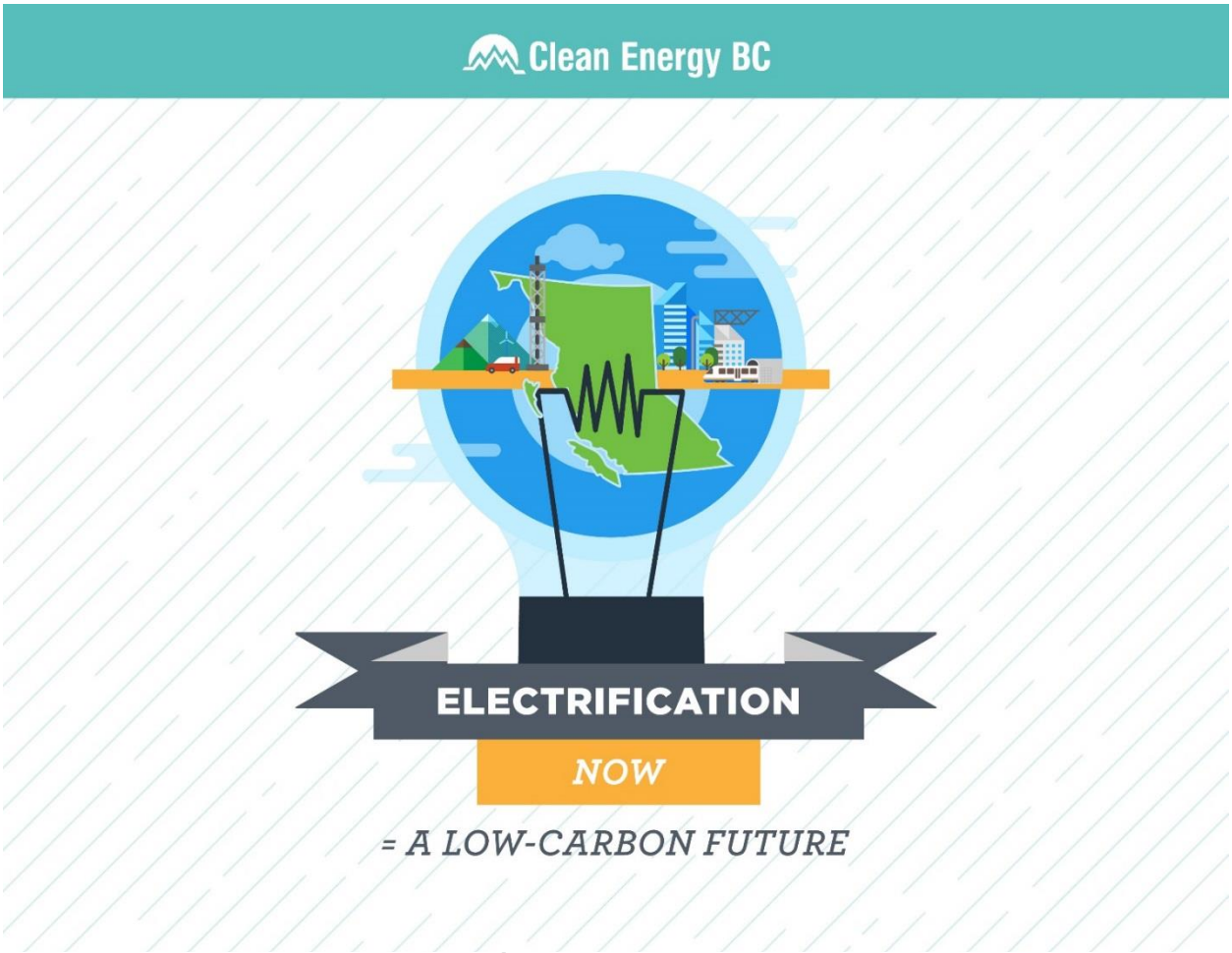

Electrification of British Columbia:

Assessing the Economic and Environmental Benefits of Extensive Electrification in BC.

Clean Energy BC White Paper, 15th October 2018.

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Executive Summary

On May 7, 2018 the Government of British Columbia established ambitious new 2030 greenhouse gas reduction targets in the Climate Change Accountability Act. With the launch of the BC Government's Clean Growth Intentions Papers in August 2018, the Government's focus on electric transportation, increasing building energy efficiency and establishing a green growth incentive program for industry is vital. This paper breaks down the main opportunities for GHG reduction and highlights the potential growth in emissions without extensive electrification. Meeting these targets will require deep cuts to carbon pollution across the economy; especially in industry, transportation, and the built environment. Between 2007 and 2015 modest progress has been made in GHG reductions in British Columbia[1] where emissions declined by 4.7%; while at the same time, the GDP grew by 16%. This demonstrates that climate solutions and clean growth work hand in hand. However, the GHG reductions that have been committed to far exceed these levels; therefore, the task will be exceptionally challenging.

A key solution is electrification. Government could incentivize and/or require the necessary clean energy conversion of a vast majority of vehicles, buses, trucks, boilers, furnaces, and industrial facilities that presently run on fossil fuels to instead run on clean electricity. It would also need to incentivize and/or use regulations, mandates and phase-outs to ensure that companies interested in building liquefied natural gas (LNG) plants ensure that all aspects of their proposed facilities would run on clean electricity wherever possible. A funding mechanism would need to be set up that enables for this rapid electrification transition to take place in time for the province to meet the GHG reduction targets. This could look like the government providing access to low interest loans for green mortgages which require double the return on investment from upgrades like heat pumps. If money is loaned at 2.5% and a heat pump offers a 5% return on investment, then the cost of servicing the loan is much less than the financial benefit. With models like these already in use in Europe, BC can benefit from other countries' best practices. The Global Green Bond Partnership supports efforts of sub-national entities such as cities and provinces, regions, corporations, private companies, and financial institutions to accelerate the issuance of green bonds every year to 2030 to fully implement the Paris Climate Agreement.

Currently in BC, the cost of wind and solar is about $50-60/MW with prices expecting to drop over the next 5 years to around $45/MW. Extending transmission to remote facilities and industrial customers and speeding up the process of connecting them to the grid is vital for extensive electrification. This needs to be done in a way that addresses conservation values like sensitive habitats and Indigenous rights.

California recently announced that it is aiming to become zero-carbon by 2045. British Columbia is particularly well-suited for clean electrification. In fact, electrification offers the province a critical competitive advantage in the global pursuit of clean growth. The province boasts one of the lowest-carbon electricity grids in North America. Its power generation sector can responsibly and cost-effectively provide the additional renewable electricity that extensive electrification will require.

The benefits of electrification when paired with enhanced energy efficiency are enormous. This paper shows that extensive electrification could reduce LNG industry emissions up to 72 percent, natural gas production emissions up to 60 percent, trucks and trucking up to 84 percent, and residential and commercial building heating by up to 98 percent. Extensive electrification would enable BC to meet our climate targets and would

[1] https://engage.gov.bc.ca/app/uploads/sites/391/2018/07/MoE-IntentionsPaper-Industry.pdf

require increasing BC's production of renewable energy by as much as 50% to meet the 2030 GHG targets, and by as much as 100% to meet the 2050 targets.

