MAY, 2020

An Integrated Energy System Pathway:

A Better Way Forward to Net-Zero in Nova Scotia

Heritage Gas

Forward *Energy.*

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Executive Summary

To mitigate the impacts of climate change, the world must significantly reduce global greenhouse gas (GHG) emissions over the next thirty years. Canada signed the Paris Climate Accord in 2015 and pledged to implement actions to drastically reduce GHG emissions. In support of Canada's commitments to fight climate change, Nova Scotia passed the Sustainable Development Goals Act (SDGA) in October 2019 and established new provincial GHG emission reduction targets to:

- reduce GHG emissions to at least 53% below 2005 levels by 2030; and,
- achieve net-zero emissions by 2050[1].

challenge of climate change. Heritage Gas is optimistic about the challenge ahead and we believe the gas distribution system has an important role to play to help Nova Scotia transition to a low-carbon economy by delivering cleaner energy where and when we'll need it.

While there is a viable pathway to achieve Nova Scotia's 2030 emissions target, reducing emissions to net-zero by 2050 will be significantly more challenging. Studies from around the world have concluded that energy efficiency measures, combined with the decarbonization of electricity generation will be important, yet insufficient to achieve net-zero emissions by 2050.

Our Vision is a resilient province with an abundance of clean, affordable energy.

To achieve these targets, Nova Scotia must fundamentally transform how energy is produced, stored, distributed, and consumed. This transformation to a resilient net-zero energy system will require a significant improvement in energy efficiency and conservation, the decarbonization of electricity generation, and a transition to low-carbon fuels for buildings, industrial processes, and transportation.

Nova Scotia relies on energy to move us forward, and the decades ahead will be defined by how we meet the

The future energy system that Nova Scotia needs to achieve net-zero emissions should be built on two foundational principles:

1. **Energy efficiency and conservation.** The government of Canada's Generation Energy Council reported that Canada can achieve at least one-third of our emissions targets by improving energy efficiency and conservation[2]. The energy we don't use saves money and reduces the cost of doing business in Nova Scotia.

1 An Act to Achieve Environmental Goals and Sustainable Prosperity, 2019.

2 The Generation Energy Council, Canada's Energy Transition, 2018.

2. **Cleaner electricity and gas grids.** Nova Scotia's net-zero energy system will need to be fueled by low-carbon energy. We can decarbonize our energy system by transitioning to renewable electricity, renewable natural gas (RNG), and low-carbon hydrogen. Nova Scotia has made significant progress in reducing the emissions intensity of electricity generation, and further reductions are possible by replacing coal-fired generation with additional hydro, wind energy, or natural gas. The emissions intensity of the gas grid can also be reduced by displacing fossil natural gas with RNG, by blending low-carbon hydrogen with natural gas and, over the longer term, by converting the natural gas grid to a 100% clean hydrogen, so we can leverage the gas infrastructure we have today to deliver the cleaner energy we'll need tomorrow.

Increasingly, governments are concluding that the large-scale production of **hydrogen will be needed to deliver the clean energy that Nova Scotia will need to achieve net-zero emissions by 2050.** The European Union's Hydrogen Roadmap Report, for example, concluded that *"achieving the energy transition in the EU will require hydrogen at large scale. Without it, the EU will miss its decarbonization objective"*[3].

Hydrogen will play an important role in the decarbonization of key energy sectors:

Buildings: Hydrogen can play a valuable role in the decarbonization of building heat by delivering a low-carbon fuel for gas boilers, integrated with electric heat pumps in hybrid heating systems.

Industry: Hydrogen can produce the high-grade heat required in many industrial processes that cannot be produced by electricity.

Heavy Transportation: Hydrogen is the most promising fuel to decarbonize heavy trucks, buses, ships, trains, large cars, and commercial vehicles, where the lower energy density, high initial costs, and slow recharging performance of batteries are major disadvantages[4].

Power Generation: The surplus electricity generated by variable renewable energy (i.e. wind, solar) can be used to produce 'green' hydrogen through electrolysis to support the deployment of more renewable electricity generation and for the storage of renewable power.

> **"Hydrogen will be needed to deliver the clean energy that Nova Scotia will need to achieve net-zero emissions by 2050."**

Energy storage and linked electricity and gas grids will be important components of an **integrated energy system** – the most viable pathway to meet Nova Scotia's SDGA goals at the lowest cost while providing flexibility, diversity, and resiliency.

3 Fuel Cells and Hydrogen Joint Undertaking, Hydrogen Roadmap Europe - A Sustainable Pathway for the European Energy Transition, 2019, page 4.

4 *Ibid.*

5 European Parliamentary Research Service, Energy Storage and Sector Coupling, 2019.

Hydrogen energy storage and batteries can work together to balance short-term and seasonal energy supply and demand in Nova Scotia's winter peaking energy system. As more variable renewable energy, especially wind, is deployed on the electric grid in Nova Scotia, balancing supply and demand while ensuring grid stability will become more challenging. Energy storage will play a crucial role to bridge the imbalances between energy production and consumption[5]. **Surplus wind generation in Nova Scotia can be converted to 100% green hydrogen through the process of electrolysis to convert renewable electricity into a gas that has all the flexibility but none of the carbon emissions of natural gas.**

Linked electricity and gas grids can work together in complementary ways to build a more flexible and resilient energy system. They can support the conversion of surplus wind generation in Nova Scotia to zero-carbon 'green' hydrogen, enable the efficient on-site generation of heat & power for buildings and industrial processes, and integrate in hybrid heating systems to minimize the increase in peak electricity demand that occurs with increased penetration of electric heat pumps for space heat in buildings[6].

An **integrated energy system** has several advantages over complete electrification to meet the challenges of Nova Scotia's net-zero future:

Clean Energy Growth

The production of more renewable energy – wind power, green hydrogen, and renewable natural gas - here in Nova Scotia supports economic growth and energy independence. Significantly more wind energy generation can be added in Nova Scotia and the surplus electricity can be used to produce green hydrogen using power-to-gas facilities. The integration of wind generation, green hydrogen production, and battery storage can support further renewable energy generation in our province.

Peak Demand Management

A decarbonized energy system based on the electrification of building heat, industrial processes, and transportation poses significant challenges due to the need for additional flexibility in the electricity system, reinforcement of the transmission and distribution networks, and the significant increase in peak electric demand. The use of a cleaner gas grid for heavy transportation, high-temperature industrial processes, and hybrid heating systems for space heat in residential and commercial buildings can minimize the increase in peak electric demand.

Decarbonization of All Energy Sectors

Some energy sectors that are difficult to electrify, like high-temperature industrial processes and heavy transportation (i.e. freight, public transit, rail, marine) can be decarbonized through the use of compressed natural gas, renewable natural gas, and low-carbon hydrogen.

Improved Energy System Resiliency & Flexibility

Most of Nova Scotia's electricity transmission and distribution infrastructure is above ground, where it is exposed to increasingly frequent and more extreme weather events. Increased electrification will further increase our reliance on the electric grid in critical areas such as transportation. Conversely, gas infrastructure is located underground and is 99.996% reliable. Energy policy decisions need to consider the importance of reliable and resilient energy infrastructure.

6 European Parliament's Committee on Industry, Research and Energy, Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise?, 2018.

Moving Forward. Together.

