutions, College of the North Atlantic, Memorial University, respectively)
    - vehicle stock (2018 data from provincial Motor Registration Division)
    - transit data (2018 corporate inventory)
    - school bus data (2021 from the City)
    - municipal fleet (2018 corporate inventory)
    - City Corporation electricity use (2018 corporate inventory)
    - population share by zone (2020 data from Environics)

- Projections will extend to 2050.

Emissions Scope

The relevant emissions sources for St. John's and their emissions scope are detailed in Table 1. Of note is treatment of local electricity supplied to the grid: all emissions reductions from new local energy generation are accounted for locally, rather than distributed through the central electricity grid. However, central electrified generation facilities located within municipal boundaries, are only accounted for through the electricity grid emissions factor. This distinction is made because the current central electricity generation is already accounted for through the grid emissions factor. Reporting on such a facility is not required under GPC Protocol BASIC or BASIC+. New local energy generation projects are not included in electricity emissions factor projections.

Table 1. Sources included in St. John's model.

	Scope 1	Scope 2	Scope 3	Notes
Stationary Energy				
Residential buildings	Y	Y		
Commercial and institutional buildings and facilities	Y	Y		
Manufacturing industries and construction	Y	Y		
Energy industries	Y	Y		
Energy generation supplied to the grid				Additional renewable electricity is included beyond what is currently included in emissions factors projections
Agriculture, forestry, and fishing activities	Y	Y		
Non-specified sources				NA
Fugitive emissions from mining, processing, storage, and transportation of coal				NA
Fugitive emissions from oil and natural gas systems				N/A
Transportation				
On-road	Y	Y		
Railways				N/A
Waterborne navigation	Y	Y		
Aviation	Y	Y		
Off-road	Y	Y		
Waste				
Disposal of solid waste generated in the city			Y	
Disposal of solid waste generated outside the city				NA
Biological treatment of waste generated in the city			Y	
Biological treatment of waste generated outside the city				NA

Incineration and open burning of waste generated in the City				NA
Incineration and open burning of waste generated outside the city				NA
Wastewater generated in the city	Y		Y	
Wastewater generated outside the city				NA
Industrial processes and product use (IPPU)				
Industrial processes	Y			
Product use				NA
Agriculture, forestry and other land use (AFOLU)				
Livestock	Y			
Land	Y			
Aggregate sources and non-CO2 emissions sources on land	Y			
Other Scope 3			Y	

Emissions Factors

Table 2. Emissions accounting framework and global warming potential.

Category	Base Year Data/Assumption	Source
Emissions accounting		
Accounting Framework	Global Protocol for Community-Scale GHG Emission Inventories (GPC)	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Emissions scope	Scope 1, 2 and partial scope 3	See GPC emissions scope table for scope 3 items included.
Sectors	Stationary energy (buildings) Transportation Waste	See GPC emissions scope table for sectors and sub-sectors included.
Boundary	Municipal boundary of St. John's	City
Reporting	GPC BASIC & partial BASIC+	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Transportation methodology	GPC induced activity method	Global Protocol for Community-Scale GHG Emission Inventories (GPC)
Base year	2016	N/A
Projection year	2050	N/A
Global Warming Potential		
Greenhouse gases	Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N20) are included. GWP: CO2 = 1 CH4 = 34 N2O = 298 Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and nitrogen trifluoride (NF3) are not included.	Myhre, G. et al., 2013: Anthropogenic and Natural Radiative Forcing. Table 8.7. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Table 3. Emissions factors for fuels in St. John's model.

Category	Base Year Data/Assumption	Source
Emissions Factors		
Natural gas	49 kg CO2e/GJ	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Tables A6-1 and A6-2.
Electricity	**2016:** CO2: 36 g/kWh CH4: 0.0006 g/kWh N2O: 0.001 g/kWh 2018: CO2: 26g/kWh CH4: 0.0004 g/kWh N2O: 0.00 g/kWh **2050:** CO2: 0.0 g/kWh CH4: 0.0 g/kWh N2O: 0.0 g/kWh	2016 NIR: Elec Emissions factor - Table A13-2 NIR Part 3 2018 NIR: Elec Emissions factor - Table A13-2 NIR Part 3 Canada Energy Regulator, "Canada's Energy Future" (2016). for 2050 projection Note: though some remote communities may continue to rely on diesel generators, the City of St. John's is expected to have a fully decarbonized central electricity supply by 2050.
Gasoline	g / L CO2: 2316 CH4: 0.32 N2O: 0.66	2016 NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Diesel	g / L CO2: 2690.00 CH4: 0.07 N2O: 0.21	2016: NIR Part 2 Table A6–12 Emission Factors for Energy Mobile Combustion Sources

Fuel oil	**Residential g/L** CO_2: 2560 CH_4: 0.026 N_2O: 0.006 **Commercial g/L** CO_2: 2753 CH_4: 0.026 N_2O: 0.031 **Industrial g/L** CO_2: 2753 CH_4: 0.006 N_2O: 0.031	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–4 Emission Factors for Refined Petroleum Products
Wood	**Residential kg/GJ** CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 **Commercial kg/GJ** CO_2: 299.8 CH_4: 0.72 N_2O: 0.007 **Industrial kg/GJ** CO_2: 466.8 CH_4: 0.0052 N_2O: 0.0036	Environment and Climate Change Canada. National Inventory Report 1990-2015: Greenhouse Gas Sources and Sinks in Canada. Part 2. Table A6–56 Emission Factors for Biomass

Propane	g/L **Transport** CO_2: 1515.00 CH_4: 0.64 N_2O: 0.03 **Residential** CO_2: 1515.000 CH_4 : 0.027 N_2O: 0.108 **All other sectors** CO_2: 1515.000 CH_4: 0.024 N_2O: 0.108	NIR Part 2 Table A6–3 Emission Factors for Natural Gas Liquids Table A6–12 Emission Factors for Energy Mobile Combustion Sources
Waste/WW	**wastewater emissions factors** CH_4: 0.48 kg CH_4/kg BOD N_2O: 3.2 g / (person * year) from advanced treatment 0.005 g /g N from wastewater discharge landfill emissions are calculated from first order decay of degradable organic carbon deposited in landfill derived emission factor in 2016 = 0.015 kg CH_4 / tonne solid waste (assuming 70% recovery of landfill methane), .05 kg CH_4 / tonne solid waste not accounting for recovery K values are sourced from IPCC table 3.3, temperate wet column	CH_4 wastewater: IPCC Guidelines Vol 5 Ch 6, Tables 6.2 and 6.3, we use the MCF value for anaerobic digester N_2O from advanced treatment: IPCC Guidelines Vol 5 Ch 6 Box 6.1 N_2O from wastewater discharge: IPCC Guidelines Vol 5 Ch 6 Section 6.3.1.2 Landfill emissions: IPCC Guidelines Vol 5 Ch 3, Equation 3.1

II. Modelling Method

1. About CityInSight

CityInSight is an integrated, spatially-disaggregated energy, emissions, and finance model developed by Sustainability Solutions Group and whatIf? Technologies. The model enables bottom-up accounting for energy supply and demand, including renewable resources, conventional fuels, energy consuming technology stocks (e.g., vehicles, heating systems, dwellings, buildings), and all intermediate energy flows (e.g. electricity and heat).

CityInSight incorporates and adapts concepts from the system dynamics approach to complex systems analysis. Energy and GHG emissions are derived from a series of connected stock and flow models. The model accounts for physical flows (i.e., energy use, *new* vehicles, vehicle kilometres travelled) as determined by stocks (i.e., buildings, vehicles, heating equipment, etc). For any given year within its time horizon, CityInSight traces the flows and transformations of energy from sources through energy currencies (e.g., gasoline, electricity) to end uses (e.g., personal vehicle use, space heating) to energy costs and to GHG emissions. The flows evolve on the basis of current and future geographic and technology decisions/assumptions (e.g., EV uptake rates). An energy balance is achieved by accounting for efficiencies, conservation rates, and trade and losses at each stage in the journey from source to end use. Characteristics of CityInSight are described in Table 1.