Fossil fuels currently play a leading role in our society and economy as they supply two-thirds of British Columbia's energy needs. Extensive electrification would substantially diminish the role of these fuels in the energy system, while subsequently improving resilience and positioning the province's products and services for success in the global clean growth economy. This would also involve supporting workers from the fossil fuel sectors in the transition through retraining.

Introduction

In May 2018, the Government of British Columbia updated and strengthened the province's greenhouse gas reduction targets by establishing new targets to reduce emissions 40 percent below 2007 levels by the year 2030, and 60 percent below 2007 levels by 2040. It also reiterated its commitment to its existing mid-century target of reducing emissions 80 percent by the year 2050.

The legislation also enabled the Minister of Environment and Climate Change to establish sector-specific targets for GHG reductions. In its final report, the previous government's BC Climate Leadership Team recommended three such sector-specific targets:

- Industry: 30 percent below 2015 levels by 2030.
- Transportation: 30 percent below 2015 levels by 2030.
- Built Environment: 50 percent below 2015 levels by 2030.

In the fall of 2018, the BC government plans to deliver a *Clean Growth Strategy*. The strategy is expected to outline the policies and programs intended to meet those targets. Though the strategy's specifics are still evolving, the research compiled for this paper suggests that government will need to make a strong electrification commitment that goes beyond transport and energy efficiency to encourage industry to improve its performance if it is to deliver on its climate targets.

About This Document

This white paper compiles recent and existing research into the greenhouse gas reduction benefits of electrifying key sectors of the economy. We also detail other key co-benefits that we expect a strong electrification commitment would unlock.

The goal of this paper is to inform the development of the *Clean Growth Strategy*, as well as other related provincial policies presently underway, such as the *Energy Roadmap*. It will be submitted to the Minister of Environment and Climate Change, the Minister of Energy, Mines and Petroleum Resources, the Minister of Jobs, Trade and Technology and the co-chairs of the Climate Solutions and Clean Growth Advisory Council.[2]

This paper is based upon the work of a number of energy experts listed below:

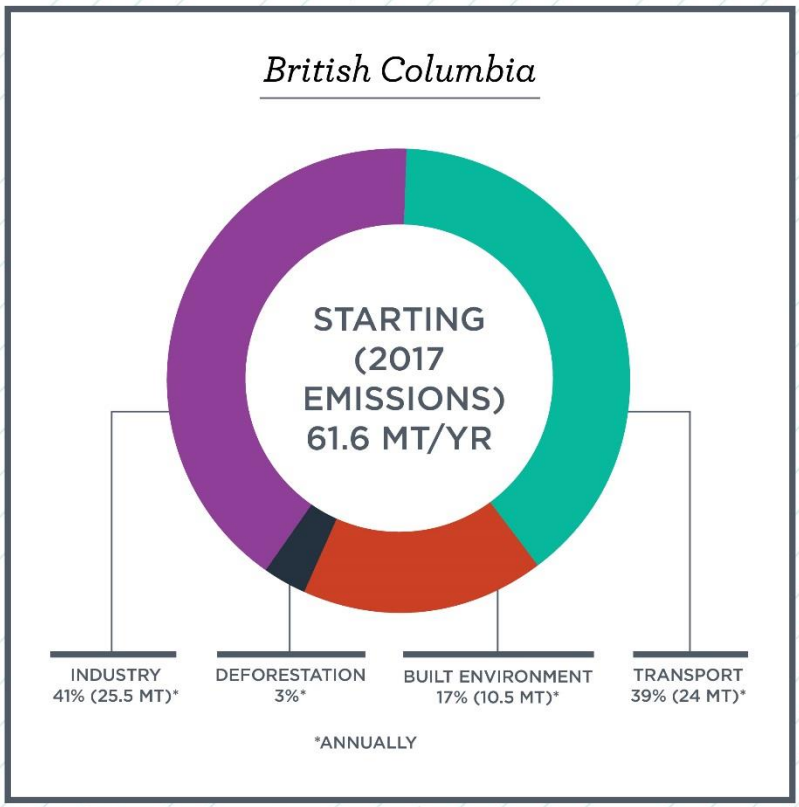
- Curran Crawford, Ph.D. and Julian-Alberto Fernandez-Orjuela, Ph.D. at the University of Victoria Institute for Integrated Energy Systems.
- Richard Harper, M.Eng., P.Eng.

[2] In October 2017 the Province of British Columbia established the Climate Solutions and Clean Growth Advisory Council with a mandate to advise it on policies, regulations, and actions that will underpin its *Climate Solutions and Clean Growth Strategy*.

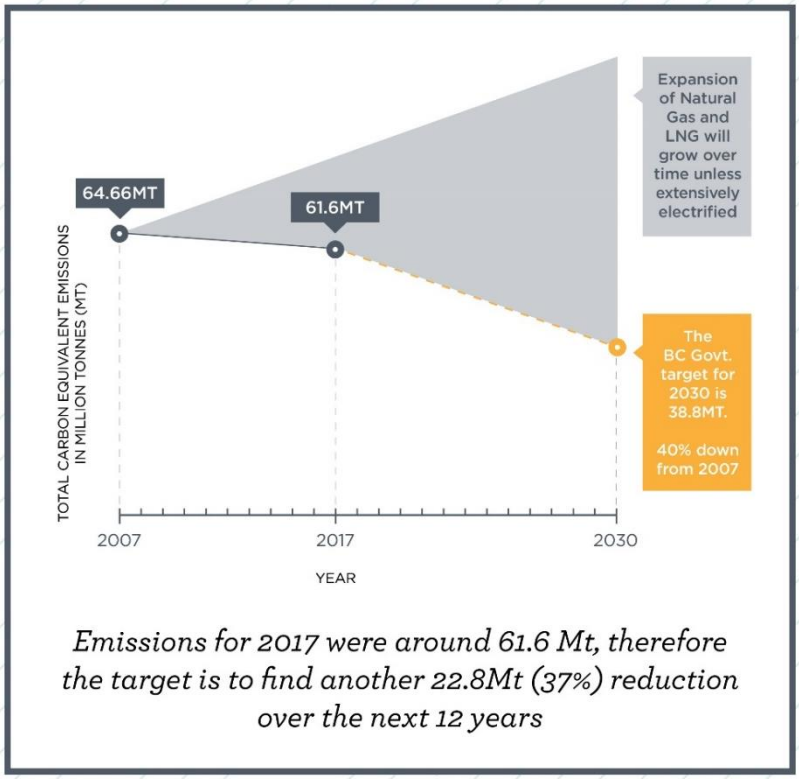
- Steve Davis, P.Eng., MBA
- Ron Monk M.Eng., P.Eng., Principal & Energy Sector Leader at Kerr Wood Leidal Associates Ltd. & Alex Charpentier P.Eng.

Thank you to the above parties for your work and critical contributions.

British Columbia Today



As noted above, the new Act commits BC to reduce greenhouse gas emissions 40 percent below 2007 levels by the year 2030. In practical terms, this reduction amounts to an emission target of 38.8 million tonnes (Mt) of equivalent carbon dioxide emissions (Mt CO_2e). Given that the impacts of climate change are being acutely felt around the province and the world, this target is appropriately ambitious.