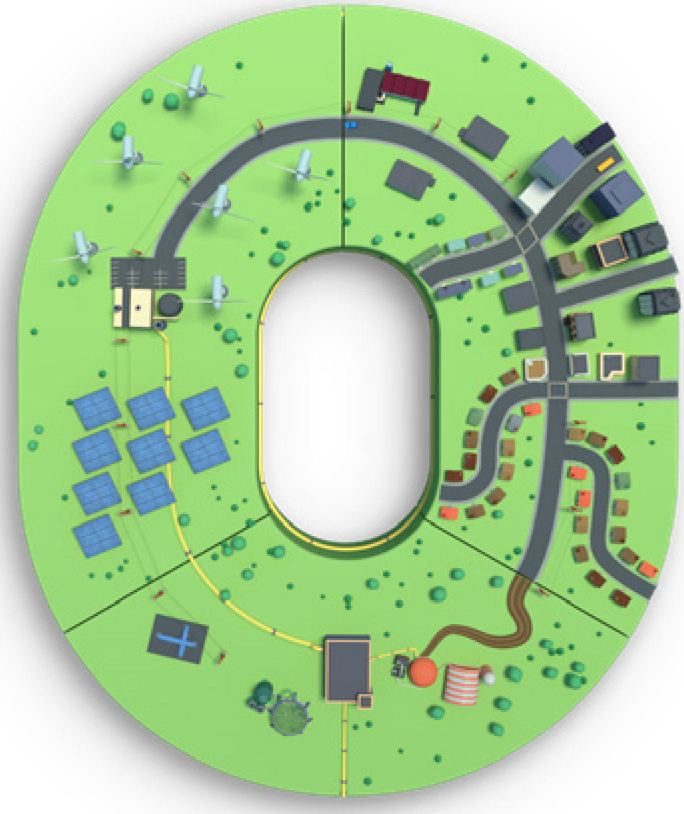
Now is the time for Nova Scotia to demonstrate leadership in climate action and we all have an important role to play. We must work together to reduce our energy consumption and invest in clean energy technologies so we can achieve our ambitious goal to achieve net-zero emissions by 2050. Nova Scotia is uniquely positioned to lead the clean growth and green jobs transformation in Canada. Our province has been a resource economy for generations. Moving forward, let's use our wind, biomass, tides, and green hydrogen resources as catalysts to transform Nova Scotia into a green energy economy.

Instead of depending on imported energy, we can leverage this transformation to achieve energy independence.

What's Next?

The Integrated Energy System described in this study is an important first step toward the development of a viable plan to achieve net-zero emissions in Nova Scotia by 2050. Next, Heritage Gas proposes collaborating with other energy companies, industries, academia, government, and other key stakeholders to complete a feasibility study that builds on this study and the modeling and analyses conducted by other organizations. The study should further evaluate the potential for green hydrogen production, energy storage, and linking the electricity and gas grids in Nova Scotia.

Introduction



To mitigate the impacts of climate change, the world must significantly reduce global GHG emissions over the next thirty years. To help achieve this ambitious goal, Canada signed the Paris Climate Accord in 2015 and pledged to implement actions to reduce GHG emissions to 30% below 2005 levels by 2030, and to deeper reductions by 2050[7]. In 2018, an Intergovernmental Panel on Climate Change (IPCC) report highlighted the urgency to lower emissions to **"net-zero" by 2050,** in an effort to limit global warming to 1.5 degrees Celsius[8].

In support of Canada's commitments to fight climate change, the Nova Scotia legislature passed the Sustainable Development Goals Act (SDGA) in October 2019 and established new provincial greenhouse gas (GHG) emission reduction targets to:

- Reduce GHG emissions to at least 53% below the levels that were emitted in 2005 levels by 2030 (from 16 Mt in 2017 to approximately 11 Mt by 2030); and
- Achieve net-zero emissions by balancing greenhouse gas emissions with GHG removals and other offsetting measures by 2050 (approximately 2-3 Mt).

In 2020, Nova Scotia will complete a *Climate Change Plan for Clean Growth* to outline how the Province will:

- Achieve the GHG emission targets of 53% below 2005 levels by 2030 and net-zero by 2050;
- Adapt to the impacts of climate change and building a climate resilient Province;
- Accelerate the integration of sustainable and innovative technologies and approaches; and
- Achieve clean inclusive growth[9].

Nova Scotia GHG Emissions Trends and Projections to 2050:

Starting with the passing of the Environmental Goals and Sustainable Prosperity Act in 2007, Nova Scotia has been a leader in lowering GHG emissions. The Province's emissions have declined by 33% from 23.2 Mt in 2005 to 15.6 Mt in 2017. Most of Nova Scotia's emissions are produced by electricity generation (42%), transportation (32%), and heat for buildings and industrial processes (18%)[10].

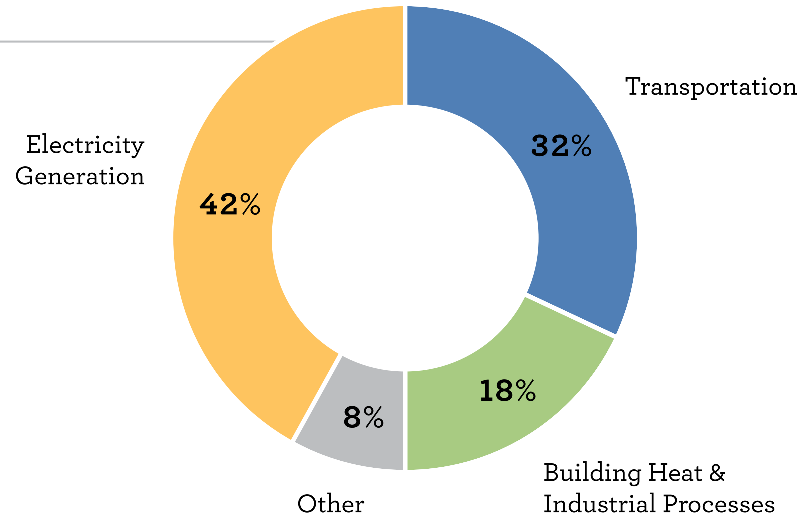
7 Environment and Climate Change Canada – News release, 2019.

8 IPCC, Global Warming of 1.5C: Summary for Policymakers, 2018.

9 Nova Scotia Sustainable Development Goals Act, 2019.

10 Canada Energy Regulator, Provincial and Territorial Energy Profiles – Nova Scotia, 2017.

Nova Scotia's GHG Emissions, by Source



To achieve the SDGA 2030 emission reduction target, however, Nova Scotia must reduce emissions by an additional 29%, to 11 Mt. Based on the measures included in all three emission-reduction scenarios in a recent report, Nova Scotia is projected to achieve or exceed the 11 Mt. 2030 emissions target[11].

While there is a viable pathway to achieve Nova Scotia's 2030 emissions reduction target, reducing emissions to net-zero by 2050 will be significantly more challenging.

By 2050, the ways in which energy is produced, stored, distributed, and used must fundamentally change.

Nova Scotia will need to significantly improve energy efficiency and conservation, decarbonize electricity generation, transition to low-carbon fuels for heating buildings, running industrial processes, and transporting people and freight, all while ensuring energy reliability and resiliency.

Studies from around the world have concluded that energy efficiency measures, combined with the decarbonization of electricity generation will be important, yet insufficient to achieve net-zero emissions by 2050. The most cost-effective and resilient pathway to net-zero emissions is through the integration of energy generation, storage, and consumption, to deliver reliable energy, with a cleaner electricity grid and a cleaner gas grid.