The model is spatially explicit. All buildings, transportation and land use data is tracked within the model through a GIS platform, and by varying degrees of spatial resolution. Where applicable, a zone type system can be applied to break up the city into smaller configurations. This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future dates using GIS-based platforms. CityInSight's GIS outputs can be integrated with city mapping systems.

Table 1. Characteristics of CityInSight.

Characteristic	Rationale
Integrated	CityInSight is designed to model and account for all sectors that relate to energy and emissions at a city scale while capturing the relationships between sectors. The demand for energy services is modelled independently of the fuels and technologies

	that provide the energy services. This decoupling enables exploration of fuel switching scenarios. Physically feasible scenarios are established when energy demand and supply are balanced.
Scenario-based	Once calibrated with historical data, CityInSight enables the creation of dozens of scenarios to explore different possible futures. Each scenario can consist of either one or a combination of policies, actions and strategies. Historical calibration ensures that scenario projections are rooted in observed data.
Spatial	The configuration of the built environment determines the ability of people to walk and cycle, accessibility to transit, feasibility of district energy and other aspects. CityInSight therefore includes a full spatial dimension that can include as many zones - the smallest areas of geographic analysis - as are deemed appropriate. The spatial component to the model can be integrated with City GIS systems, land-use projections and transportation modelling.
GHG reporting framework	CityInSight is designed to report emissions according to the GHGProtocol for Cities (GPC) framework and principles.
Economic impacts	CityInSight incorporates a full financial analysis of costs related to energy (expenditures on energy) and emissions (carbon pricing, social cost of carbon), as well as operating and capital costs for policies, strategies and actions. It allows for the generation of marginal abatement curves to illustrate the cost and/or savings of policies, strategies and actions.

2. Model Structure

The major components of the model (sub-models), and the first level of modelled relationships (influences), are represented in Figure 1. These sub-models are all interconnected through various energy and financial flows. Additional relationships may be modelled in CityInSight by modifying inputs and assumptions—specified directly by users, or in an automated fashion by code or scripts running “on top of” the base model structure. Feedback relationships are also possible, such as increasing the adoption rate of non-emitting vehicles in order to meet a particular GHG emissions constraint.

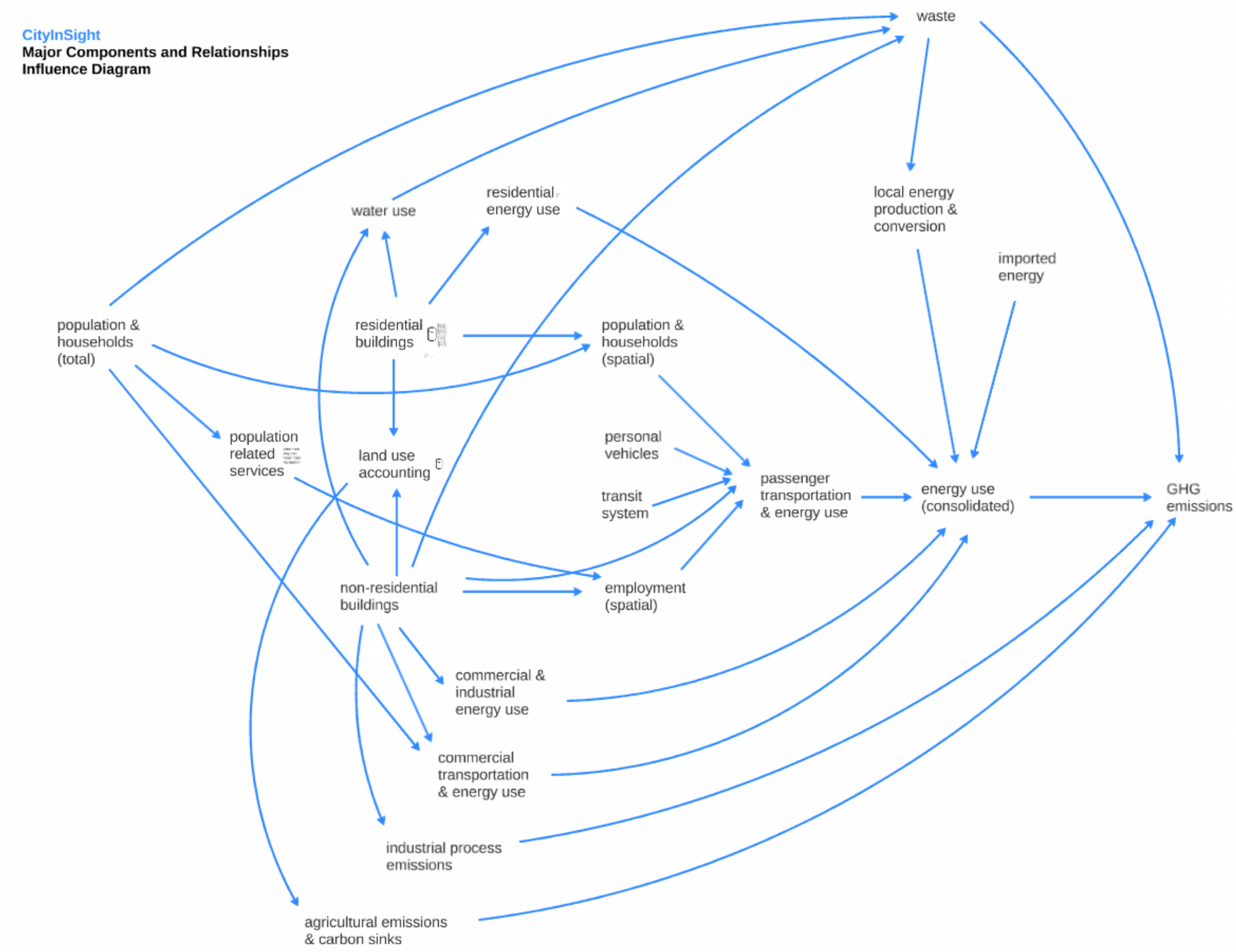

Figure 1. Representation of CityInSight's structure.

3. Stocks and Flows

Within each sub-model is a number of stocks and flows that represent energy and emissions processes in cities. For any given year various factors shape the picture of energy and emissions flows in a city, including: the population and the energy services it requires; commercial floorspace; energy production and trade; the deployed technologies which deliver energy services (service technologies); and the deployed technologies which transform energy sources to currencies (harvesting technologies). The model makes an explicit mathematical relationship between these factors—some contextual and some part of the energy consuming or producing infrastructure—making up the energy flow picture.

Some factors are modelled as stocks: counts of similar things, classified by various properties. For example, population is modelled as a stock of people classified by age and gender.

Population change over time is projected by accounting for: the natural aging process, inflows (births, immigration) and outflows (deaths, emigration). The fleet of personal use vehicles, an example of a service technology, is modelled as a stock of vehicles classified by size, engine type and model year - with a similarly-classified fuel consumption intensity. As with population, projecting change in the vehicle stock involves aging vehicles and accounting for major inflows (new vehicle sales) and major outflows (vehicle discards). This stock-turnover approach is applied to other service technologies (e.g., furnaces, water heaters) and also harvesting technologies (e.g., electricity generating capacity).

4. Sub-models

The stocks and flows that make up each sub-model are described below.

Population, Households, and Demographics

- City-wide population is modelled using the 'standard population cohort-survival method', which tracks population by age and gender on a year-by-year basis. It accounts for various components of change: births, deaths, immigration and emigration.

- Population is allocated to households, and these are placed spatially in zones, via physical dwellings (see land-use accounting sub-model).

- The age of the population is tracked over time, which is used for analyzing demographic trends, generational differences and implications for shifting energy use patterns.

