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ACCELERATING 5G IN CANADA:

The Role of 5G in the Fight Against Climate Change

FOREWORD:

The Canadian Wireless Telecommunications Association and Accenture undertook the task of estimating the effect of fifth generation (5G) and other wireless technologies on the environment. Through quantitative modeling and qualitative surveying, we sought to understand the role that 5G will play in our collective efforts to save the planet.

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EXECUTIVE SUMMARY

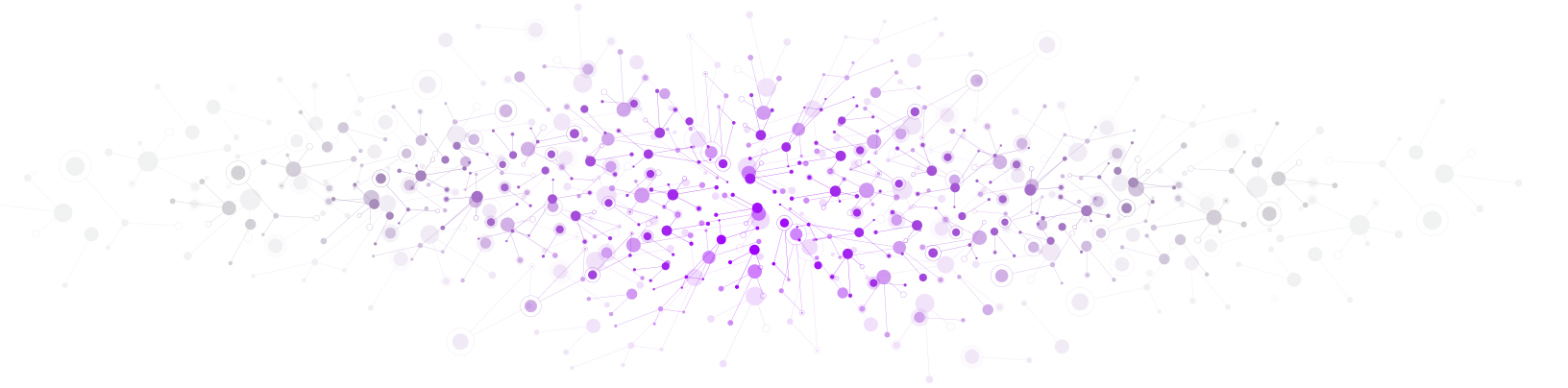
The Canadian wireless industry has an important role in the fight against human-made climate change. Investments in new wireless technologies such as 5G will be key in enabling reductions in greenhouse gas emissions across Canadian industries, while reducing the carbon footprint of the wireless industry itself.

Human-made climate change is a growing concern across the globe. If not counteracted, it is expected to cause enormous disruption and harm to both the global economy and society in general. The projected impact includes flooding of many coastal cities, increased incidences of heat waves of growing severity, and changing rainfall patterns resulting in extreme drought and flooding events.

To address this concern, Canada has committed to work with other nations to reduce the increase in global average temperature through a reduction in the emission of greenhouse gases (GHG).

Our study shows the important role that Canada's wireless industry has played in the reduction of GHG, and how a fast and effective deployment of 5G is key to Canada's ability to meet its climate change reduction commitments.

In their 2019 report, the Exponential Climate Action Roadmap, exponential technology is identified as a game-changer. "From digitalization to robotics and synthetic biology, a technological revolution is underway and artificial intelligence, cloud computing, 5G and the Internet of Things (IoT) are poised to create further disruption in the next decade"[a].



[a]Exponential Roadmap Version 1.5, Sept 2019, "Scaling 36 Solutions to Halve Emissions by 2030" URL: https://exponentialroadmap.org/wp-content/uploads/2019/09/Exponential-Roadmap-1.5-September-19-2019.pdf The deployment of 5G can be a contributor to achieving the United Nations Sustainable Development Goal (SDG) 9: Industry, Innovation and Infrastructure.