In February 2020, Nova Scotia Power Inc. (NSPI) commissioned Energy & Environmental Economics, Inc. (E3) to *"perform an independent analysis of strategies to achieve long-term, province-wide GHG reductions, with a focus on electricity, buildings, and transportation sectors".* While the analysis did not include specific strategies to achieve net-zero emissions by 2050, the Deep Decarbonization in Nova Scotia: Phase 1 Report concluded that **additional actions beyond significant emissions reductions from electricity generation and deep electrification would be required to achieve net-zero emissions by 2050[12].**

11 Canada's 4th Biennial Report on Climate Change, 2019.

The analysis identified five potential emissions mitigation scenarios (Building Electrification Only, Moderate Electrification, High Electrification, Very High Electrification, and High Biofuels) to reduce total GHG emissions in Nova Scotia to 80% below 2005 levels by 2050. The scenarios are outlined in Tables 9 and 10 on page 54 of the Deep Decarbonization in Nova Scotia: Phase 1 Report developed by E3. **The results of E3's analyses indicate that increasing levels of electrification do not achieve greater emission reductions.**

Several government and energy industry studies in Europe, Asia, and North America have reached similar conclusions that electrification with renewable electricity will be an important, yet insufficient, pathway to achieve net-zero emissions by 2050.

In addition to electricity, other energy sources, including liquid fuels and gases, must become cleaner.

Hydrogen Storage Facility

Windmill Farm

In the Netherlands and Germany, two utilities TenneT and Gasuine conducted a study on the integrated energy infrastructure that will be required to achieve net-zero emissions. Their study stated that:

"To meet the 2050 emission targets set in the Paris Climate Agreement, the energy transition will require a complete overhaul of the current fossil fuel-dominated energy system. Although electricity produced from sun and wind is seen as the main source of energy by 2050, a major part of it has to be converted to molecules (such as hydrogen) to meet the demand of the chemical and fertilizer industries, and other forms of final consumption, all of which are difficult to electrify."[13]

These studies have all concluded that achieving net-zero emissions by 2050 will not be as simple as decarbonizing electricity generation and electrifying all energy use sectors. Some sectors, like heavy transportation and high temperature industrial processes, will be very difficult to electrify. In other sectors, especially building heat in Northern climates, the impact of more electrification will be significantly higher peak electric demand and the need for deployment of additional seldom-used generating capacity to meet it. The decarbonization of all major energy use sectors, including building heat, heavy transportation, and industry will require a more coordinated and integrated solution beyond electrification.

12 E3, Deep Decarbonization in Nova Scotia: Phase 1 Report (Feb 27 Pathways Presentation), 2020.

13 Infrastructure Outlook 2050, 2019.

The Role of Hydrogen

To achieve net-zero emissions in Nova Scotia, we need to transform the gas that flows through our underground infrastructure from traditional natural gas to renewable natural gas and low-carbon hydrogen gas.

The large-scale production of hydrogen will be needed to deliver the clean energy that Nova Scotia will require to achieve net-zero emissions by 2050.

The European Union's Hydrogen 2050 Report, for example, concluded that:

> *"Achieving the energy transition in the EU will require hydrogen at large scale. Without it, the EU will miss its decarbonization objective. The fuel offers a versatile, clean, and flexible energy vector for this transition.*
>
> *While hydrogen is not the only decarbonization lever, it is an essential lever among a set of other technologies. It makes the large-scale integration of renewables possible because it enables energy players to convert and store energy as a renewable gas. It can be used for energy distribution across sectors and regions and as a buffer for renewables. It provides a way to decarbonize segments in power, transport, buildings, and industry, which would otherwise be difficult to decarbonize."*[14]

With respect to the use of the existing gas grid, the report states that:

> *"Hydrogen...can act as a complement to heat pumps. Producers can distribute some hydrogen by blending it into the existing grid without the need for major upgrades, but it is possible to go much further than this. Ultimately, energy suppliers can convert grids to run on pure hydrogen. Alternatively, natural gas can be replaced with synthetic natural gas (SNG) produced from hydrogen and* CO_2*".*

14 Hydrogen Roadmap (Europe) – A Sustainable Pathway for the European Energy Transition, 2019.

Furthermore, the U.K. Committee on Climate Change concluded that:

> *"Producing hydrogen in low-carbon ways and using it to meet challenging demands (e.g. for heat in industrial processes, for heating buildings on colder winter days and for heavy transport) is likely to be an important part of the next stage of the UK's energy transition. Hydrogen can be a strong complement to electrification."*[15]

Hydrogen will play an important role in the decarbonization of key energy sectors:

Buildings: Hydrogen can play a valuable role in the decarbonization of building heat by delivering a low-carbon fuel for gas boilers integrated with electric heat pumps in hybrid heating systems.

Industry: Hydrogen can produce the high-grade heat required in many industrial processes that cannot be produced by electricity.

Heavy Transportation: Hydrogen is the most promising fuel to decarbonize heavy trucks, buses, ships, trains, large cars, and commercial vehicles, where the lower energy density, high initial costs, and slow recharging performance of batteries are major disadvantages[16].

Power Generation: The surplus electricity generated by variable renewable energy (i.e. wind, solar) can be used to produce 'green' hydrogen through electrolysis to support the deployment of more renewable electricity generation and for the storage of renewable power.

Hydrogen, like electricity, is an energy carrier that can be made from a variety of energy sources and feedstocks. It can be transmitted and distributed by pipeline and efficiently consumed in many ways: to produce electricity in a fuel cell or turbine, to heat a home, to fuel a vehicle or to produce high-grade heat for industrial processes. Hydrogen can be stored at large scale underground and used in cold winter months, a capability that may never be matched by battery storage.