- The population sub-model influences energy consumption in various sub-models:
  - School enrollment totals (transportation)
  - Workforce totals (transportation)
  - Personal vehicle use (transportation)
  - Waste generation

Building Land-Use Accounting

Land use accounting identifies buildings in space and over time, through construction, retrofits and demolitions. In the baseline, this is often directly informed by building-related geospatial data. Land use accounting consists of the follow elements:

- Quantitative spatial projections of residential dwelling units, by:
    - Type of residential structure (single detached, semi detached, row house, apartment, etc);
    - Development type (greenfield, intensification); and
    - Population is assigned to dwelling units.
- Quantitative spatial projections of non-residential buildings, by:
    - Type of non-residential structure (retail, commercial, institutional);
    - Development type (greenfield, intensification);
    - Buildings are further classified into archetypes (such as school, hospital, industrial - see Table 2).[21] This allows for the model to account for differing intensities that would occur in relation to various non residential buildings; and
    - Jobs are allocated to zones via non-residential floor area, using a floor area per worker intensity.
- Land-use accounting takes "components of change" into account, year over year:
    - New development;
    - Removals / demolitions; and
    - Year of construction.
- Land use accounting influences other aspects of the model, notably:
    - <u>Passenger transportation:</u> the location of residential buildings influences where home-to-work and home-to-school trips originate, which in turn also influences their trip length and the subsequent mode selected. Similarly, the location and identification of non-residential buildings influences the destination for many trips. For example, buildings identified as schools would be identified in home-to-school trips.
    - <u>Access to energy sources by buildings:</u> building location influences access to energy sources, for example, a rural dwelling may not have access to natural gas or a dwelling may not be in proximity to an existing district energy system. It can

[21] Where possible, this data comes directly from the municipality.

also be used to identify suitable projects: for example, the location and density of dwellings is a consideration for district energy development.

- Non-residential building energy: the identification of non-residential building archetypes influences their energy consumption based on their use type. For example, a building identified as a hospital would have a higher energy use intensity than a building identified as a school.

Table 2. Non-residential archetypes represented in the model.

- College, university - School - Retirement or nursing home - Special care home - Hospital - Municipal building - Fire station - Penal institution - Police station - Military base or camp - Transit terminal or station - Airport - Parking - Hotel motel inn - Greenhouse - Greenspace - Recreation - Community centre - Golf course - Museums, art gallery - Retail - Vehicle and heavy equipment service - Warehouse retail - Restaurant	- Commercial retail - Commercial - Commercial residential - Retail residential - Warehouse commercial - Warehouse - Religious institution - Surface infrastructure - Energy utility - Water pumping or treatment station - Industrial generic - Food processing plants - Textile manufacturing plants - Furniture manufacturing plants - Refineries all types - Chemical manufacturing plants - Printing and publishing plants - Fabricated metal product plants - Manufacturing plants miscellaneous processing plants - Asphalt manufacturing plants - Concrete manufacturing plants - Industrial farm - Barn

Residential and Non-Residential Building Energy

Building energy consumption is closely related to the land use accounting designation it receives, based on where the building is located, its archetype, and when it was constructed. Building energy consumption is calculated in the model by considering:

- Total energy use intensity of the building type (including the proportion from thermal demand) is built from energy end uses in the building. End uses include heating, lighting, auxiliary demand, etc. The energy intensity of end uses is related to the building or dwelling archetype and its age.
- Energy use by fuel is determined based on the technologies used in each building (e.g. electricity, heating system types). Heating system types are assigned to building equipment stocks (e.g., heating systems, air conditioners, water heaters).
- Building energy consumption in the model also considers:
  - Solar gains and internal gains from sharing walls;
  - Local climate (heating and cooling degree days); and
  - Energy losses in the building.
- Building equipment stocks (water heaters, air conditioners) are modelled with a stock-turnover approach that captures equipment age, retirements, and additions. In future projections, the natural replacement of stocks is often used as an opportunity to introduce new (and more efficient) technologies.

The model has residential and non-residential building energy sub-models. They influence and produce important model outputs:

- Total residential energy consumption and emissions and residential energy and emissions by building type, by end use, and by fuel;
- Total non-residential energy consumption and emissions and residential energy and emissions by building type, by end use, and by fuel; and
- Local/imported energy balance: how much energy will need to be imported after considering local capacity and production.

Figure 2 details the flows in the building energy sub-model at the building level.

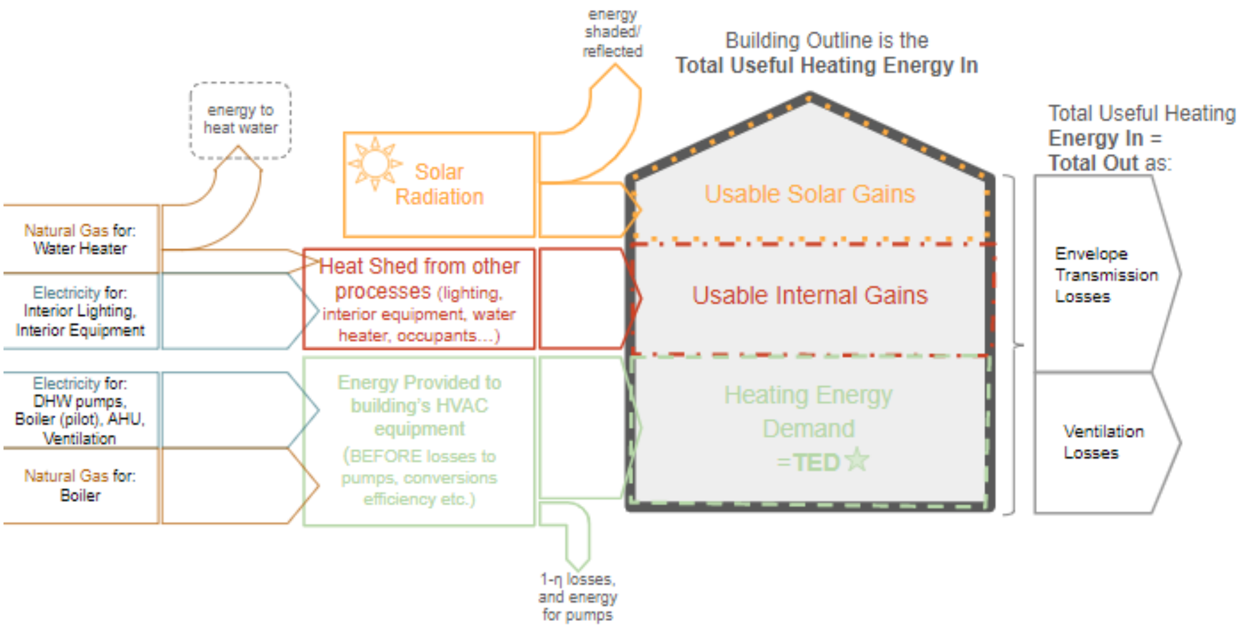

Figure 2. Building energy sub-model schematic.

Transportation

CityInSight includes a spatially explicit passenger transportation sub-model that responds to changes in land use, transit infrastructure, vehicle technology, travel behavior changes and other factors. It has the following features:

- CityInSight uses the induced method for accounting for transportation related emissions; the induced method accounts for in-boundary tips and 50% of transboundary trips that originate or terminate within the city boundary. This shares energy and GHGs between municipalities.
- The model accounts for “trips” in the following sequence:
    1. Trip generation. Trips are divided into four types (home-work, home-school, home-other, and non-home-based), each produced and attracted by different combinations of spatial influences identified in the land-use accounting sub-model: dwellings, employment, classrooms, non-residential floorspace.
    2. Trip distribution. Trips are then distributed with the number of trips specified for each zone of origin and zone of destination pair. Origin-Destination (O-D) matrix data is based on local travel surveys and transportation models.