In 2007, the province's total carbon (equivalent) emissions amounted to 64.66 Mt. Today, they total around 61.6 Mt. To meet its 2030 target, the province must find an additional 22.8 Mt (37 percent) of reductions over the next 12 years — while also accounting for expected growth of transportation and building emissions in the interim, as well as pollution produced by existing, new, and proposed industries such as liquefied natural gas production. This paper shows that by 2030 the potential to reduce BC's GHG emissions by over 20 Mt exists. So too does the potential to increase the emissions by even more than 20Mt.

British Columbia in 2030

Should British Columbia meet its 2030 greenhouse gas target, it will have transformed its communities, transportation systems, and industries, thus positioning the province for competitiveness and prosperity in the global low-carbon economy. Along the way, the province will have established the following:

- BC Hydro will need to be one of the province's primary delivery bodies for climate change mitigation.
- The British Columbia Utilities Commission (BCUC) will need to have climate change mandated into its core decision-making functions.
- Infrastructure will be in place to affordably and responsibly generate, store, and distribute clean energy extensively throughout the province.
- The province's forestry, mining, and fossil fuel sectors will be producing some of the lowest-carbon resource commodities available in the world.
- Many more remote developments will be connected to the electrical grid.

- New customers who request service connections will receive prompt cost estimates and quick interconnections from BC Hydro.
- Cars, buses, trucks, and ships — and port and factory equipment — will run on clean electricity, provided by electric batteries and hydrogen fuel cells.
- Though citizens and industries will have sharply reduced their reliance on liquid fossil fuels, they will still be widely available and produced to meet strict standards for carbon content.
- Natural gas distributors will be sourcing a significant and growing percentage of their product from renewable sources.
- Buildings, vehicles, appliances, and industrial machines will be clearly labeled to show their energy performance and embodied carbon content.
- Virtually all new buildings will meet a net-zero energy-ready performance level. Efforts to upgrade existing buildings will be underway.
- First Nations will continue to actively partner in developing clean energy projects. Clean and renewable energy sources will meet the needs of all off-grid and remote communities, indigenous and otherwise.
- The province will be a clean technology incubation and investment hub. Its renowned low-carbon electricity, high quality of life, and skilled workforce will have attracted new industries.
- A higher proportion of companies will be adding value to raw natural resources rather than simply extracting and exporting them.
- The price to develop renewable power will have continued to drop significantly, positioning the province as an attractive destination for energy-intensive industries.

In 2030, British Columbia will be positioned for success in a decarbonizing global economy. Investors all over the world will associate the province's brand with low-carbon products, services, and expertise.

Electrification as the Path to a Low-Carbon Future

While other jurisdictions struggle to reduce the carbon intensity of their electricity, in 2018 British Columbia already enjoys some of the cleanest electricity in the world — right out of our wall sockets. For this we can thank BC Hydro's extensive system of large hydroelectric dams, as well as the many run-of-river plants and wind, solar and biomass facilities. The immense and largely untouched potential for renewable natural gas, geothermal, energy storage, and marine renewables offers a phenomenal competitive advantage.

As all countries implement the policies necessary to meet their *Paris Agreement* commitments, the global market for low-carbon products and services will grow dramatically.[3] British Columbia can capitalize on this opportunity, while reducing its own greenhouse gas emissions in line with its targets. But doing so will require the province to embrace extensive electrification. Doing so will involve converting energy services that today rely on fossil fuels — such as the provision of space and hot water heating, mobility, and industrial processes — to efficiently run on renewable clean electricity.

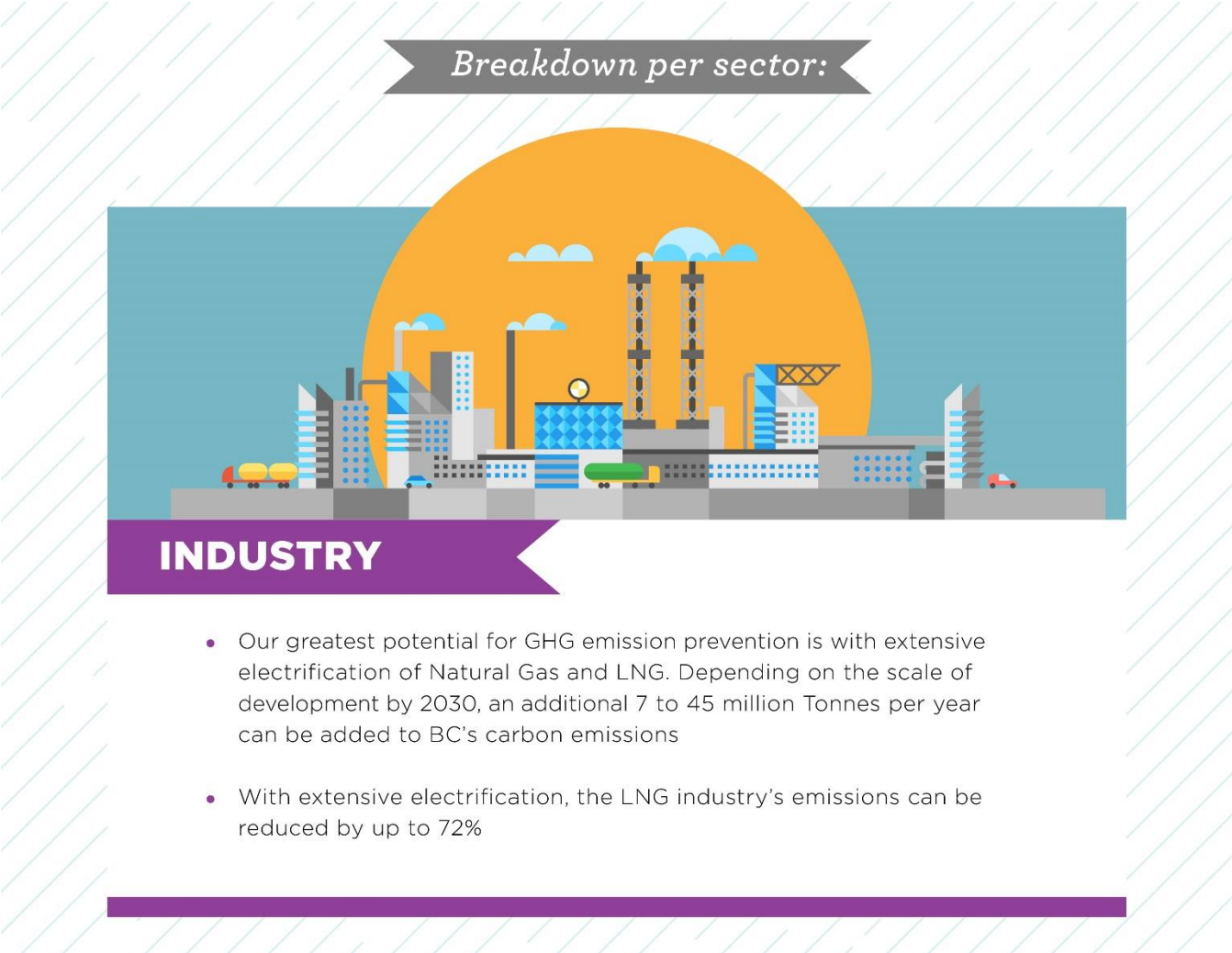
Electrification is the path to a strong, resilient, and innovative British Columbia economy. An electrified British Columbia economy will be:

[3] To date, 179 of 197 *Paris Agreement* signatory nations have ratified their commitments to reduce their greenhouse gas emissions 80 percent by 2050. The list includes every major economy except the United States.