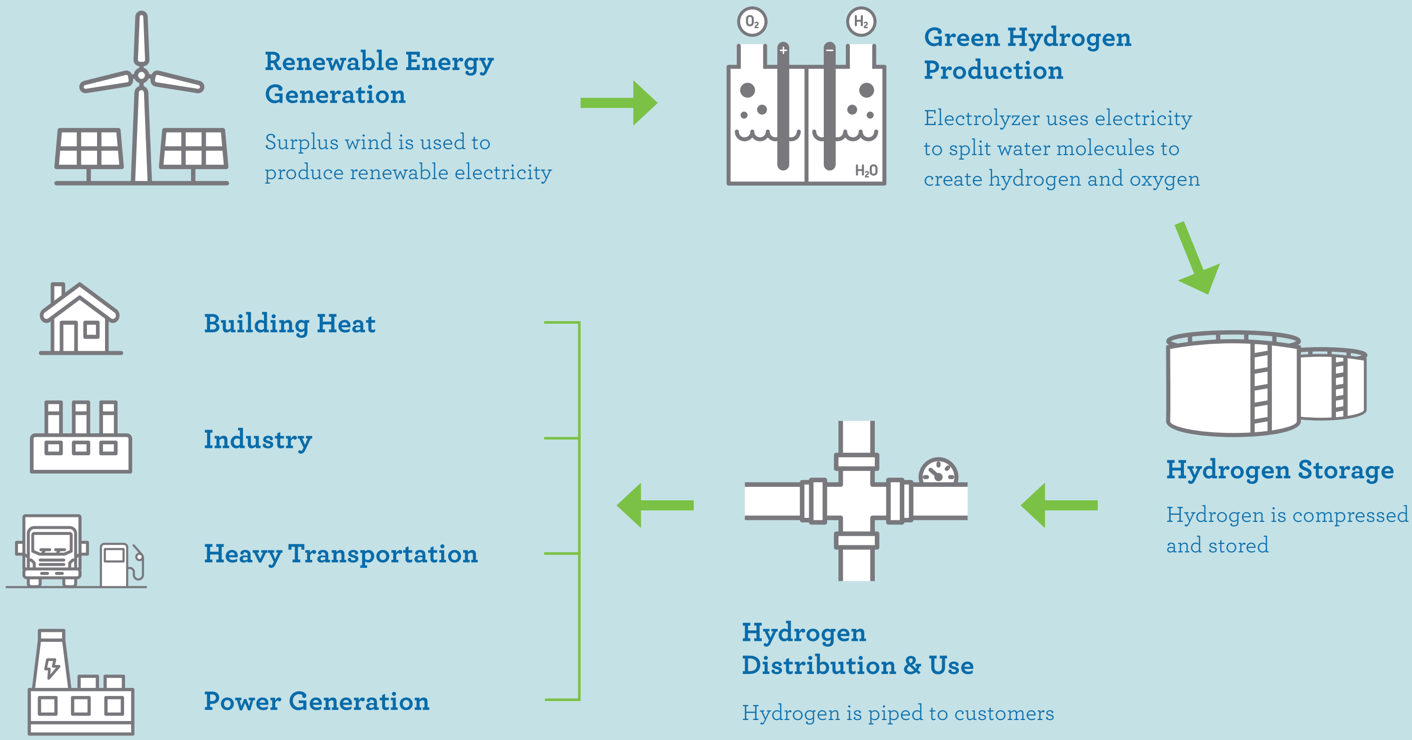
There are three main categories of hydrogen production.

- **Grey Hydrogen** is produced from fossil fuels, typically natural gas, through thermal processes that break down larger molecules like methane into hydrogen and carbon. This is a common method of global hydrogen production and it results in CO_2 emissions at a similar level to that of natural gas.
- **Blue Hydrogen** is produced in the same way as Grey Hydrogen, except the carbon that is emitted is captured and sequestered, typically deep underground in specific geologic formations.

15 U.K. Committee on Climate Change – Hydrogen in a Low-Carbon Economy, 2018.

16 Hydrogen Roadmap (Europe) – A Sustainable Pathway for the European Energy Transition, 2019, page 25..

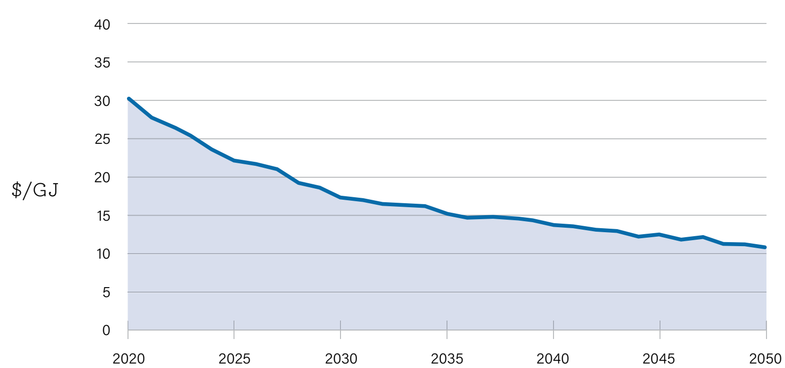
How Green Hydrogen Works



- **Green Hydrogen** is produced from renewable electricity through the process of electrolysis. Electric current is applied to water molecules, which split into hydrogen and oxygen to produce clean-burning, 100% renewable hydrogen fuel. The cost of hydrolysis is projected to decline significantly (see Figure 1, right)[17].

Figure 1:

Green Hydrogen Production from "Best Case Wind" Scenario (IRENA 2019 Report)



17 IRENA – Hydrogen: A renewable energy perspective, page 34.

A Better Way Forward to Net-Zero

Achieving net-zero emissions in Nova Scotia by 2050 will be challenging. Several key actions will be important including energy efficiency, energy conservation, and a transition to low-carbon energy to meet most of our energy needs. Nova Scotia must transform the energy systems used to produce, store, deliver, and use energy while also providing sufficient, reliable, and resilient low-carbon energy to meet our energy needs when and where we'll need it.

Electrification will be important, especially a low-carbon electricity grid, but renewable electricity alone is not a viable pathway to net-zero.

E3's Deep Decarbonization in Nova Scotia report reached a similar conclusion that, in addition to electricity:

"Other low-carbon fuels are still needed to provide incremental carbon-neutral energy services after all economic clean energy and electrification measures are implemented. Advanced biofuels were used as the main low-carbon fuel in this analysis, although other options like hydrogen produced with clean electricity could serve this need". [18]

An Integrated Energy System with a cleaner gas grid working in complementary ways with a cleaner electricity grid is a better way forward to meet Nova Scotia's diverse energy needs at the lowest total cost, while providing flexibility and resiliency. A recent report from London's Imperial College report concluded that energy systems integration could be *"the most cost-effective way to decarbonize energy sectors, increase energy efficiency, and produce a more resilient system".* [19]

18 E3, Deep Decarbonization in Nova Scotia: Phase 1 Report (Feb 27 Pathways Presentation), 2020.

19 Imperial College London, Unlocking the Potential of Energy Systems Integration.

The Ecology Action Centre's (EAC) 2019 Accelerating the Coal Phase-Out study[20], which outlines a scenario for a low-carbon transition for Nova Scotia's electricity and energy systems by 2030, indicates that *"accommodating a large contribution to electric supply from wind and solar energy requires new technologies and new approaches to grid management".* The low-carbon scenario modeled for in the EAC study includes adding up to 800 MW of new wind generation capacity and estimates that 43% of Nova Scotia's total electricity supply in 2030 will be provided by wind generation and 5% from solar. The production of green hydrogen from surplus wind generation can support the deployment of this additional wind capacity Nova Scotia. The same conclusion was established in the Infrastructure Outlook 2050 study:

"In the energy system of the future, electricity, heat and gas will be increasingly integrated in order to absorb the large fluctuations in solar and wind power production." [21]

The analysis performed in the Infrastructure Outlook 2050 study determined that integrating electric and gas grids gives the energy system flexibility and provides enough seasonal storage to meet the extra energy demand for winter heating, in an energy system based on renewable power.

Furthermore, Great Britain's National Grid Electricity System Operator's Future Energy Scenarios report concluded that a *"whole systems view across electricity, gas, heat, and transport underpins a sustainable energy transformation".* [22] The report determined that connecting the gas and electricity systems will support new energy technologies like hybrid heating systems and hydrogen production from electrolysis and help Great Britain achieve its net-zero emissions target.

20 Ecology Action Centre, Accelerating the Coal Phase Out: Nova Scotia and the Climate Emergency, November, 2019.

21 Infrastructure Outlook 2050, 2019.

22 National Grid Electricity System Operator's Future Energy Scenarios, 2019.

Nova Scotia's future net-zero energy system should be built on two foundational principles:

Energy Efficiency and Conservation

The government of Canada's Generation Energy Council reported that Canada can achieve at least one-third of our emissions targets by improving energy efficiency and conservation.[23] The energy we don't use saves money and reduces the cost of doing business. Nova Scotia's energy end-use final demand was 164 PJ in 2016. 60% of this demand was supplied by refined petroleum products, 23% by electricity, 9% by natural gas, and 8% by biofuels[24].