3. Mode share. For each origin-destination pair, trips are shared over walk/bike, public transit and automobile.
    a. Walk / bike trips are identified based on a distance threshold: ~2km for walking, ~5-10km for biking.
    b. Transit trips are allocated to trips with an origin or destination within a certain distance to a transit station.
4. Vehicle distance. Vehicle kilometres travelled (VKT) are calculated based on the number of trips by mode and the distance of each trip based on a network distance matrix for the origin-destination pairs.

- VKT is also assigned to a stock of personal vehicles, based on vehicle type, fuel type, and fuel efficiency. The number of vehicles is influenced by the total number of households identified in the population sub-model. Vehicles also use a stock-turnover approach to model vehicle replacements, new sales and retirements.
- The energy use and emissions associated with personal vehicles is calculated by VKT of the stock of personal vehicles and their type, fuel and efficiency characteristics.
- Personal mobility sub-model is one of the core components of the model. It influences and produces important model outputs:
    - Total transportation energy consumption by fuel, including electricity consumption
    - Active trips and transit trips, by zone distance.

Trips accounted for in the model are displayed in Figure 3.

Figure 3. Trips assessed in the personal mobility sub-model.

Google Environmental Insights Explorer (EIE) data is used to inform average trip length for internal (6km) and cross boundary trips (19km outbound, 20km inbound).

Waste

Households and non-residential buildings generate solid waste and wastewater, and the model traces various pathways to disposal, compost and sludge. If present in the city, the model can also capture energy recovery from incineration and biogas. Waste generation is translated to landfill emissions based on first order decay models of carbon to methane.

Local Energy Production

The model accounts for energy generated within city boundaries. Energy produced from local sources (e.g., solar, wind, biomass) is modelled alongside energy imported from other resources (e.g., the electricity grid and the natural gas distribution system). The model accounts for conversion efficiency. Local energy generation can be spatially defined.

Financial and Employment Impacts

Energy related financial flows and employment impacts are captured through an additional layer of model logic. Costs are calculated as new stock is incorporated into the model, through energy flows (annual fuel costs), as well as other operating and maintenance costs. Costs are based on a suite of assumptions that are input into the model. See Section 6 for financial variables tracked within the model.

Employment is calculated based on non-residential building archetypes and their floor area. Employment related to investments are calculated using standard employment multipliers, often expressed as person-years of employment per million dollars of investment.

5. Energy and GHG Emissions Accounting

CityInSight accounts for the energy flows through the model, as shown in Figure 6.

Source fuels crossing the geographic boundary of the city are shown on the left. The four "final demand" sectors—residential, commercial, industrial, and transportation—are shown toward the right. Some source fuels are consumed directly in the final demand sectors (e.g., natural gas used by furnaces for residential heating, gasoline used by personal vehicles for transportation). Other source fuels are converted to another energy carrier before consumption in the final demand sectors (e.g., solar energy converted to electricity via photovoltaic cells, natural gas combusted in heating plants and the resulting hot water distributed to end use buildings via district energy networks). Finally, efficiencies of the various conversion points (end uses, local energy production) are estimated to split flows into either "useful" energy or conversion losses at the far right side of the diagram.

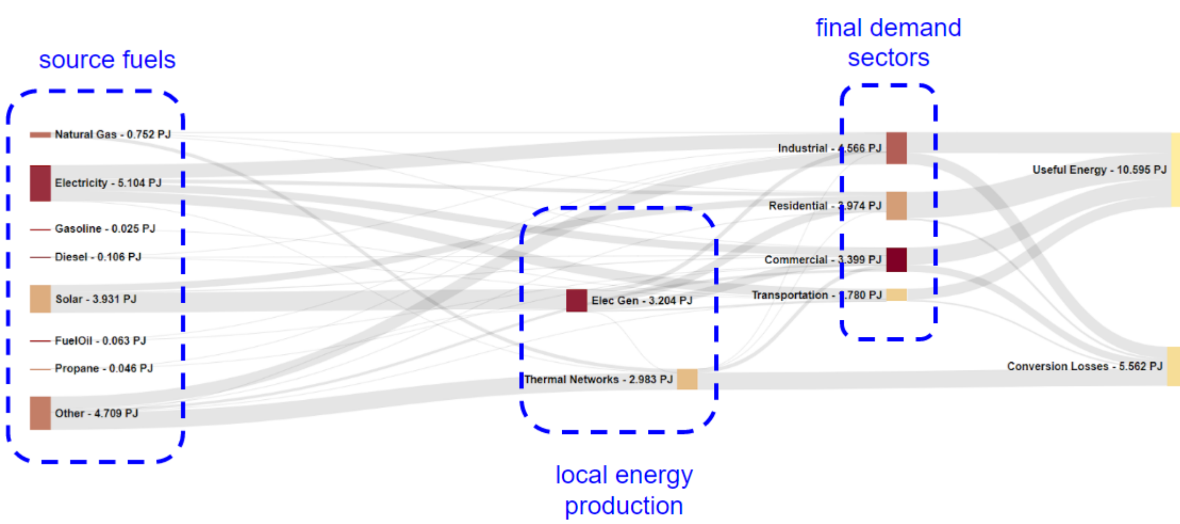

Figure 4. Energy flow Sankey diagram showing main node groups

Figure 4 above shows the potential for ambiguity when energy is reported: which of the energy flows circled are included and how do you prevent double counting? To address these ambiguities, CityInSight defines two main energy reports:

- **Energy Demand,** shown in Figure 5. Energy Demand includes the energy flows just before the final demand sectors (left of the dotted red line). Where the demand sectors are supplied by local energy production nodes, the cut occurs after the local energy production and before demand.
- **Energy Supply,** shown in Figure 6. Energy Supply includes the energy flows just after the source fuel nodes (left of the dotted red line). Where the source fuels supply local energy production nodes, the cut occurs between the source fuels and local energy production.

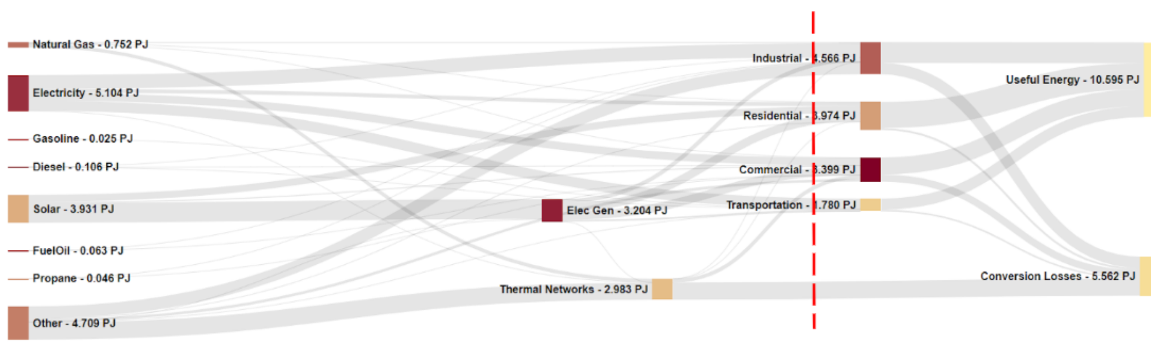

Figure 5. Energy Demand report definition

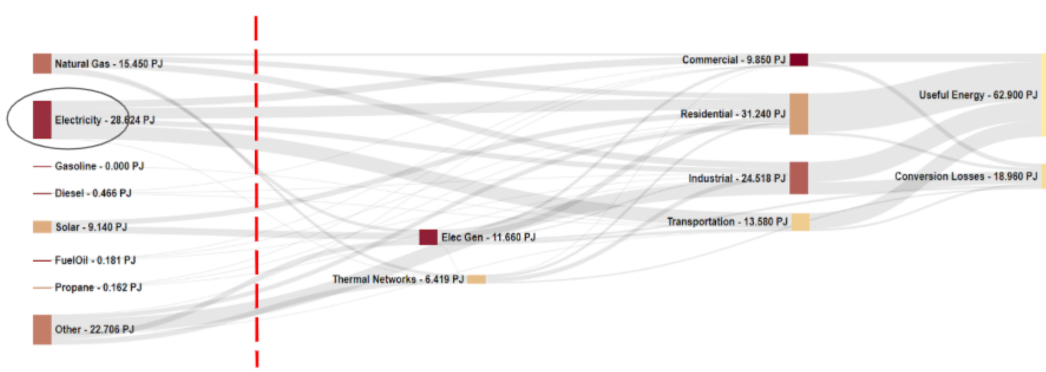

Figure 6. Energy Supply report definition.