- Less exposed to the economic risks of climate change.
- More prosperous as it sends a strong message to investors, manufacturers, suppliers and educators that the province is open for business in the global low-carbon economy.
- Creating a fertile environment for longer term investors.
- Enabling BC to benefit from the job growth and retention that is associated with the wide and varied electrification industries.
- Sheltered from the volatility of energy commodity markets and associated price fluctuations.

As identified in BC's Clean Growth Future strategy, Clean Energy BC has also identified the same three sectors of the BC economy that create 97% of BC's emissions. They all offer opportunities for extensive electrification.

1. Electrifying Industry



In 2017, industry produced approximately 25.3 Mt, or about 41 percent, of British Columbia's greenhouse gas emissions. The province assesses the relative contributions of the largest players as follows:

- Forestry, mining, and manufacturing: 21 percent (approximately 12.9 Mt).
- Fossil fuel production, coal, oil, natural gas, and liquefied natural gas (LNG): 19 percent (approximately 11.7 Mt).
- Electricity production: 1 percent (approximately 0.6 Mt).

In all but the most aggressive decarbonization pathway scenarios, liquid and gaseous fossil fuels — including Liquid Natural Gas (LNG) — will continue to play a leading role well into the decades of this century.[4] However, increasing regulation will require those fuels to have a progressively decreasing carbon intensity. If British Columbia is to develop an LNG industry, the energy needed for extraction, transport and compression into LNG must have the lowest possible emissions intensity to ensure its future competitiveness and fit within the Pan Canadian Framework on Climate and Clean Growth. Natural Resources Canada's Regional Electricity Cooperation and Strategic Infrastructure (RECSI) Western Study[5] found significant potential for GHG reduction through electrification. This paper aims to show that the GHG reduction/avoidance opportunities are even greater than those identified in the Western Study; which demonstrated that BC's greatest potential for GHG emission reduction is through extensive electrification of the production of natural gas and LNG.

The Mining Association of BC continues to emphasize low-carbon mining as a key area of focus. The minerals and metals needed for extensive electrification — and for manufacturing wind turbines, solar panels, batteries, and electric vehicles — all require energy for extraction and processing. British Columbia already produces some of the lowest-carbon aluminum in the world as the result of innovation and renewable electricity.[6] Every year there are growing examples of industries that are considered among the most difficult to decarbonize coming up with solutions.[7][8]

Additional research and development is needed to understand the impacts of electrification on manufacturing, waste treatment, the chemical industry, forestry, smelting and mining[9], but this shift has already begun across the globe.

1.1 Liquefied Natural Gas (LNG) "Downstream Sector"

Given extensive electrification, it is possible to reduce the greenhouse gas emissions associated with turning natural gas into LNG by as much as 72 percent below a business-as-usual level.[10]

The Government of British Columbia's Natural Gas Development Framework, released in March 2018, established a series of four broad goals for LNG development. The fourth in the list references the potential for the proposed LNG sector to support climate solutions and a low-carbon industrial strategy.[11]

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[4] In its *World Energy Outlook 2017*, the International Energy Agency expects natural gas will account for a quarter of global energy demand by 2040, becoming the second largest fuel in the global mix after oil. Eighty percent of the projected growth in demand will occur in developing economies — China, India, and other Asian nations.

[5] NRCan's Regional Electricity Cooperation and Strategic Infrastructure (RECSI) Western Study (pg 14) https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/clean/RECSI_WR-SPM_eng.pdf

[6] "Rio Tinto boss lauds B.C.'s clean energy as trade advantage" Nelson Bennett, *Business in Vancouver*, September 26, 2017.

[7] Low and Zero emission concrete https://news.vattenfall.com/en/article/cementa-aims-zero-emissions-vattenfall

[8] Öresund Bridge be built in 2045 with zero greenhouse gas emissions http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedish-environmental-work/Work-areas/Innovation-competition-for-zero-emissions-infrastructure/Winner-in-the-innovation-competition/

[9] Clean Energy Canada's "A plan for Climate Leadership in BC" publication http://cleanenergycanada.org/wp-content/uploads/2018/03/A-Plan-for-Climate-Leadership-in-BC-Final-Oct-27-12pm-2015.pdf figure 9

[10] Richard Harper's 2018 LNG/Upstream Gas Electrification and GHG Reduction.

[11] "Protect our air, land, water, including support for climate solutions and a low-carbon industrial strategy."

However, without extensive electrification of the sector, this commitment will be very difficult to achieve. On a business-as-usual basis, the province's proposed LNG industry would contribute as few as seven million tonnes and as many as 45 million tonnes of greenhouse gas emissions to the atmosphere per year. Assuming the province continues its population growth — with attendant buildings and vehicles — it is difficult to accommodate this added pollution while also lowering emissions by the necessary 22.8 million tonnes per year by 2030.

The LNG industry measures carbon intensity in MPTA — an expression of millions of tonnes of GHG produced each year per tonne of LNG produced. Three of the world's lowest-carbon LNG facilities are, or will be:

- **Freeport LNG**: Freeport LNG Development is currently upgrading an LNG import terminal near Freeport, Texas to produce and export LNG. It expects to begin export operations in 2019.
- **Woodfibre LNG**: In March 2018, the Government of Canada issued an Environmental Assessment approval to this facility that would be located on Howe Sound near Squamish. Once built, the project will produce 2.1 million tonnes of LNG per year for export for 25 years.
- **Tilbury LNG**: Fortis BC recently expanded its Tilbury LNG plant in Delta, BC. The original and expanded facility is fully electrified, and compresses gas using grid power.

All of these plants will have a carbon intensity of approximately 0.07 or 0.08 MPTA (excluding GHG emissions from the electricity generation), because they use, or will use, electric-drive (or e-drive) technology to compress and liquefy natural gas.

As global markets transition to lower-carbon fuel sources, they will increasingly consider the full life cycle of natural gas and LNG GHG emissions. Electrified British Columbia LNG would have a competitive advantage over the majority of the world's LNG facilities, which still primarily burn gas to drive the majority of the extraction, transport and compression trains.

Even if these other competing compression facilities convert to e-drives, they will still likely be at a disadvantage, as much of the world's utility power has a much higher carbon footprint than that in British Columbia.

In the tables below, we outline the GHG and energy-use implications of a range of hypothetical LNG plants — from the first phase of a single facility to a well-established provincial industry.

Table 1.1, below, depicts the first phase of a hypothetical medium LNG plant that would initially produce 13MPTA (1.734 Bcfd).[12]

[12] LNG Canada has proposed an LNG facility for Kitimat BC that would produce fuel with a GHG intensity of 0.15 MPTA. While there are many pathways to achieving this, it is unclear how the proponents would do so using gas compression drives and the BC Hydro grid for power. Given the right financial framework, the proposed facility could potentially reach a carbon intensity of 0.075 MPTA.