ABATEMENT POTENTIAL

Wireless Network Efficiencies	Enabled Abatement	
10 $MTCO_2e$ of abatement from Canadian MNOs between 2020-2030 by creating more efficient networks[b]	**48-54 $MTCO_2e$** of abatement across industries enabled by wireless technologies by 2025	**18-23%** of total enabled abatement can be attributed to 5G
Roughly equivalent to **15 million** passengers flying from Toronto to Vancouver[c]	Roughly equivalent to taking **10.5 million** passenger vehicles off the road for a full year[d] and achieves 23% of Canada's emission reduction targets by 2025	

5G Enables More Efficient Wireless Networks

While the carbon footprint of wireless carriers is relatively low compared to the value they add to the economy, Canadian providers have taken concrete steps to limit their emissions, such as reducing energy consumption, switching to more efficient network equipment, and sourcing renewable energy where possible. But to offset increases in energy consumption resulting from densifying networks to meet increasing consumer demand for mobile data, wireless carriers must look beyond 4G. It has been shown that for a general 5G cell site, energy used in data transmission will be 8-15% of what it currently is for a similar 4G cell site and milimeter wave technology can further reduce energy consumption to 1-2% of a 4G macro site. These figures represent relative performance, as optimal energy loads may not scale across the entire network. **Considering 5G's substantially greater energy efficiency, it is predicted that 5G will support a thousand-fold traffic increase in the next 10 years, while the full network's energy consumption will be half the current levels. With a rapid rollout, 5G will enable up to 10 $MtCO_2e$ equivalent reduction from Canadian wireless carriers between 2020-2030 compared to emissions without 5G.**[e] This theory comes to life as innovative equipment manufacturers release the hardware to enable energy savings.

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b STL Partners, Huawei, "Curtailing Carbon Emissions – Can 5G Help?" URL: https://carrier.huawei.com/~/media/CNBGV2/download/program/Industries-5G/Curtailing-Carbon-Emissions-Can-5G-Help.pdf

c Air Canada and Less Emissions, "Offset my Flight", emission per one way passenger trip from Toronto to Vancouver accounting for high altitude emissions, 0.647 tonnes of CO_2, URL: https://www.less.ca/en-ca/flights.cfm?auid=ac

d Accenture 5G Abatement Model, per vehicle emissions of 4.6 Metric Tonnes of CO_2 per car per year from the United States Environmental Protection Agency URL: https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

e This analysis focuses primarily on network operation because installation has been shown to be <5% of a sites carbon footprint over its life cycle. It is also assumed that the installation emissions between 5G and 4G networks will be comparable for more information please see: STL Partners, Huawei, "Curtailing Carbon Emissions - Can 5G Help?" URL: http://carrier.huawei.com/~/media/CNBGV2/download/program/Industries-5G/Curtailing-Carbon-Emissions-Can-5G-Help.pdf

5G and Other Wireless Technology Enhances Abatement from Other Industries

Wireless technologies also provide high-emitting industries with the ability to reduce their own emissions – a process known as abatement. Previous research has shown that the use of wireless technologies has abated approximately ten times as much CO_2 as the mobile industry's own operations have generated. Our baseline models estimate that, by 2025, 4G and prior wireless technologies will generate up to 41.3 $MtCO_2e$ of abatement in Canada across various high-emitting industries. **The adoption of 5G will add between 6.4 and 12.2 $MtCO_2e$ of additional abatement during this period. This implies 5G can contribute an additional abatement of up to 20% of total wireless technologies enabled abatement, with mobile technologies having the potential to address 23% of Canada's total 2030 emission reduction target by 2025.** We estimate that 70% of this additional abatement comes from three use case categories (1) smart working, living, & health (2) smart transportation, and (3) smart buildings.