In the integrated CityInSight energy and emissions accounting framework, GHG emissions are calculated after energy consumption is known.

6. Financial Accounting

The model also has a financial dimension expressed for most of its stocks and flows. Costs and savings modelling considers:

- Upfront capital expenditures: this is related to new stocks, such as new vehicles or new building equipment.
- Operating and maintenance costs: Annualized costs associated with stocks, such as vehicle maintenance.
- Energy costs: this is related to energy flows in model, accounting for fuel and electricity costs, and
- Carbon pricing: Calculated by on emissions generation.

Expenditure types that are evaluated in the model are summarized in Table 3. Financial assumptions will be included in further iterations of the Halton Hills model.

Table 3. Categories of expenditures.

Category	Description
Residential buildings	Cost of dwelling construction and retrofitting; operating and maintenance costs (non-fuel).
Residential equipment	Cost of appliances and lighting, heating and cooling equipment.
Residential fuel	Energy costs for dwellings and residential transportation.
Residential emissions	Costs resulting from a carbon price on GHG emissions from dwellings and transportation.
Commercial buildings	Cost of building construction and retrofitting; operating and maintenance costs (non-fuel).
Commercial equipment	Cost of lighting, heating and cooling equipment.

Commercial vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel).
Non-residential fuel	Energy costs for commercial buildings, industry and transport.
Non-residential emissions	Costs resulting from a carbon price on GHG emissions from commercial buildings, production and transportation.
Energy production emissions	Costs resulting from a carbon price on GHG emissions for fuel used in the generation of electricity and heating.
Energy production fuel	Cost of purchasing fuel for generating local electricity, heating or cooling.
Energy production equipment	Cost of the equipment for generating local electricity, heating or cooling.
Municipal capital	Cost of the transit system additions (no other forms of municipal capital assessed).
Municipal fuel	Cost of fuel associated with the transit system.
Municipal emissions	Costs resulting from a carbon price on GHG emissions from the transit system.
Energy production revenue	Revenue derived from the sale of locally generated electricity or heat.
Personal use vehicles	Cost of vehicle purchase; operating and maintenance costs (non-fuel).
Transit fleet	Costs of transit vehicle purchase.
Active transportation infrastructure.	Costs of bike lane and sidewalk construction.

Financial Reporting Principles

The financial analysis is guided by the following reporting principles:

1. Sign convention: Costs are negative, revenue and savings are positive.
2. The financial viability of investments will be measured by their net present value.

3. All cash flows are assumed to occur on the last day of the year and for purposes of estimating their present value in Year 1 will be discounted back to time zero (the beginning of Year 1). This means that even the initial capital outlay in Year 1 will be discounted by a full year for purposes of present value calculations.
4. We will use a discount rate of 3% in evaluating the present value of future government costs and revenues.
5. Each category of stocks will have a different investment horizon
6. Any price increases included in our analysis for fuel, electricity, carbon, or capital costs will be real price increases, net of inflation.
7. Where a case can be made that a measure will continue to deliver savings after its economic life (e.g. after 25 years in the case of the longest lived measures), we will capitalize the revenue forecast for the post-horizon years and add that amount to the final year of the investment horizon cash flow.
8. In presenting results of the financial analysis, results will be rounded to the nearest thousand dollars, unless additional precision is meaningful.
9. Only actual cash flows will be included in the financial analysis.

7. Inputs and Outputs

The model relies on a suite of assumptions that define the various stocks and flows within the model for every time-step (year) in the model.

Base Year

For the baseline year, many model inputs come from calibrating the model with real energy datasets. This includes real building and transportation fuel data, city data on population, housing stock and vehicle stock etc. Other assumptions come from underlying relationships between energy stocks and flows identified through research, like the fuel efficiency of personal vehicles, the efficiency of solar PV.

Future Projections

CityInSight is designed to project how the energy flow picture and emissions profile will change in the long term by modelling potential change in:

- the context (e.g. population, development patterns),
- emissions reduction actions (that influence energy demand and the composition of stocks).

Potential changes in the system are also based on a suite of input assumptions, and are frequently referred to as “actions”. Actions are an intervention point in the model that changes the relationship between a certain stock and flow at a certain time. Action assumptions can be based on existing projections and on proposed policy design, and can be as wide ranging the stocks and flows present in the model.

Stock-turnover models enable users to directly address questions about the penetration rates of new technologies over time constrained by assumptions such as new stock, market shares and stock retirements. Examples of outputs of the projections include energy mix, mode split, vehicle kilometres of travel (VKT), total energy costs, household energy costs, GHG emissions and others. Energy, emissions, capital and operating costs are outputs for each scenario. The emission and financial impacts of alternative climate mitigation scenarios are usually presented relative to a reference or “business as planned” scenario.

For example, an action may assume: “Starting in 2030, all new personal vehicles are electric.” This assumption would be input into the model, where, starting in 2030, every time a vehicle is at the end of its life, rather than be replaced with an internal combustion engine vehicle, it is replaced with an electric vehicle. As a result, the increase in the electric vehicle stock means greater VKT allocated to electricity and less to gasoline, thereby resulting in lower emissions.

8. Spatial Disaggregation

As noted above, a key feature of CityInSight is the geocoded stocks and flows that underlie the energy and emissions in the community. All buildings and transportation activities are tracked within a discrete number of geographic zones, specific to the city. This enables consideration of the impact of land-use patterns and urban form on energy use and emissions production from a baseline year to future points in the study horizon. CityInSight outputs can be integrated with city mapping and GIS systems. This is the feature that allows CityInSight to support the assessment of a variety of urban climate mitigation strategies that are out of reach of more aggregate representations of the energy system. Some examples include district energy, microgrids, combined heat and power, distributed energy, personal mobility (the number, length and mode choice of trips), local supply chains, and EV infrastructure.

For stationary energy use, the foundation for the spatial representation consists of land use, zoning and property assessment databases routinely maintained by municipal governments. These databases have been geocoded in recent years and contain detailed information about the built environment that is useful for energy analysis.

For transportation energy use and emissions, urban transportation survey data characterizes personal mobility by origin, destination, trip time, and trip purpose. This in turn supports the spatial mapping of personal transportation energy use and greenhouse gas emissions by origin or destination.

III. Modelling Process

CityInSight is designed to support the process of developing a municipal strategy for greenhouse gas mitigation. Usually the model is engaged to identify a pathway for a community to meet a greenhouse gas emissions target by a certain year, or to stay within a cumulative carbon budget over a specified period.

Data Collection, Calibration and Baseline

A typical CityInSight engagement begins with an intensive data collection and calibration exercise in which the model is systematically populated with data on a wide range of stocks and flows in the community that affect greenhouse gas emissions. A picture literally emerges from this data that begins to identify where opportunities for climate change mitigation are likely to be found in the community being modeled. The calibration and inventory exercise helps establish a common understanding among community stakeholders about how the greenhouse gas emissions in their community are connected to the way they live, work and play. Relevant data are collected for variables that drive energy and emissions—such as characteristics of buildings and transportation technologies—and those datasets are reconciled with observed data from utilities and other databases. The surface area of buildings is modeled in order to most accurately estimate energy performance by end-use. Each building is tracked by vintage, structure and location, and a similar process is used for transportation stocks. Additional analysis at this stage includes local energy generation, district energy and the provincial electricity grid. The primary outcome of this process is an energy and GHG inventory for the baseline year, with corresponding visualizations.