Table 1.1: Phase 1 of hypothetical medium LNG plant producing 13 MPTA (1.734 Bcfd) [13]

Scenario 1 **LNG 13 MPTA Export Capacity (1.734 Bcfd) - Emissions Based on LNG Plant Input Gas Volume**

Segment	Conventional Approach (GHG Tonnes/yr)	Emissions Claimed by LNG Canada	% Reduction (LNG Canada)	Extensive Electrification (GHG Tonnes/yr) (4)	% Reduction (Conventional)	Power Requirements (MW)	Power Requirements (GWhr)	% increase from 2017 BC electricity production
LNG Facility	3,380,000	1,976,000	51%	975,000	71%	750	6,390	9.7%
Transmission[2]	350,000	350,000[5]	0%	15,000	96%	100	852	1.3%
Upstream[1]	3,865,000	3,865,000[5]	0%	1,141,000	70%	310	2,180	3.3%
Total	**7,595,000**	**6,191,000**	**18%**	**2,131,000**	**72%**	**1,160**	**9,422**	**14.2%**

***LNG Canada type project with extensive electrification (transmission & upstream) = 2,846,000 Tonnes of CO2e or a 63% reduction.**

(1) Emissions based on Gas volume required for LNG and Transmission combustion emissions accounting for Upstream processing losses
(2) Emissions based on required transmission gas compression facilities to convey required LNG plant inlet volume
(4) Based on electrification of Combustion sources
(5) Estimated by CEBC, data not provided by LNG Canada

Table 1.2 outlines the estimated GHG reductions for a hypothetical large facility upon completion. That proponent would accomplish a 62 percent greenhouse gas reduction by electrifying the facility.

Table 1.2: Phase 2 of hypothetical large LNG plant producing 26 MPTA (3.468 Bcfd)

Scenario 2 **LNG 26 MPTA Export Capacity (3.468 Bcfd) - Emissions Based on LNG Plant Input Gas Volume**

Segment	Conventional Approach (GHG Tonnes/yr)	Emissions Claimed by LNG Canada	% Reduction (LNG Canada)	Extensive Electrification (GHG Tonnes/yr) (4)	% Reduction (Conventional)	Power Requirements (MW)	Power Requirements (GWhr)	% increase from 2017 BC electricity production
LNG Facility	6,760,000	3,979,000	41%	1,950,000	71%	1,480	12,610	19.1%
Transmission[2]	1,800,000	1,800,000[5]	0%	30,000	96%	360	3,155	4.8%
Upstream[1]	9,945,000	9,945,000[5]	0%	4,498,000	55%	620	4,370	6.6%
Total	**18,505,000**	**15,724,000**	**15%**	**6,478,000**	**65%**	**2,460**	**20,135**	**30.4%**

***LNG Canada type project with extensive electrification (transmission & upstream) = 8,507,000 Tonnes of CO2e or a 54% reduction.**

(1) Emissions based on Gas volume required for LNG and Transmission combustion emissions accounting for Upstream processing losses
(2) Emissions based on required transmission gas compression facilities to convey required LNG plant inlet volume
(3) It is noted that Provincial Government has recently indicated that total emission from well to water for LNG Canada is 3,450,000 tones/yr for Phase 1 of LNG Canada
(4) Based on electrification of Combustion sources
(5) Estimated by CEBC, data not provided by LNG Canada

[13] In 2017, British Columbia's total electricity production and sales, excluding private and self-generation, totaled approximately 66,144 GWh. Assumptions: Fortis BC's electricity sales were 3,305 GWh (Fortis BC 2017 Annual Report) less transmission losses estimated at 7.9%, or 260 Gwh, for a total of 3,565 Gwh. BC Hydro's electricity production totaled 57,652 GWh (Source: BC Hydro), less transmission losses of 4,927 Gwh, for a total of 62,597 Gwh.

Table 1.3 outlines the greenhouse gas emissions and reduction potential of a hypothetical provincial LNG industry of 60 MPTA (7.23 Bcf/d) capacity. This is approximately the equivalent of two large, one medium, and two smaller LNG plants. We find that electrifying all plants would reduce greenhouse gas emissions 62 percent, while increasing overall provincial power needs 72.4 percent above current levels.

Table 1.3: Substantial BC LNG industry producing 60 MPTA (7.23 Bcfd)

Scenario 3 — **LNG 60 MPTA Export Capacity (7.23 Bcfd) - Emissions Based on LNG plant Input Gas Volume**

Segment	Conventional Approach (GHG Tonnes/yr)	Extensive Electrification (GHG Tonnes/yr) (4)	% Reduction	Power Requirements (MW)	Power Requirements (GWhr)	% increase from 2017 BC electricity production
LNG Facility	15,600,000	4,500,000	71%	3,420	29,140	44.1%
Transmission[2]	5,315,000	50,000	99%	1,000	8,760	13.2%
Upstream[1]	24,133,000	11,547,000	52%	1,420	9,980	15.1%
Total	**45,048,000**	**16,097,000**	**64%**	**5,840**	**47,880**	**72.4%**

(1) Emissions based on Gas volume required for LNG and Transmission combustion emissions accounting for Upstream processing losses
(2) Emissions based on required gas compression facilities to convey required LNG plant inlet volume
(4) Based on electrification of Combustion sources

Unless the Government of British Columbia requires or strongly incentivizes proponents to extensively electrify the entire process, it will need to find deep reductions in other sectors of the economy. However, in doing so it will significantly increase electricity requirements.

1.2 Natural Gas "Upstream Sector"

As leading economies decarbonize, the future viability of British Columbia's natural gas and LNG sectors will hinge on linking their production to the province's clean power. On the natural gas front, the province has a unique opportunity to cleanly electrify its upstream production. Doing so provides investors long-term confidence to keep their money in the sector, as their investments will be less exposed to regulatory changes and market forces in our carbon-constrained world.

Research and analysis by Steve Davis & Associates Consulting Ltd. [14] forecasts that extensive electrification of oil and gas production in BC's Montney Basin could reduce greenhouse gas emissions by 60 percent, or 16.2 megatonnes per year (MtCO2e/yr) in 2030.

This forecast for 2030 assumes that:

- Montney Basin will be producing 11 billion cubic feet per day (Bcfd) of natural gas.
- One large and one small LNG terminal exporting a total of 28 MTPA will be fully operating.
- All of the natural gas for the LNG terminals will come from the Montney.
- Current average emission intensity of Montney basin is 2.75 MtCO2e/year per Bcfd.

[14] This section is based upon the GHG Reduction from Electrifying Montney report prepared by Steve Davis & Associates Consulting Ltd. for CEBC.

- 60% of emissions can be reduced by extensive electrification of gas production facilities.
- If there is no new electrification, emissions produced would be 28.3 Mt CO2e/year.