With actions to improve energy efficiency and conservation in the buildings, transportation, and industrial sectors, Nova Scotia's energy demand is projected to decline by 12% between 2020 and 2040[25]. E3's Reference scenario projects 2050 energy demand to decline by 11% by 2050, while the Building Electrification Only and Moderate Electrification scenarios would reduce energy demand by up to 30%[26].

The Government of Canada has announced additional policies under the Pan-Canadian Framework that will help reduce energy consumption further, including carbon pricing, retrofit building codes for existing buildings, net-zero ready building codes for new buildings, more stringent standards for equipment and appliances in the buildings sector, support for industrial efficiency, and an electric vehicle strategy[27].

Halifax, Nova Scotia

Cleaner Electricity and Gas Grids

Nova Scotia's net-zero energy system will need to be fueled by low-carbon energy. **In 2017, the emissions intensity of Nova Scotia's total energy emissions intensity was 101 kg CO_2e/GJ, the 2nd highest in Canada, and 59% higher than the Canadian average**[28], driven by using fossil fuels for much of the province's electricity generation and the high penetration of fuel oil for building heat.

23 The Generation Energy Council, Canada's Energy Transition, 2018.

24 Canada Energy Regulator, Canada's Energy Future, 2019.

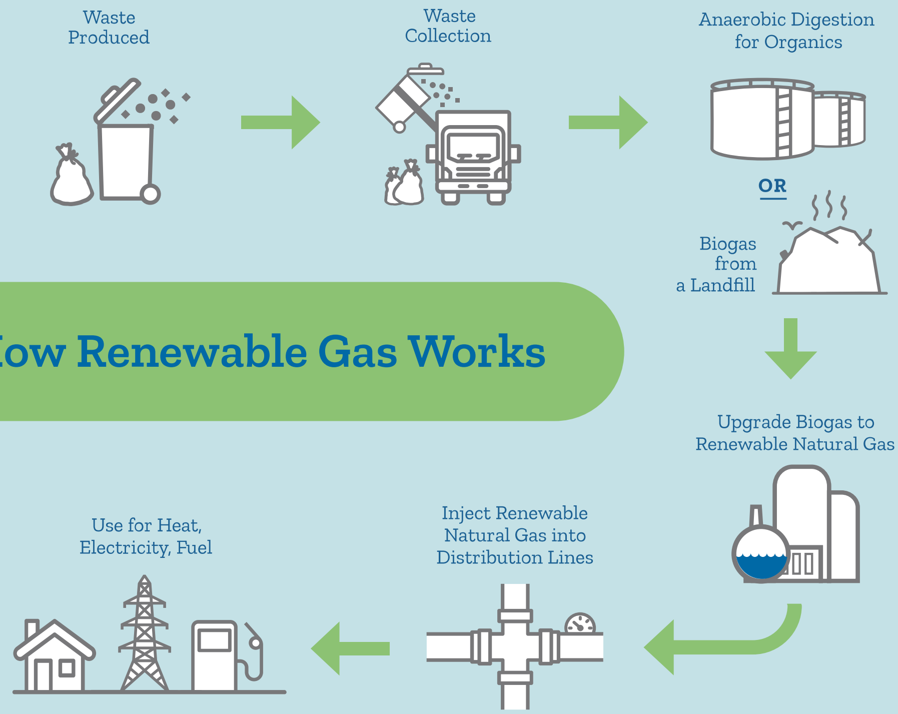
25 *Ibid.*

26 E3, Deep Decarbonization in Nova Scotia: Phase 1 Report (Feb 27 Pathways Presentation), 2020.

27 Canada's Fourth Biennial Report on Climate Change, 2019.

28 Canada Energy Regulator, Provincial & Territorial Energy Profiles, 2016 & 2017.

How Renewable Gas Works



We can decarbonize our energy system by transitioning to renewable electricity, RNG, and low-carbon hydrogen. Nova Scotia has made significant progress in reducing the emissions intensity of electricity generation, and further reductions are possible by replacing coal-fired generation with additional hydro, wind energy, or natural gas.

RNG can be produced from a variety of feedstocks, including organic waste, landfills, wastewater treatment facilities, agricultural waste and woody biomass. There are a number of potential RNG projects in the province that will allow Nova Scotia to turn the waste we generate today, into the energy we'll need.

The potential use of Nova Scotia's wood waste resource (woody biomass) as a feedstock for RNG development is an encouraging opportunity. Not only would it allow for large scale production of green gas, but it also increases our energy independence and offers support to the local forestry sector. The emissions intensity of the gas grid can also be reduced by displacing fossil natural gas with RNG and by initially blending up to 20% low-carbon hydrogen with natural gas. By 2030, Heritage Gas estimates that RNG could supply 5-15% of current Nova Scotia natural gas demand. The combination of RNG and hydrogen blended into the gas grid could reduce the emissions intensity of natural gas by 25-35%, from 51 kgCO_2e/GJ in 2020 to 33-38 kgCO_2e/GJ.

Over the next 30 years the natural gas grid can be converted to a 100% clean hydrogen grid so we can use the gas infrastructure we have today, to deliver the cleaner energy we'll need tomorrow, similar to the plan proposed for the city of Leeds, UK[29].

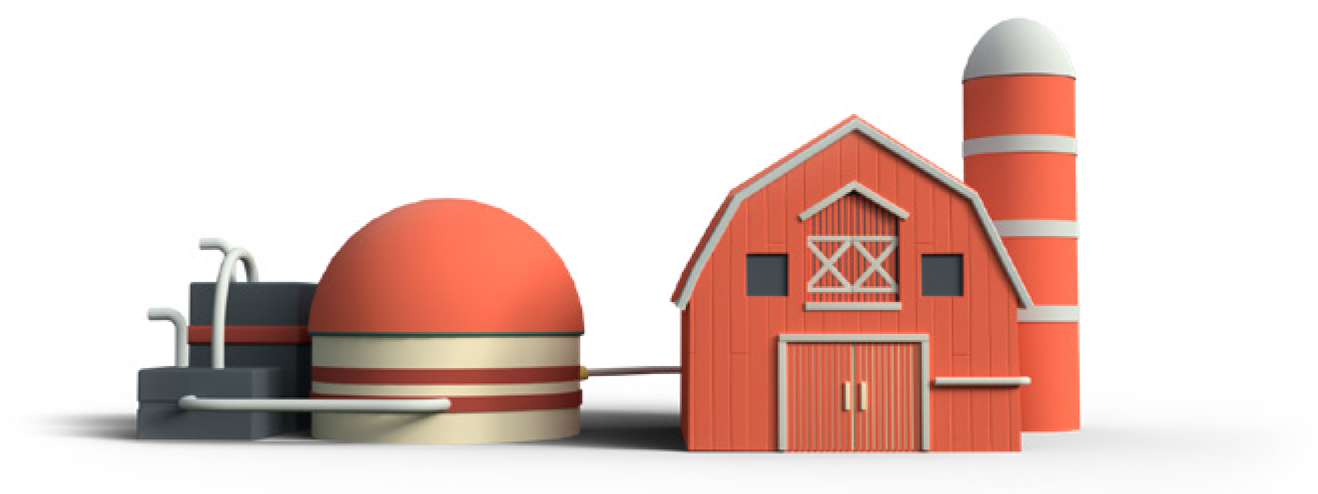
H21 Project

The City of Leeds in the United Kingdom is developing a plan to convert the natural gas distribution system to 100% hydrogen. A feasibility study determined that the H21 project is technically possible and an economically viable way to decarbonize large parts of the UK gas grid. Once implemented, this would represent the single most significant contribution to emissions reduction in the UK.[1]

Halifax, Nova Scotia is similar to Leeds, UK, in both geography and population. Halifax is uniquely positioned to convert its natural gas distribution system to hydrogen because, like Leeds, almost all of the natural gas pipes in Halifax are made from polyethylene plastic, a key requirement for the distribution of hydrogen.