The Base Year and Reference Projection

Once the baseline is completed, a reference projection to the target year or the horizon year of the scenario exercise is developed. The reference projection is based on a suite of input assumptions into the model that reflect the future conditions. This is often based on: existing municipal projections, for buildings and population; historical trends in stocks that can be determined during model calibration. In particular, future population and employment and allocating the population and employment to building types and space. In the process the model is calibrated against historical data, providing a technology stock as well as an historical trend for the model variables. This process ensures that the demographics are consistent, that the stocks of buildings and their energy consumption are consistent with observed data from natural gas and electricity utilities, and that the spatial/zonal system is consistent with the municipality's GIS and transportation modelling.

The projection typically includes approved developments and official plans in combination with simulation of committed energy infrastructure to be built, existing regulations and standards (for example renewable energy and fuel efficiency) and communicated policies. The projection incorporates conventional assumptions about the future development of the electrical grid, uptake of electric vehicles, building code revisions, changes in climatic conditions and other factors. The resulting projection serves as a reference line against which the impact and costs of GHG mitigation measures can be measured. Sensitivity analysis and data visualizations are used to identify the key factors and points of leverage within the reference projection.

Low-Carbon Scenario and Action Plan

The low-carbon scenario uses a new set of input assumptions to explore the impacts of emissions reduction actions on the emissions profile. Often this begins with developing a list of candidate measures for climate mitigation in the community, supplemented by additional measures and strategies that are identified through stakeholder engagement. For many actions, CityInSight draws on an in-house database that specifies the performance and cost of technologies and measures for greenhouse gas abatement. The low carbon scenario is analyzed relative to the reference projection. The actions in the low carbon scenario are together to ensure that there is no double counting and that interactive effects of the proposed measures are captured in the analysis.

IV. Addressing Uncertainty

There is extensive discussion of the uncertainty in models and modelling results. The assumptions underlying a model can be from other locations or large data sets and do not reflect local conditions or behaviours, and even if they did accurately reflect local conditions, it is exceptionally difficult to predict how those conditions and behaviours will respond to broader societal changes and what those broader societal changes will be (the "unknown unknowns"). The modelling approach identifies four strategies for managing uncertainty applicable to community energy and emissions modelling:

1. Sensitivity analysis: From a methodological perspective, one of the most basic ways of studying complex models is sensitivity analysis, quantifying uncertainty in a model's output. To perform this assessment, each of the model's input parameters is described as being drawn from a statistical distribution in order to capture the uncertainty in the parameter's true value (Keirstead, Jennings, & Sivakumar, 2012).
    a. Approach: Each of the variables will be increased by 10-20% to illustrate the impact that an error of that magnitude has on the overall total.
2. Calibration: One way to challenge the untested assumptions is the use of 'back-casting' to ensure the model can 'forecast' the past accurately. The model can then be calibrated to generate historical outcomes, which usually refers to "parameter adjustments" that "force" the model to better replicate observed data.
    a. Approach: Variables for which there are two independent sources of data are calibrated in the model. For example, the model calibrates building energy use (derived from buildings data) against actual electricity data from the electricity distributor.
3. Scenario analysis: Scenarios are used to demonstrate that a range of future outcomes are possible given the current conditions that no one scenario is more likely than another.
    a. Approach: The model will develop a reference scenario.

4. **Transparency:** The provision of detailed sources for all assumptions is critical to enabling policy-makers to understand the uncertainty intrinsic in a model.
    a. **Approach:** The assumptions and inputs are presented in this document.

Appendix D: Resilient St. John's Community Plan: Mitigation Implementation Framework

November 2021

Purpose of this Document

The Implementation Framework provides guidance for the near-term implementation of the GHG mitigation portion of Resilient St. John's. It is not a comprehensive list. Many of these actions have the potential for greater efficiency and effectiveness if done in collaboration with other neighbouring municipalities, levels of government, and organizations. These opportunities should always be explored first.

Acronyms

CoSJ	City of St. John’s
DE	District Energy
EV	Electric Vehicle
FCM	Federation of Canadian Municipalities
GHG	Greenhouse Gas
ICI	Industrial, Commercial, and Institutional buildings
KPI	Key Performance Indicator
MUN	Memorial University of Newfoundland
PACE	Property Assessed Clean Energy
REC	Renewable Energy Cooperative
RNG	Renewable Natural Gas
RSJ	Resilient St. John’s

Co-benefit and Implementation Definitions

In addition to varying levels of greenhouse gas (GHG) reductions, actions included in this Plan result in additional benefits, which are described as co-benefits. These include: equity improvements, employment increases, and return on investment. For simplicity a code has been created for each potential co-benefit—enabler, low, medium, and high—which is described in the table below.

Indicator	Enabler	Low	Medium	High
Greenhouse gas emissions	Enables GHG Emissions	<100 ktCO2e reduction by 2050	100 to 3,000 ktCO2e reduction by 2050	>3,000 ktCO2e reduction by 2050
Costs	-	($0 - $100,000)	($100,000 - $1,000,000)	($1,000,000+)
Equity	No discernible effect	Without intervention, this action may favour certain groups or create a greater disparity between higher and lower income groups	This action is more likely to be implemented in the community fairly, but existing powerful groups may still be at an advantage	This action contributes to enhanced equity
Employment	Enables employment	0-5 person years of employment per $ million invested	5-10 person years of employment per $million invested	>10 person years of employment per $million invested
Cost-effectiveness	No cost associated with supporting action	This program will need incentives, loans, or grants in order to be completed	This action has the ability to break even, especially if paired with a more attractive investment vehicle	This action will be a driver of total cost-effectiveness of the entire program

For each implementation action, a primary implementation mechanism is listed (e.g., policy, program, initiative, or infrastructure), each is defined in the table below.

Mechanism	Definition
Policy	A policy developed by the Municipality, and approved by Council
Program	An ongoing effort by the Municipality, with staff and financing to support the effort
Initiative	A study or project, undertaken by the Municipality or private sector, with a specific focus, that is implemented for a set time period
Infrastructure	Investment in physical infrastructure by the municipality or private sector

The Focus Areas

Five key focus areas for Resilient St. John's Community Climate Plan were identified by the consultant through the combination of consultation with the public, and through technical modelling. These include:

1. Municipal leadership and planning
2. Affordable, efficient buildings for all
3. Transportation transformation
4. Clean energy for resilience
5. Low-waste future

There will be some overlap between the programs in each of the focus areas, as well as between program areas themselves. Systematic implementation of the programs ensures that one program will support another. For example, building retrofits increase the impact of solar PV installations by ensuring that there is more clean electricity for electric vehicles.