Government could reduce gas industry emissions to the above levels by providing incentives or requiring the sector to:

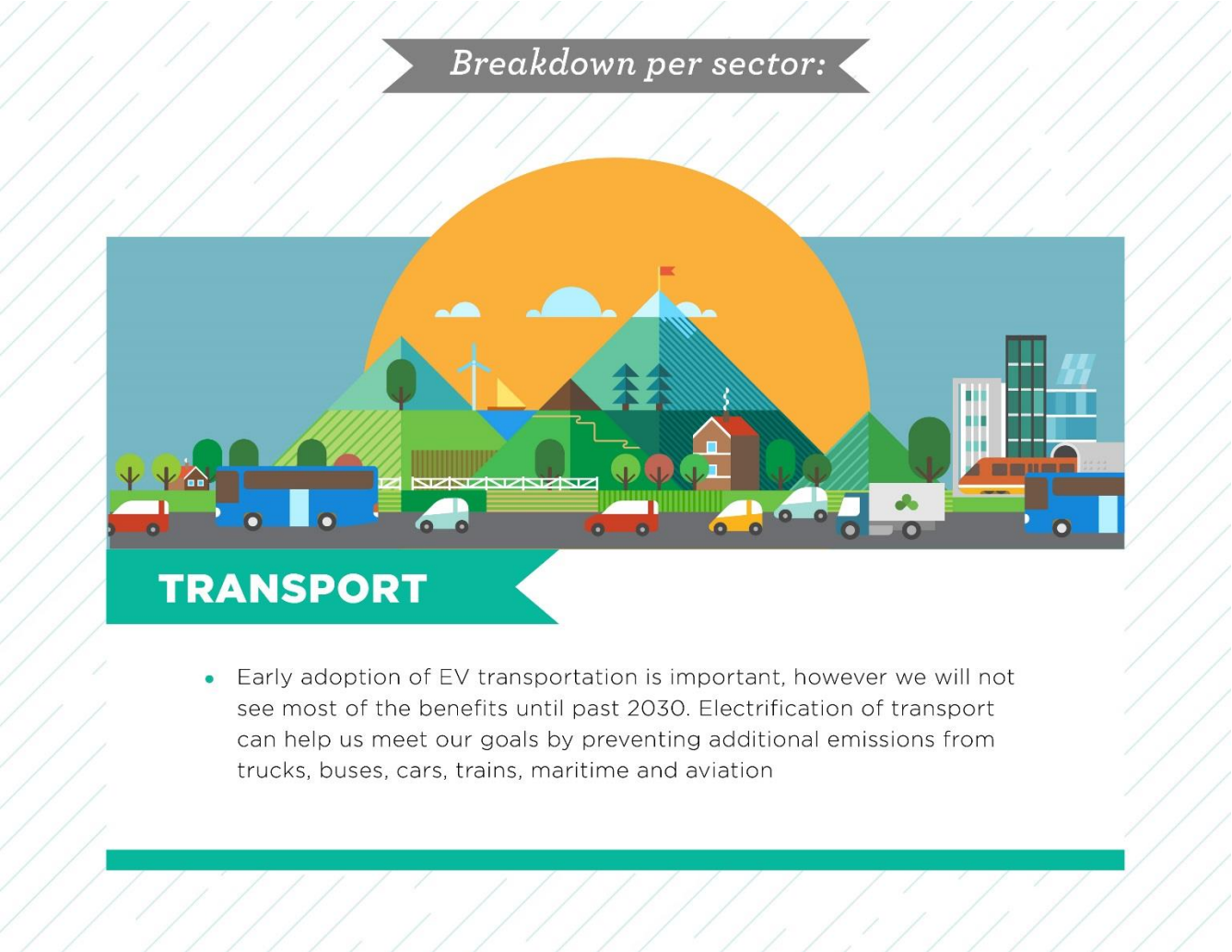
- Extend several transmission lines further into the Montney Basin.
- Connect all new gas production facilities to the electricity grid.
- Power compression and ancillary equipment with electricity, not natural gas or diesel.
- Connect the majority of viable existing gas production activities to the grid.
- Convert existing compression and ancillary equipment from natural gas to electricity.
- Build the new transmission lines and new connection to gas production facilities quickly.
- Implement extensive fuel switching policies through phased in regulation.

Government could realise the largest greenhouse gas reductions by switching compressor and generator power from natural gas and diesel to clean grid electricity. Replacing gas activated pumps and compressors with electrical equipment will eliminate or reduce methane venting and fugitive emissions, assisting the industry in meeting the methane emission regulations recently introduced by the Government of Canada.

Table 1.4: GHG reduction through extensive electrification of Montney gas production (2030)

Gas Production Volume	Emission Intensity with no electrification	Emissions with no electrification	Emission Reduction/ Electrification Percentage	Emissions Reduction from 60% electrification	Emissions Reduction from past electrification	Emissions if no new electrification	Emission Reduction from remaining
Bcfd	*MtCO2e/Bcfd*	*MtCO2e*	*%*	*MtCO2e*	*MtCO2e*	*MtCO2e*	*MtCO2e*
11	2.75	30.3	60%	18.2	2	28.3	16.2

2. Electrifying Transportation



In 2017, transportation contributed approximately 24 Mt, or about 39 percent, of British Columbia's greenhouse gas emissions.[15] The province assesses the relative contributions of the largest subsectors as follows:

- Personal transportation: 14 percent (approximately 8.6 Mt).
- Commercial transportation: 25 percent (approximately 15.4 Mt).

A generous body of research provides the evidence basis for the greenhouse gas reduction benefits of electrifying transportation, and of the need for supply and demand side policies to do so.[16]

Electric-vehicle range is steadily increasing, and costs are continuing to fall as battery costs decline. Meanwhile, the diversity of models and classes has grown tremendously.

[15] This section of the paper is based upon the work by Curran Crawford, Ph.D. & Julian-Alberto Fernandez-Orjuela, Ph.D. at the University of Victoria Institute for Integrated Energy Systems.

[16] Melton, Noel. Axsen, Jonn. Goldberg, Suzanne. "Evaluating plug-in electric vehicle policies in the context of long-term greenhouse gas reduction goals." *Energy Policy*. Volume 107, August 2017, Pages 381-393.

The total GHG reduction for this 2030 electric vehicle scenario is only 2.9 million tonnes/year. This is the result of inherently slow fleet turnover — freight vehicles have a typical life span of between 15 and 20 years. Changing internal combustion engine (ICE) vehicle emission standards also influences uptake.

Although the reduction in emissions between electric and ICE drivetrains initially appears small, overall emissions are being significantly reduced. Though the time horizon of this paper is 2030, our analysis shows that GHG benefits increase quickly by the start of the following decade. Due to this gradual shift, it is vital that this transition to electrification starts as soon as possible because it will be slow to take hold, but will then accelerate. The UVic hypothetical scenario outlined below assumes that all segments of the transportation sector will reach 99% of electric vehicles new sales by 2032. This assumption is required for BC to reach the target in 2030 for the on-road transportation sector. By 2040 the vast majority of internal combustion vehicles are no longer in use.