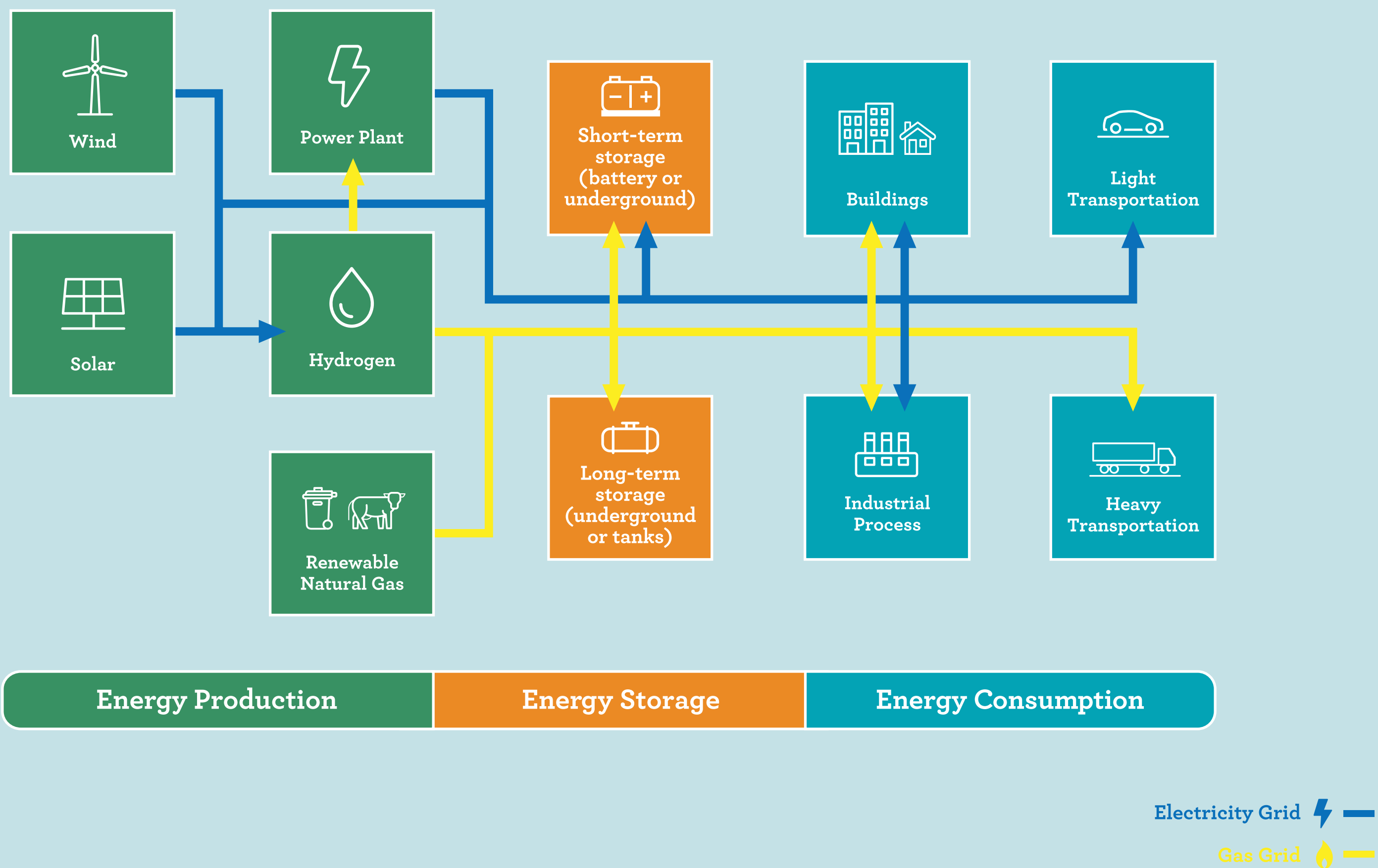
1 https://www.leedsclimate.org.uk/hydrogen-gas

While it is understood that we must reduce our energy demand and use cleaner forms of energy to achieve net-zero by 2050, we must also effectively store and distribute energy to achieve this target.



29 H21 Leeds City Gate film, 2017.

An Integrated Energy System for Nova Scotia



An **integrated energy system** that links cleaner electricity and gas grids is the most viable pathway to meet Nova Scotia's SDGA goals at the lowest cost, while providing flexibility, diversity, and resiliency.

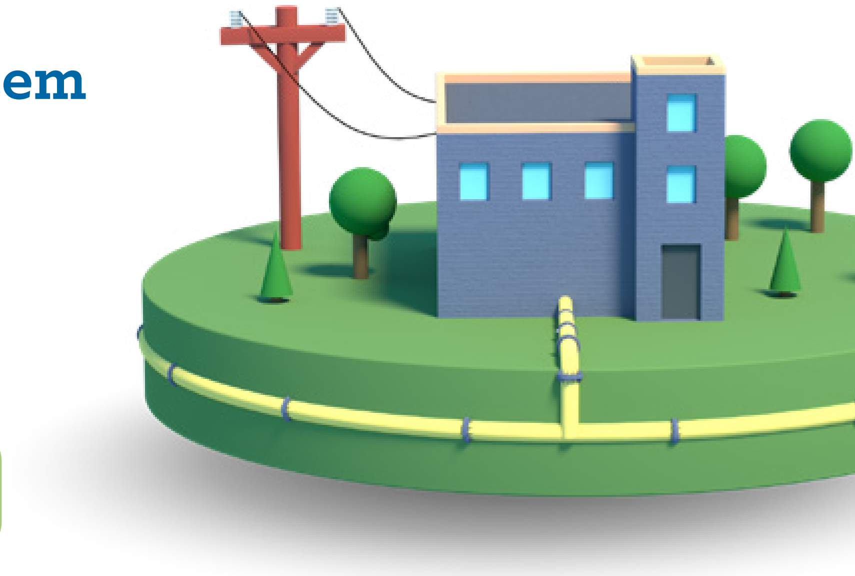
Hydrogen energy storage can balance energy short-term and seasonal supply and demand in Nova Scotia's winter peaking energy system. As more variable renewable energy, especially wind, is deployed on the electric grid in Nova Scotia, balancing supply and demand while ensuring grid stability will become more challenging. Energy storage will play a crucial role to bridge the imbalances between energy production and consumption[30]. Surplus wind generation in Nova Scotia can be converted to 100% 'green' hydrogen through the process of electrolysis to convert renewable electricity into a gas that has all the flexibility but none of the carbon emissions of natural gas.