5G Enables Groundbreaking New Use Cases

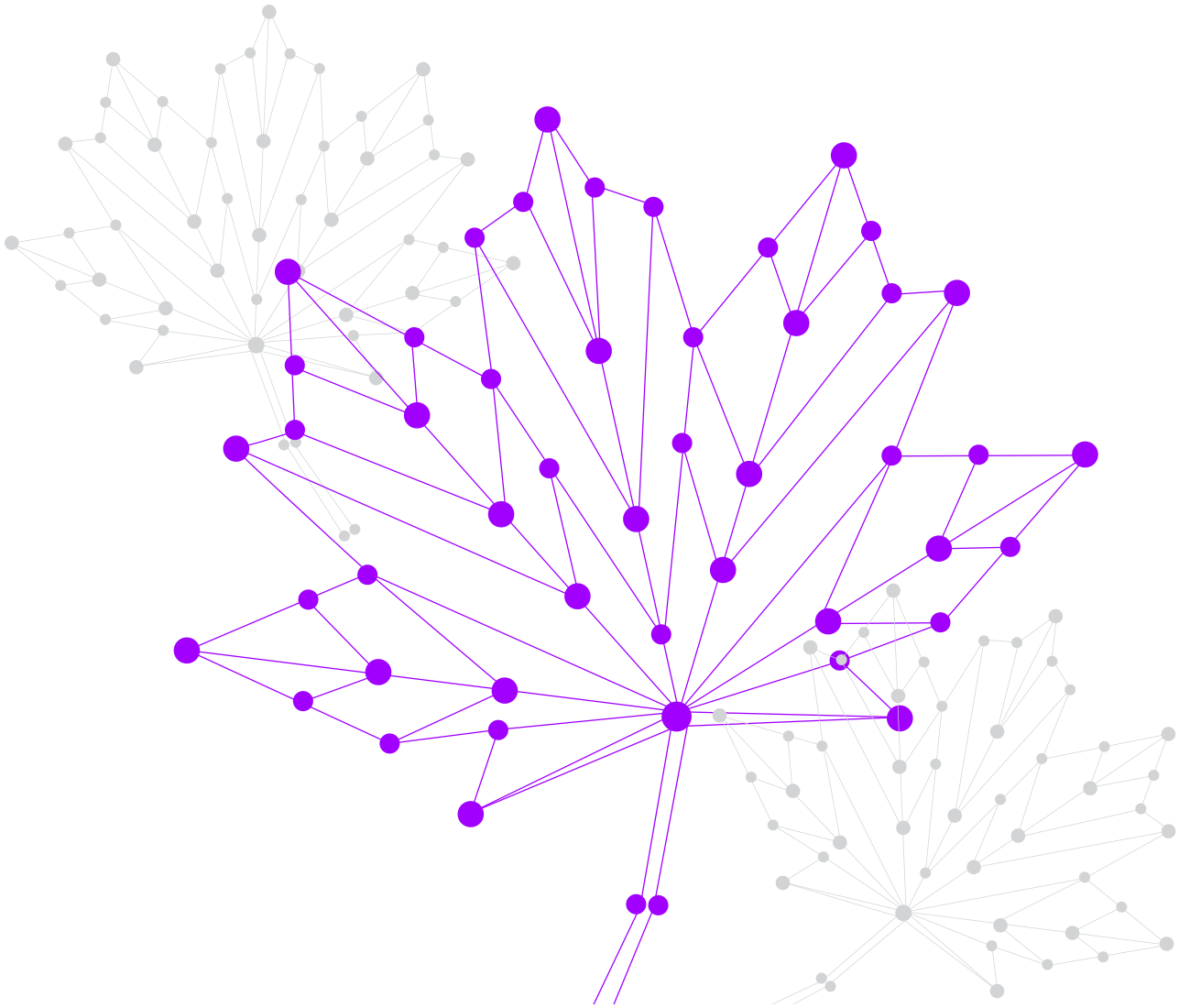
We used 3G to send texts and emails. With 4G we can download video and begin connecting machines. 5G, will allow for a totally connected society – one where machines connect to many machines at lightning fast speeds with microscopic latency. It is about more than better smart phones – it is about robots on the factory floor, sensors on farmland and autonomous vehicles. The impacts of net new use cases that are enabled by 5G and new wireless technologies are also very exciting. These new use cases will change the way we live and work, resulting in substantial reductions of Canada's greenhouse gas footprint. For example, the implementation of 5G use cases in connected transportation in three Canadian cities (Toronto, Montreal, and Vancouver) can enable up to 0.83 $MtCO_2e$ of abatement. Similarly, 5G can enable conferences and trade show virtually which can bring abatement driven by reduction in hotel room stays and travel emissions. It is estimated that Canadian conferences can reduce their emissions by cumulative 7,000 metric tonnes CO_2e over five years. Beyond carbon abatement, advanced wireless technologies allow for more precise monitoring of our environment, combatting other forms of environmental degradation such as reduction of pesticide usage in agriculture or water quality testing for drinking water consumption. With the application of precision agriculture enabled by 5G in oilseed farming in Canada, it is estimated that the annual usage of pesticides can be reduced by 20%, leading to 15.6 tonnes of pesticide savings per year in oilseed farming across Canada.