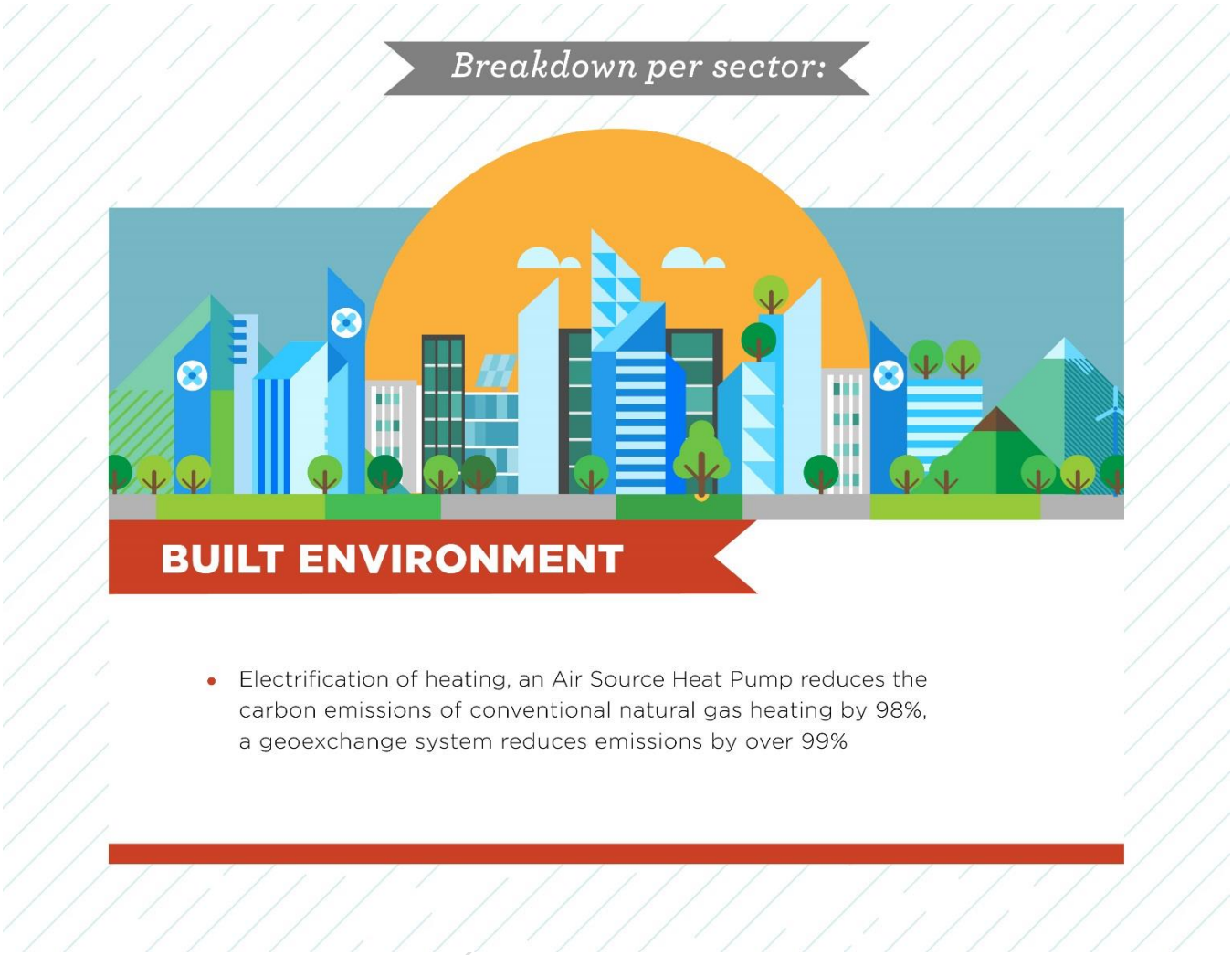
Table 2.1: GHG and load implications of transportation electrification, 2030 Hypothetical Scenario

Electrified vehicle Class	Additional Electricity Required (GWh)	GHG reductions (Mt CO2e)	Total GHG Reductions (Mt CO2e)	% of GHG Reduction per Vehicle Class	Increase above 2017 BC electricity production
Passenger cars	1,185	0.43	0.43	14.9%	1.8%
Pass. light trucks	1,178	0.55	2.44	84%	8%
Freight light trucks	443	0.21			
Medium-duty trucks	2,563	1.29			
Heavy-duty trucks	1,130	0.39			
School buses	4	0.00	0.03	1.1%	0.1%
Transit vehicles	44	0.03			
Intercity buses	7	0.00			
Total	**6,554**	**2.9**			**9.9%**

Table 2.2: GHG and load implications of transportation electrification, 2040 Hypothetical Scenario

Electrified vehicle Class	Additional Electricity Required (GWh)	GHG reductions (Mt CO2e)	Total GHG Reductions (Mt CO2e)	% of GHG Reduction per Vehicle Class	Increase above 2017 BC electricity production
Passenger cars	4,297	1.51	1.51	13.4%	6.5%
Pass. light trucks	4,334	1.99	9.6	85.7%	32.7%
Freight light trucks	1,584	0.75			
Medium-duty trucks	11,500	5.51			
Heavy-duty trucks	4,211	1.36			
School buses	10	0.01	0.1	0.9%	0.3%
Transit vehicles	160	0.06			
Intercity buses	30	0.03			
Total	**26,127**	**11.2**			**39.5%**

3. Electrifying the Built Environment



In 2015, buildings produced approximately 10.5 Mt, or about 17 percent, of British Columbia's greenhouse gas emissions.[17] [18] The province assesses the contributions of the various subsectors as follows:

- Residential: 6 percent (approximately 3.7 Mt).
- Commercial: 4 percent (approximately 2.5 Mt).
- Waste: 7 percent (approximately 4.3 Mt).

In British Columbia, most residential and commercial emissions are the results of fossil fuels — overwhelmingly, natural gas — burned for space heating and domestic hot water. A variety of proven technologies could significantly reduce these emissions by way of electrification. Options include air-source heat pumps, which could reduce the carbon emissions of gas heating by 98 percent and, where applicable, ground-source heat

[17] Provincial Greenhouse Gas Inventory, Province of British Columbia.
[18] This section of this paper is based on work by Kerr Wood Leidal entitled, "Development of an Electrification Policy Framework for British Columbia," Climate Action Secretariat, Province of British Columbia.

pumps, which could reduce emissions even further.[19] Over time, the BC step code will serve to significantly improve the efficiency of new buildings through BC's commitment to 100 percent net-zero energy-ready new construction by 2032. However, demand-side efforts will be inadequate to deliver the carbon reductions that have been outlined above.

While electric-resistance heating — for example, electric baseboard heaters — offers a much lower carbon option than natural gas, it is a very costly way to heat a building. However, heat pumps, which currently involve a higher up-front investment, provide extremely low-carbon space heating at a fraction of the operational cost. A heat pump works like a refrigerator running in reverse — it extracts heat from outdoor air, ground, or water, and transfers it inside the building. When averaged over the year, modern air-source heat pumps typically produce around 3 kWh of heat for every 1 kWh of electricity; while its ground-source counterpart typically produces 4.5 kWh of heat for every 1 kWh of electricity.

Air-source heat pumps can efficiently heat buildings when the external air temperature is above -15 C. With backup when needed from a direct electric-heating element, the heat pump can heat a building regardless of the external air temperature. This additional heating element drops the efficiency to approximately 1 kWh of heating per 1 kWh of electricity during very cold temperatures. A properly designed and installed ground-source heat pump provides highly consistent efficiency throughout the year.

Electrically powered low-carbon energy sources suitable for British Columbia are:

- Air-source heat pump
- Industrial waste heat recovery
- Sewer heat recovery
- Ground-source heat pump
- Solar thermal heat exchange
- Water-source heat pumps using rivers, lakes and the ocean

Some examples of electrified low-carbon heating projects in British Columbia include:

- The Alexandra District Energy Utility, in Richmond, BC, which uses ground- and air-source heat.
- The Southeast False Creek Neighbourhood Energy Utility, in Vancouver, BC, which uses sewer heat.
- The Cheakamus Crossing District Energy System, in Whistler, BC, which uses treated wastewater heat.
- Both the Bella Bella Heat Pump project, led by Ecotrust Canada, and the Haida Gwaii Heat Pump Project, led by the Skidegate Band Council, use air-source heat pumps to reduce heating bills, reduce greenhouse gas emissions, and improve local indoor air quality.