Linked electricity and gas grids can work together in complementary ways to build a more flexible and resilient energy system. They can support the conversion of surplus wind generation in Nova Scotia to zero-carbon green hydrogen, support the efficient on-site generation of heat & power for buildings and industrial processes, and be integrated in hybrid heating systems to minimize the increase in peak electricity demand that occurs with increased penetration of electric heat pumps for space heat in buildings[31].

30 European Parliamentary Research Service, Energy Storage and Sector Coupling, 2019.

31 European Parliament's Committee on Industry, Research and Energy, Sector coupling: how can it be enhanced in the EU to foster grid stability and decarbonise?, 2018.

The Benefits of an Integrated Energy System



An integrated energy system pathway that combines cleaner electricity and gas grids with short-term and seasonal energy storage offers several important advantages over electrification to meet the challenges of achieving net-zero emissions in Nova Scotia.

Clean Energy Growth

An integrated energy system supports the production of more renewable energy – wind power, solar, green hydrogen, and renewable natural gas - here in Nova Scotia to promote local economic growth and energy independence. Development of a local hydrogen economy and energy system integration will support a strong clean-tech sector while reducing our dependence on energy from outside the Province.

Surplus wind generation in Nova Scotia can be used to produce green hydrogen. Total installed wind generation capacity in Nova Scotia has increased significantly over the past decade to over 600 MW, making Nova Scotia a national leader in wind energy as a percentage of total generation capacity. However, since wind is a variable generation resource, the deployment of additional wind capacity in Nova Scotia will likely result in surplus energy.

Heritage Gas engaged Power Advisory to conduct an analysis of the potential to use surplus wind energy to produce green hydrogen in Nova Scotia using power-to-gas facilities[36]. Their analysis determined that adding 200 MW of wind generation in Nova Scotia would reduce GHG emissions by 0.5 Mt and result in approximately 150,000 MWh of surplus wind energy annually - enough to produce 400,000 GJ of green hydrogen. The addition of 400 MW of wind generation would reduce GHG emissions by 0.9 Mt and result in approximately 375,000 MWh of surplus wind energy annually, enough to produce approximately 1 million GJ of green hydrogen. The integration of wind generation, green hydrogen production, and battery storage can support further renewable energy generation in Nova Scotia. For example, adding 400 MW of wind generation combined with a 400 MW battery storage system with 8 hours of energy storage capability, and 100 MW of hydrogen production capacity could utilize up to 99% of the additional wind generation.

Peak Demand Management

In planning for increased electricity load, utilities need to consider both base demand energy and peak demand energy needs. Peak demand occurs over a short period of time when demand is at its highest. In northern geographies, such as Nova Scotia, peak demand typically occurs on the coldest winter evenings. Peak demand establishes the amount of electricity generation capacity that must be available to meet customers' maximum requirements in a given year, even though this capacity is only required for a limited number of hours each year. Furthermore, the cost to generate electricity to meet peak demand is typically higher than the cost to meet base demand.

32 IRENA – Hydrogen: A renewable energy perspective, page 34.

An integrated energy system that leverages the different and complementary capabilities of the gas grid and electric grid will enable Nova Scotia to manage peak demand more effectively. Electricity is a just-in-time energy system that must match demand and supply in real time, across wide distances, and can be vulnerable to disruptions of supply and spikes in demand. Conversely, the gas grid is designed to meet highly variable energy demand and can easily handle peak energy demands, even on the coldest winter days. The gas grid utilizes resilient, underground infrastructure to distribute chemical energy (molecules) and has buffering and storage capabilities to address short-term and seasonal supply and demand imbalances.

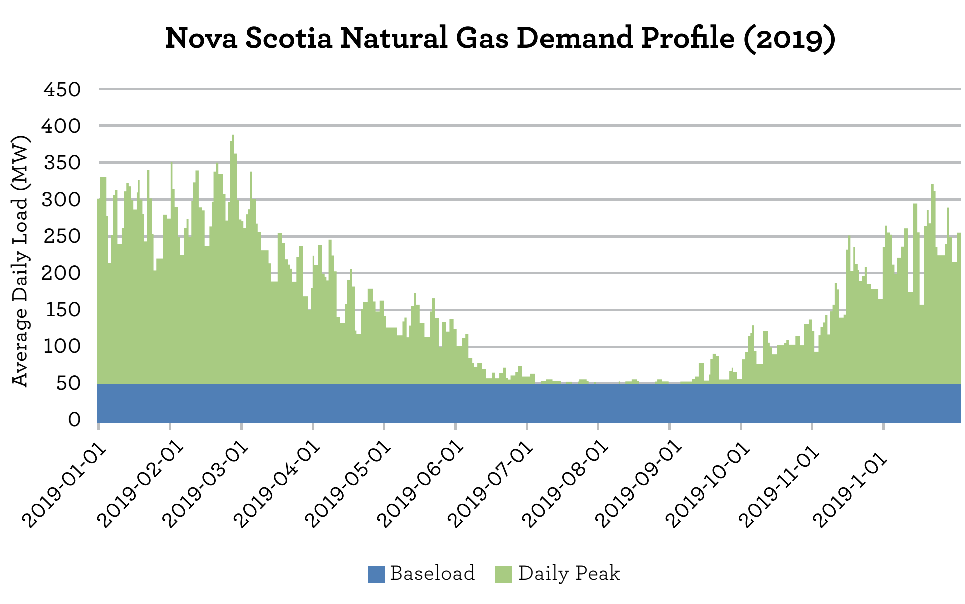
If electric heat pumps are used to heat more buildings and electric vehicle (EV) penetration increases, peak electric demand will also increase, even with complementary actions like energy efficiency and conservation, building energy retrofits, and battery storage. E3's modeling indicates that:

"Winter peak may increase as a result of electrified space heating, driven by customers switching away from oil furnaces, the most prevalent heating appliances in Nova Scotia, to heat pumps. E3 notes, however, that as temperature drops, heat pump efficiencies decline until, in very cold conditions, heat pumps revert to electric resistance mode as back-up heat. Because heat pumps might operate in electric resistance mode during the coldest winter hours in Nova Scotia, there would be no reduction in peak load impact from switching from electric resistance units to heat pumps, even though switching from electric resistance units to heat pumps would provide efficiency gains for most of the year".[33]

E3 estimated that the High Electrification scenario could increase peak demand by 15-54% from approximately 2,000 MW currently to 2,300 - 3,080 MW and the Moderate Electrification case could increase peak demand by 8-28%.

Peak space heating demand in Nova Scotia's residential and commercial buildings is significant. Natural gas demand for space heating and domestic hot water, for example, is 6 to 7 times higher on cold winter days than on warmer spring, summer, and fall days (see Figure 2). If the current natural gas heating load in Nova Scotia was switched to electricity, peak electricity demand would increase by over 500 MW.

Figure 2:



33 E3, Deep Decarbonization in Nova Scotia: Phase 1 Report (Feb 27 Pathways Presentation), 2020.

To understand the impact of peak winter heating demand in the residential and commercial sectors in Nova Scotia, Heritage Gas commissioned Power Advisory to prepare a Building Electrification Analysis. The report's findings indicate that retaining dual-fuel heating with electric heat pumps and natural gas for back-up on the coldest days reduces costs relative to complete electrification of heating load. Natural gas heating acts as 'demand response' in the electricity sector to dramatically reduce peak electricity loads. Peak loads increase electric system costs significantly due to the need to add electric infrastructure that is seldom used.