f For example, the Nokia AirScale Base Station, which has allowed for up to 69% energy savings when installed. For more details please see- Nokia, "Zero Emission 5G Radio Networks" URL: https://www.nokia.com/networks/technologies/zero-emission/

The Need for Rapid Deployment of 5G

As shown in our previous study, *Fuel for Innovation, Canada's Path in the Race to 5G*[g], a timely rollout of 5G will foster substantial economic growth and job creation in Canada. Here, we show the important role that the mobile industry will play in fighting climate change. In both instances, a rapid deployment of 5G will position Canada to realize these critical benefits.

Realizing these economic and environmental benefits requires the recognition by all stakeholders of 5G's importance to Canada, and the support from federal, provincial, and municipal authorities to remove barriers to deployment of 5G and create an environment that encourages private sector investment in 5G networks.



[g] CWTA, Accenture, "Fuel for Innovation: Canada's Place in the Race for 5G", URL: https://www.5gcc.ca/wp-content/uploads/2018/06/CWTA-Accenture-Whitepaper-5G-Economic-Impact_Updates_WEB_06-19-2018.pdf

AN INTRODUCTION TO CLIMATE CHANGE & 5G

Climate change and other environmental harm is a pressing problem for all countries. 5G and other wireless technologies can help reduce contribution to climate change. How? By making our use of resources more efficient and enabling groundbreaking new use cases.

Climate Change and Environmental Damage

Human-made climate change is one of the growing concerns confronting societies and economies around the world. It has the potential to cause enormous disruption and harm whether through changing weather patterns, rising sea levels, or other effects that will dramatically impact the way we live. The exact effects of climate change are difficult to predict. But what is certain is that if we cannot adjust our way of life to reduce emissions of greenhouse gasses (GHGs) - the main driver of climate change - the human and economic costs will be enormous.

The Intergovernmental Panel on Climate Change (IPCC) has found that the rise in mean global temperatures must be limited to less than 1.5°C above pre-industrial levels in order to curb the worst effects of climate change. While a rise of 1.5°C would still cause significant damage, allowing global mean temperatures to rise above this point would be much worse. Indeed, the difference between a 1.5°C and 2°C mean temperature rise includes a 15% increase in sea level rise, a doubling in projected reductions in global crop yields, and an almost complete disappearance of coral reefs and the delicate ecosystems that rely on them by 2100.[1] [2]

As one of the signatories of the 2015 Paris Agreement, Canada has committed to work with the other signatories to limit the increase in global average temperature to "well below 2°C" above pre-industrial levels, and to pursue efforts to limit the increase to 1.5°C. As a developed, industrialized country enjoying first-world living standards, Canada is one of the highest per-capita emitters of greenhouse gasses (estimated at 19 t/person/year of CO_2e in 2019,[3] compared to a global average of around 5 t/person/year[4]).