1. Municipal leadership and planning

Actions, co-benefits, and reporting

Action	GHG impact	Co-benefits	Costs	Implementation Mechanism	Reporting Metrics	Timing
1.1 Integrate climate considerations into city-wide development policies	Enabler	**Equity:** Enabler **Employment:** Enabler **CE:** TBD	$	**Policy:** Ensure that climate considerations are fully Integrated into St. John's Municipal Plan, subsequent neighbourhood-level plans, and updates of other strategies. • i.e., as soon as possible, the City will establish ambitious densification targets (e.g., 10% vs. 5% expected in the BAU) for designated areas.	Review of relevant policy sections for any needed updates	Short

1.2 Continue to provide annual GHG and energy use reporting (for City and broader community)	Enabler	**Equity:** N/A **Employment:** Low **CE:** N/A	$	**Program:** Public, annual reporting on progress of action, and at least a 5-year community-wide GHG and energy use reporting.	Annual reporting by action Tracking changes over time	Ongoing
1.3 Develop and implement a climate lens for all City budget decisions	Enabler	**Equity**: N/A **Employment:** Low **CE:** N/A	$	**Policy:** Develop a climate lens policy to guide City budget decisions **Program:** Annual reporting on corporate GHGs and energy use	Annual reporting on emissions by department to council and public by means of staff reports Tracking changes over time	Short
1.4 Undertake regular reviews and updates of RSJ	Enabler	**Equity:** N/A **Employment:** Low **CE:** N/A	$	**Initiative:** Establish a 5-year update to RSJ	Completion of review and update to RSJ in 2026	Every 5 years
1.5 Natural area protection and enhancement	Low	**Equity:** N/A **Employment:** Low **CE:** N/A	$	**Program:** Continue and expand urban tree planting and naturalization programs **Program:** Continue to naturalize greenspace, and protect wetlands and waterway buffers	# trees planted Area of greenspace and natural areas protected	Ongoing

1.6 Business and industry working groups	Enabler	**Equity:** N/A **Employment:** Low **CE:** N/A	$	**Initiative:** Establish a working group with local industries to develop strategies to meet climate goals	Progress toward GHG reduction targets	Immediate
1.7 Partnership with academic institutions and entrepreneurship incubators for pilot project and training	Enabler	**Equity:** Enabler **Employment:** Medium **CE:** N/A	$	**Initiative:** Work with academic institutions and entrepreneurship incubators to identify opportunities for innovation, training, and development	# local industries developed or expanded # labourforce training programs developed	Immediate

Implementation Pathway

Implementation Mechanism	Partners	Funders	Next steps
Policy: Ensure that climate considerations are fully Integrated into St. John's Municipal Plan, subsequent neighbourhood-level plans, and updates of other strategies.	CoSJ	CoSJ staff time	Identify climate policies and targets that can be incorporated as policies into the Municipal Plan. Prepare a planning brief on climate action as an input into the Municipal Plan Process. Review the Municipal Plan from the perspective of climate action, and propose any required updates.
Program: Public, annual reporting on progress of action, and at least a 5-year community-wide GHG and energy use reporting.	CoSJ	CoSJ staff time	Ensure annual reporting of corporate GHGs and RSJ program KPIs

Policy: Develop a climate lens policy to guide City budget decisions	CoSJ	CoSJ staff time	Develop policy and framework for corporate climate lens, to be expanded to community-wide decisions.
Program: Annual reporting on corporate GHGs and energy use	CoSJ	CoSJ staff time	Ensure annual reporting of corporate GHGs and RSJ program KPIs
Program: Continue and expand urban tree planting and naturalization programs	CoSJ, local conservation groups	CoSJ staff time	Identify areas for future tree planting and naturalization opportunities to engage with the public.
Program: Continue to naturalize greenspace, and protect wetlands and waterway buffers	CoSJ, Ducks Unlimited Canada	CoSJ staff time	Complete a study to identify areas at high risk for development that play a role in flood management and erosion control, and adopt conservation measures
Initiative: Establish a 5-year update to RSJ	CoSJ	CoSJ staff time	Ensure annual reporting of progress and RSJ program KPIs Track stakeholder feedback on program implementation Track and research opportunities for new programs, technologies, policies, regulations to improve existing programs and to address the carbon gap On an ongoing basis seek to pilot new solutions, the climate emergency does not wait for the 5-year review cycle In 2026, draft a public-facing report that clearly summarizes annual progress to date from implementing RSJ, lessons learned, any new solutions

			that have been explored in the interim period, and changes toRSJ going forward to improve implementation and address the carbon gap for 2025-2030.
Initiative: Convene a working group with local industries to develop strategies to meet climate goals	CoSJ, local industry representatives	CoSJ staff time	Identify key partners within local industry to participate in working group Explore what approach would best support local industry to identify goals and timelines to meet GHG goals
Initiative: Work with academic institutions to identify opportunities for innovation, training, and development	CoSJ, MUN, CNA, other academic institutions or training providers	CoSJ staff time	Continue to collaborate with MUN and the CNA to identify potential opportunities for entrepreneurship, skill development, and capacity building

2. Affordable, efficient buildings for all

Actions, co-benefits, and reporting

Action	GHG impact	Co-benefits	Costs	Implementation Mechanism	Reporting Metrics	Timing
2.1 All new buildings are net-zero by 2030	Medium	**Equity:** Enabler **Employment:** Medium **CE:** High	$$	**Policy:** Establish new Sustainable Development Guideline	GHG intensity of new buildings (kgCO2e/m2)	Immediate
2.2 Mass deep retrofits to existing homes and buildings, followed by switching to electric heat pumps and water heaters, achieving net-zero or net-zero ready	High	**Equity:** High **Employment:** High **CE:** Low	$$$	**Program:** Develop a deep retrofit program for all buildings **Initiative:** Pilot a neighbourhood retrofit **Initiative:** Pilot a low-income housing retrofit **Initiative:** Pilot a rental property retrofit **Leading by example/Infrastructure:** Retrofit municipal buildings to net zero or net zero ready	# of buildings/homes retrofit GHG intensity of new buildings (kgCO2e/m2)	Ongoing
2.3 Heat pumps and electric water heaters in all buildings	High	**Equity:** Enabler **Employment:** High **CE:** High	$$$		Number of non-electric systems replaced Total energy savings from space heating/water heating	Ongoing

2.4 Convene a roundtable to address energy poverty	N/A	**Equity:** High **Employment:** N/A **CE:** N/A	$	**Initiative:** Convene a roundtable to address energy poverty	#households experiencing energy poverty	Immediate

Implementation Pathway

Implementation Mechanism	Partners	Funders	Next steps
Policy: Establish new Sustainable Development Guideline	CoSJ, Canada Green Building Council, other cities undertaking similar actions.	CoSJ staff time, FCM	Communicate with cities that have undertaken similar policies, such as Toronto, Vancouver, or Whitby Review building standards that align with Net-Zero building standards
Program: Develop a deep retrofit program for all buildings	Local construction businesses, post-secondary education institutions, trade associates, MUN, NL Power	FCM, PACE programming led by the Municipality, revolving loans, provincial and federal governments.	Develop a small-scale financing and incentive program for homes, leveraging existing programs Complete a pilot project with 8-10 small businesses to complete deep retrofits, and share lessons learned
Initiative: Pilot a neighbourhood retrofit	MUN, CNA, Local construction businesses, EnergieSprong, Home Builders Association of Canada, Canada Green Building Council/ Passive House Institute Canada	FCM	Develop a project concept and create criteria for selecting a neighbourhood. Identify a funding source, such as FCM.

Initiative: Pilot a low-income housing retrofit	CoSJ, Province of NL, local construction businesses, MUN, CNA	FCM, Federal government	Identify a pilot project location, and share learnings for the project
Initiative: Pilot a rental property retrofit	CoSJ, local construction businesses, MUN, CNA	FCM, Federal government	Identify a pilot project location, and share learnings for the project
Infrastructure: Retrofit municipal buildings to net zero or net zero ready	Local construction/renovation/energy efficiency companies, Canada Green Building Council, Passive House Institute Canada, Province of NL, NL Power.	CoSJ, FCM, federal government	Explore energy performance contracting as a framework to realize early operational savings through energy retrofits to make city buildings net-zero or net-zero ready Identify a building or group of buildings for the first net-zero retrofit and share learnings from that project
Initiative: Convene a roundtable to address energy poverty	CoSJ, Province of NL, NL Power, End Homelessness St. John's, other NGOs or groups working in poverty reduction	CoSJ staff time	Identify key partners to participate in the roundtable and establish clear goals for their participation

3. Transportation transformation

Actions, co-benefits, and reporting

Action	GHG impact	Co-benefits	Costs	Implementation Mechanism	Reporting Metrics	Timing
3.1 Electrify personal, municipal, and commercial vehicles	High	**Equity:** Low **Employment:** High **CE:** High	$$$	**Infrastructure:** Partner on the deployment of electric vehicle charging stations **Initiative:** Working with local car dealerships to improve access to EVs **Initiative:** Develop an EV education program **Initiative:** Convene a commercial fleet decarbonization working group **Leading by Example:** Purchase electric vehicles for municipal fleet	Electric vehicle sales Transportation emissions # of charging stations by level	Ongoing