Power Advisory modeled electric system loads and peak demand to 2050 for three scenarios:

1. Base Case using NSP's latest IRP for total energy consumption and peak demand from 2020 to 2050,
2. 100% Electrification Case in which all residential and commercial space heating is converted to air source heat pumps with electric resistance heat as back-up,
3. Hybrid Case in which all residential and commercial space heating is converted to air source heat pumps with the building's original space heating source maintained as the back-up. The Hybrid Case assumes that back-up heat is used when the outdoor air temperature drops below -15C.

While total annual electricity consumption only increases moderately, even with 100% Electrification, due to the higher efficiency of air source heat pumps, peak demand increases from approximately 2,400 MW in the Base Case to over 3,100 MW, resulting in significantly higher annual costs. Conversely, the Hybrid Case provides approximately $100 Million in net annual savings by 2050 due to reduced peak demand relative to the 100% Electrification Case as natural gas heating is used on cold days rather than electric resistance.

Nova Scotia faces a significant challenge to serve peak demand with a growing reliance on intermittent renewable generation, such as wind and solar, to meet our electricity requirements. While wind and solar have an important role in the transition to net-zero emissions, they provide limited capacity to meet peak load requirements, especially in the winter.

Downtown Halifax, Nova Scotia

Integrating the electric and gas grids through power-to-gas facilities would allow intermittent renewable generation like wind and solar to efficiently satisfy winter energy needs without over-building generating capacity or wasting energy.

Decarbonization of All Energy Sectors

Some energy sectors that are difficult to electrify, like high-temperature industrial processes and heavy transportation (i.e. freight, public transit, rail, marine) can be decarbonized through the use of compressed natural gas, renewable natural gas, and green hydrogen.

The high cost of transportation fuels (i.e. gasoline, diesel) makes the transportation sector attractive for conversion to lower-carbon fuel alternatives. While the emissions intensity of light-duty transportation can be reduced by converting to electric vehicles, electrification of the heavy freight transportation, public transit, and marine transportation segments will be more challenging. Fueling passenger and light-duty vehicles with electricity and heavy transportation and public transit vehicles with compressed natural gas (CNG), liquefied natural gas (LNG), hydrogen fuel cells, or hydrogen-diesel fuel blends offers the best pathway to decarbonize transportation while minimizing the peak electricity demands from electric vehicle charging.

Improved Energy System Resiliency & Flexibility

Most of Nova Scotia's electricity transmission and distribution infrastructure is above ground, where it is exposed to increasingly frequent and more extreme weather events. Increased electrification will further increase our reliance on the electric grid in critical areas such as transportation. Conversely, gas infrastructure is located underground and is 99.996% reliable.

Energy policy decisions need to consider the importance of reliable and resilient energy infrastructure.

An integrated energy system offers increased flexibility and improved resiliency to extreme weather events.

Moving Forward. Together.

Reducing Nova Scotia's emissions to net-zero by 2050 is an ambitious goal, and we all have an important role to play in achieving it. By working together and taking action now, Nova Scotia can lead the way to a clean energy future for our province and the planet. We must work together to reduce our energy consumption and invest in clean energy technologies.

Nova Scotia is uniquely positioned to lead the clean growth and green jobs transformation in Canada. Our province has been a resource economy for generations. Moving forward, let's use our wind, biomass, tides, green hydrogen, and our hydrogen-ready gas grid as catalysts to transform Nova Scotia into a green energy economy. Instead of relying on imported energy, we can leverage this transformation to achieve energy independence.

What's Next?

The Integrated Energy System described in this study is an important first step toward the development of a viable plan to achieve net-zero emissions in Nova Scotia by 2050. Next, Heritage Gas proposes collaborating with other energy companies, industries, academia, government, and other key stakeholders to complete a feasibility study that builds on this study and the modeling and analyses conducted by other organizations. The study should further evaluate the potential for further improvements in energy efficiency, renewable energy production, including renewable electricity, green hydrogen and renewable natural gas, energy storage, and linking the electricity and gas grids in Nova Scotia.

Acronyms

CO_2e – Carbon Dioxide equivalent
CNG – Compressed Natural Gas
E3 – Energy & Environmental Economics, Inc.
EAC – Ecology Action Centre
EV – Electric Vehicle
GDP – Gross Domestic Product
GHG – Greenhouse Gas
GJ – Gigajoule
H_2 - Hydrogen
IPCC – Intergovernmental Panel on Climate Change
IRP – Integrated Resource Planning
LNG – Liquefied Natural Gas
Mt – Metric ton
MW - Megawatt
MWh – Megawatt hour
PJ - Petajoule
PtG – Power to Gas
NSPI – Nova Scotia Power Inc.
RNG – Renewable Natural Gas

Glossary

Base Load: the minimum stable level of energy demand and supply over a period of time.

Compressed Natural Gas: methane stored at high pressure, which when combusted, produces lower emissions than other fuels.

Gas Grid: the infrastructure to deliver gaseous forms of energy. Currently the gas grid is used for the delivery of natural gas; however, gas grids are increasingly being used to deliver low/zero carbon energy to connected customers.

Electrolysis: the process of using electricity to split water into hydrogen and oxygen. This reaction takes place in a unit called an electrolyzer. Electrolyzers can range in size from small, appliance-size equipment that is well-suited for small-scale distributed hydrogen production to large-scale, central production facilities that could be tied directly to renewable or other non-greenhouse-gas-emitting forms of electricity production.

Energy System: all the components related to the production, conversion, delivery and end use of energy (Intergovernmental Panel on Climate Change 2014). Energy systems involve a range of fuels, technologies, processes and physical infrastructures that interact to supply energy services, mainly in the form of fuels, electricity, heat and transportation.

Energy Systems Integration (ESI): "the process of coordinating the operation and planning of energy systems across multiple pathways and/ or geographical scales to deliver reliable, cost-effective energy services with minimal impact on the environment" (O'Malley et al. 2016).

Hydrogen: a nonmetallic gaseous chemical element that is the simplest and lightest of the elements and that is currently used especially in the processing of fossil fuels and the synthesis of ammonia.

Liquefied Natural Gas: natural gas that has been cooled to a liquid state, at about -260 Fahrenheit, for shipping and storage.

Pathway: the sequence of actions (i.e. technology deployments, investments, policies) needed to achieve a desired end point.

Peak Demand: the highest rate of energy usage during a period of time.

Power-to-Gas (PtG): conversion of electrical energy to a gaseous fuel. As an example of such conversion, electricity is used to split water into hydrogen and oxygen using the electrolysis principle, where hydrogen can then be converted to methane with CO_2 as input.

Resilience: ability of the system with generating sources, transmission and distribution, conversion – to withstand high-impact, low-frequency events. This includes events that are natural, such as hurricanes or ice storms, as well as man-made, such as cyber or physical attacks on e.g. grid infrastructure.

Reliability: all the measures of the ability of the system, generally given as numerical indices, to deliver electricity to all points of utilization within acceptable standards and in the amounts desired.

Renewable Natural Gas: Biogas which has been upgraded to pipeline-quality; interchangeable with conventional natural gas.

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