[19] Though beyond the scope of this paper, widespread adoption of energy efficiency policy will also serve to significantly reduce built-environment emissions.

Table 3.1: GHG and load implications of building heat electrification, 2030 Scenario (factoring in existing buildings and the additional new buildings that are likely to exist in 2030).

Building Sector	**Conventional Approach** (Natural Gas displaced by Electricity GWh)	**Natural Gas GHG emissions** (tonnes CO2e/yr)	**Electrification power requirements** (GWhr)	**Increase above 2017 BC electricity production** (percent)	**Extensive Electrification** (tonnes CO2e/yr)	**GHG Reduction** (percent)
Residential[1]	6,806	1,392,587	2,084	3.1%	22,231	98.40%
Commercial[2]	38,667	7,912,231	11,838	17.9%	126,309	98.40%
Total	**45,472**	**9,304,817**	**13,921**	**21%**	**148,540**	**98.40%**

(1) Assumes 25 percent of residential homes and multi-family dwellings using air- or ground-source heat pumps in 2030.
(2) Assumes 30 percent of private sector office buildings and retail, wholesale, and warehousing buildings; 15 percent of all other commercial and institutional building stock have been retrofitted with heat pumps by 2030.

Conclusion

In order to meet British Columbia's climate targets, both push and pull mechanisms would be required. The need to push towards the behaviors outlined above through regulations, policies and other mechanisms like EV, heat pump or electrified fossil fuel mandates, along with pull mechanisms like setting up a very low interest green mortgage fund to finance the desired changes, are necessary because organic growth in these transitions will be insufficient to meet targets.

Even with the most ambitious energy-efficiency policies and demand-side-management programs, British Columbia must greatly expand electricity production in order to support the deep electrification required to meet the climate targets in the recent GHG Act[20][21]. It can do so while growing the economy, keeping energy prices low, creating jobs, and increasing resilience to climate impacts[22]. An electrified economy also has the advantage of making much more efficient use of energy. For instance, for every 1 kW of the energy used in an electric car, 1.71 kW of energy is required when that car is fueled by gasoline.[23]

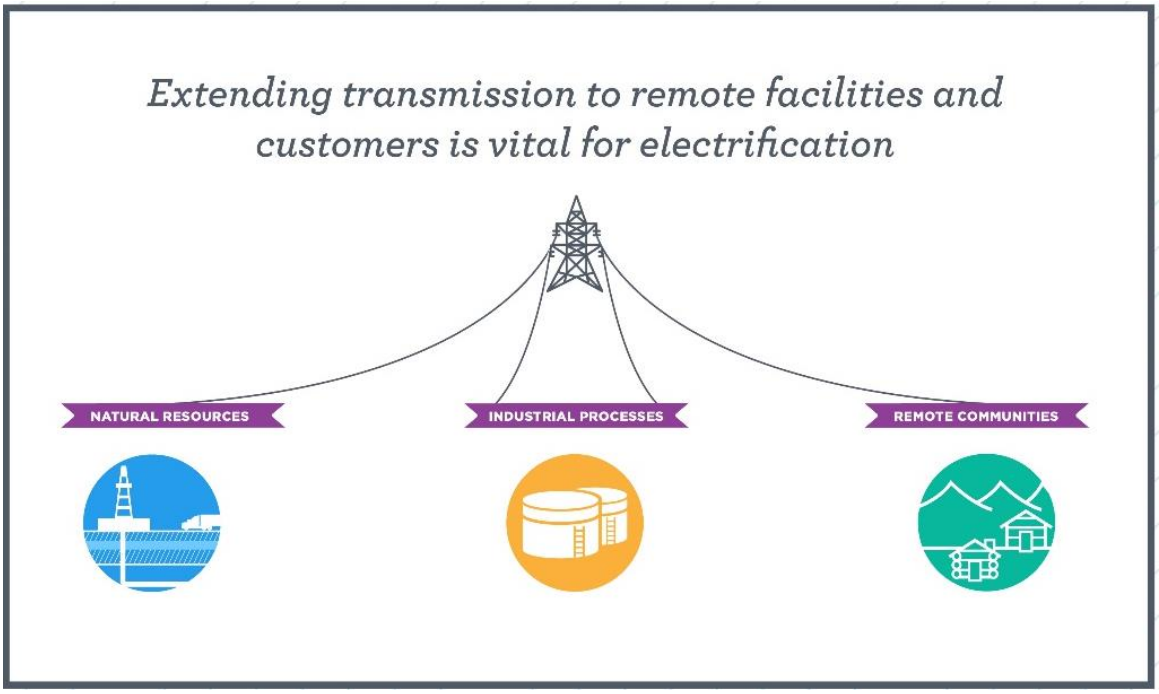
With over $10 billion of investment funds currently available, the province's independent private sector power producers are ideally positioned to deliver the infrastructure needed to provide this electricity; including that needed to electrify the natural gas sector and proposed LNG industry. These companies build projects for 25 to 40-year lifespans. Their contributions will ensure British Columbia delivers on its greenhouse gas reduction commitments.

[20] http://cleanenergycanada.org/wp-content/uploads/2018/03/A-Plan-for-Climate-Leadership-in-BC-Final-Oct-27-12pm-2015.pdf
[21] https://www.cleanenergybc.org/wp-content/uploads/2016/04/MNP-Report-April.pdf
[22] https://assets.kpmg.com/content/dam/kpmg/ca/pdf/2017/03/14179-cleantech-status-report-bc.pdf
[23] https://greet.es.anl.gov/

With California's 100% renewable energy target by 2045 in mind, BC has vast potential to develop untapped renewable energy. This represents one of the biggest development opportunities in BC's history and firmly shows that this is the time to become a North American renewable powerhouse.

Over the past decade, the costs to produce electricity from wind, solar, geothermal, marine, and run-of- river hydro have dropped significantly. A recent wind-power auction in Alberta demonstrated that wind is now the nation's most cost-effective source of new electricity. While many renewable sources are variable-output energy sources, energy storage technologies are steadily improving and BC Hydro's existing large hydro storage plants can provide an effective back-stop. As aforementioned, the costs of wind, solar and other renewable technologies have never been more affordable, as they have dropped significantly over the past five years and this trend continues.

Value-added products and commodities produced with very low-carbon electricity will be highly marketable in the growing low-carbon economy. Extensive electrification enables BC to meet our climate targets and would require increasing BC's production of renewable energy by as much as 50% to meet the 2030 GHG targets, and by as much as 100% to meet the 2050 targets. There has never been a better time for low-cost, private-sector clean energy power producers to ensure the province delivers on its climate change commitments.



To meet our targets, we need to greatly expand BC's electricity generation while also enforcing the highest standards of energy efficiency and demand reduction

Extensive electrification of gas production activities in the North East BC Montney basin alone, could reduce GHG emissions by 16.3 mega tonnes of CO2e per year (MtCO2e/yr) in 2030

98%

In a 2017 survey it was found that in BC, 98% of First Nations respondents support clean energy projects. Over 50% of the indigenous communities in BC are already exploring options to work on renewable energy projects

Approximately 1/3 of BC's energy consumption comes from our low-carbon electricity grid. BC needs to shift the 2/3 still relying on fossil fuels to electricity