3.2 Expand and electrify transit	High	**Equity:** High **Employment:** High **CE:** High	$$	**Program:** Feasibility study and pilot project for electric buses in St. John's on select routes **Initiative:** Implement the ridership growth strategies identified in the Transit Review Study, 2019 **Initiative:** Later, update transit study to identify transit needs and further increase ridership and route coverage across the city.	Ridership Vehicle kilometres travelled (VKT, km/year) Transit mode share in relevant areas	Medium
3.3 Improve and expand walking and cycling infrastructure	Medium	**Equity:** High **Employment:** Low **CE:** Low	$$$	**Initiative:** Update, engage with the public, and ramp up implementation of the Bike St. John's Master Plan **Initiative:** Initiate a review of walking infrastructure needs in the city.	Total kms of bike lanes and trails Total kms of sidewalks in development areas Traffic counter data (vehicle counts, and vehicle kilometers traveled) in key areas	Medium

Implementation Pathway

Implementation Mechanism	Partners	Funders	Next steps
Infrastructure: Partner on the deployment of electric vehicle charging stations	CoSJ, Province of NL, NL Power	FCM,NL Power	Continue work underway in the CoSJ to expand the charger network Apply for funding from the Zero Emission Vehicle Infrastructure Program
Initiative: Working with local car dealerships to improve access to EVs	Local vehicle dealerships	CoSJ staff time	Convene local partners to identify existing barriers or limitations to the availability of EVs within St. John's, including used vehicles for resale on the second-hand market
Initiative: Develop an EV education program	CoSJ, NL Power	CoSJ	Develop an electric vehicle public education program, including test drives, an education website, and printed materials that answer frequent questions, support lifecycle costing of personal vehicles, and addresses concerns about battery life and range, charging infrastructure, and local winter performance
Initiative: Convene a commercial fleet decarbonization working group	CoSJ	CoSJ staff time	Identify key partners to participate in the working group Establish a Terms of Reference for the working group with clear goals and timelines

Infrastructure: Purchase electric vehicles for municipal fleet	CoSJ	CoSJ	Establish a policy whereby all vehicle purchases are electric unless a justification otherwise can be made to Council.
Program: Feasibility study and pilot project for electric buses in St. John's on select routes	CoSJ, Metrobus, NRC	CoSJ, FCM	Complete feasibility study on the electrification of the Public Transit System Purchase a small number of electric buses for a pilot project
Initiative: Initiate a review of walking infrastructure needs in the city.	CoSJ	CoSJ	Gather data and perceptions on walking infrastructure to identify needs
Initiative: Implement the ridership growth strategies identified in the Transit Review Study	CoSJ	CoSJ	Continue to invest in the ridership growth strategies identified in the Transit Review Study
Initiative: Later, update transit study to identify transit needs and further increase ridership and route coverage across the city.	CoSJ	CoSJ	Develop a community survey, and implementation plan to expand walking infrastructure across the city
Initiative: Update, engage with the public, and ramp up implementation of the Bike St. John’s Master Plan; and	CoSJ	CoSJ	Update, engage, and Implement the Bike St. John’s Master Plan. Complete a review of walking infrastructure and opportunities to expand the trails and sidewalks, supporting active modes of transportation

4. Clean energy for resilience

Actions, co-benefits, and reporting

Action	GHG impact	Co-benefits	Costs	Implementation Mechanism	Reporting Metrics	Timing
4.1 Partnership with MUN to decarbonize the District Energy system	High	**Equity:** Low **Employment:** Low **CE:** Low	$	**Initiative:** Collaborate with MUN/EH to decarbonize the DE system	GHGs from the DE system	Short
4.2 Install wind farms to supplement the provincial electricity grid.	Medium	**Equity:** Low **Employment:** Low **CE:**ww	$$$	**Policy:** Support the implementation of the renewable energy policies in the Envision Municipal Plan **Initiative**: Renewable energy cooperative (REC) public education campaign & search for local leads	MW of wind generation infrastructure installed	Medium
4.3 Expand landfill gas capture	Medium	**Equity:** N/A **Employment:** Low **CE:** Low	$$$	**Infrastructure**: Expand the landfill gas capture system and explore collaborative frameworks for its feasible reuse	Tonnes RNG captured	Short

4.4 Ensure electricity system is planning to manage new demand and new supply mix	N/A	**Equity:** N/A **Employment:** Low **CE:** Low	$	**Initiative:** Commission an hourly analysis of electricity demand and capacity to ensure a stable, reliable electricity grid for a net-zero future	Completion of study	Short

Implementation Pathway

Implementation Mechanism	Partners	Funders	Next steps
Initiative: Collaborate with MUN/EH to decarbonize the DE system	CoSJ, MUN	CoSJ	Establish a partnership with MUN to establish goals and timelines for decarbonization
Policy: Support the implementation of the renewable energy policies in the Envision Municipal Plan	CoSJ, Province of NL, NL Power	CoSJ	Review existing policies to identify barriers and gaps that limit the use of renewable energy, and work with the Province and other stakeholders to eliminate barriers
Initiative: Renewable energy cooperative (REC) public education campaign & search for local leads	CoSJ, NL Power, other municipalities with existing RECs (Toronto, Ottawa)	CoSJ	CoSJ to provide public education campaign CoSJ to support search for potential local groups to establish REC CoSJ to design renewable energy RFPs to enable participation by RECs

Infrastructure: Expand the landfill gas capture system and explore collaborative frameworks for its feasible reuse	CoSJ, Province of NL	CoSJ, Province of NL	CoSJ and the province to collaborate to commission a feasibility study on the improvement of landfill gas capture systems at regional landfills
Initiative: Commission an hourly analysis of electricity demand and capacity to ensure a stable, reliable electricity grid for a net-zero future	CoSJ, NL Power Province of NL	CoSJ, NL Power, Province of NL	Hire a consultant to undertake an hourly analysis of how the energy efficiency improvements and electrification included in RSJ will affect the electricity system, and how the demand can be balanced to ensure a stable, reliable grid

5. Low-waste future

Actions, co-benefits, and reporting

Action	GHG impact	Co-benefits	Costs	Implementation Mechanism	Reporting Metrics	Timing
5.1 Public education to reduce overall waste production, and improve waste diversion	Low	**Equity:** N/A **Employment:** N/A **CE:** N/A	$	**Program:** Develop and deliver educational programming about waste reduction, and waste sorting	Waste diversion rates Per capita waste generation	Short
5.2 Support the development of a circular economy	Enabler	**Equity:** N/A **Employment:** N/A **CE:** N/A	$	**Initiative:** Convene a working group to identify opportunities for building a local industry for repair and reuse including community composting and building materials reuse such as: ● undertaking a review of existing guidance (e.g., Guide to Community Gardens in the City of St. John's) to incorporate neighbourhood level community composting on city-owned land. ● identifying barriers and	Tonnes garbage generated annually	Short

				opportunities for building materials re-use. ● explore the development of a food waste and resource flow map to identify food waste-to-value opportunities for innovation.		

Implementation Pathway

Implementation Mechanism	Partners	Funders	Next steps
Program: Develop and deliver educational programming about waste reduction, and waste sorting	CoSJ, Province of NL, MMSB	CoSJ, Province of NL, MMSB	Develop educational material on reducing waste production, and on the importance of waste sorting for all ages
Initiative: Convene a working group to identify opportunities for building a local industry for repair and reuse including community composting and building materials reuse	CoSJ, Province of NL, MMSB	CoSJ, Province of NL, MMSB	Identify key partners to participate in the working group Establish a Terms of Reference for the working group with clear goals and timelines