In order to hit the targets laid out by the Paris Agreement, Canada has committed to reducing its GHG emissions to 30% below 2005 levels by 2030 – a rate of 511 Mt/year of CO_2e. This constitutes a reduction of 219 Mt/year from 2005 levels, or a reduction of 209 Mt/year from 2019 levels. The 2030 target is a challenging one, and while Canada has made and is projected to continue making progress in overall reductions: the most recent studies predict that Canadian emissions in 2030 will be between 588 and 673 Mt/year of CO_2e.[5]

Three areas are responsible for the most emissions in Canada: energy, transportation, and fugitive sources. Together, these make up in excess of 80% of Canada's total GHG emissions.[6] While Canada's electricity supply is largely GHG-free, with the majority sourced from a combination of hydroelectric (60%), nuclear (15%), and non-hydroelectric renewable generation (7%),[7] this still leaves just under 20% generated from other GHG-emitting sources. Transportation is also a concern, as most Canadian cars and trucks are still powered by fossil fuels. While electric vehicles are now on the market, they currently make up less than 4% of new vehicle sales.[8] Fugitive emissions are unintended GHG emissions resulting from leakage and other irregular releases of gas. In Canada, this is primarily methane, making this an especially urgent issue, as methane has 86 time the global warming potential of CO_2.[9]

Climate change will have a major impact on the availability of potable water around the world. Water availability is already a major issue in several regions (e.g. California, India). This is projected to get worse as mean global temperatures increase and precipitation and weather patterns change.

Air, water, and soil pollutants in Canada largely stem from the same activities that emit greenhouse gasses, namely particulate emissions from coal plants, volatile organic compounds from oil sands production, and industrial emissions and runoff.

While we have painted a picture of the potential harm caused by climate change, our research suggests that, the introduction of the fifth generation next generation of wireless technology (5G) will have tremendous potential to reduce Canadian greenhouse gas emissions, as well as monitor and help counteract the pollution of our environment. 5G, with the revolutionary improvements it brings in terms of latency and bandwidth, promises new and exciting use cases that are likely to drive significant abatement, and help Canada meet its emissions goals and broader climate commitments.

Fifth Generation Wireless Technology (5G)

Wireless connectivity is an engine for the Canadian economy and brings our geographically dispersed population a bit closer together. There are over 33 million wireless subscriptions in Canada, and 90.18% of Canadians have a mobile phone.[10] As of 2018, the Canadian wireless industry generated a total of $48.2 billion, or 2.5% of Canadian GDP.[11]

The deployment of 5G, will reinvent industries and further enhance wireless experiences in our lives. 5G promises substantial improvements on current wireless technologies in terms of latency, throughput, and device connectivity. As with the move from 3G to 4G, 5G networks will be able to support more devices at higher speeds. The improvement from 4G to 5G is set to be several orders of magnitude greater than previous evolutions, allowing for revolutionary new applications of mobile technology.

5G's benefits over LTE, combined with new technological functions like mobile

edge computing (MEC) and network slicing, will allow new use cases to bloom across multiple industry verticals. These new use cases will span three categories: ultra-reliable low-latency communications (URLLC), enhanced mobile broadband (eMBB), and massive machine type communications (mMTC). 5G will fundamentally change the way we interact with technology, businesses, and each other. Use cases will span from smart city solutions to autonomous vehicle operations.

It is projected that, if deployed in a timely manner, by 2026 5G will add $40 billion to Canadian GDP, create 250,000 jobs, and induce $26 billion of capex investment by carriers.[13] With 5G, data demand per device will increase and the number of devices will also increase. How then could 5G provide a positive environmental impact? We have isolated two ways 5G will improve the Canadian environmental footprint: (1) Allowing network operators to be more energy efficient on a per unit of output level, (2) Enabling use cases that allow for improved carbon abatement from most industry verticals. These effects will allow the telecommunications industry, and the entire country, to be more energy efficient. In the face of climate change, 5G is a necessary technological step toward improving our position as a global leader in sustainability. If we implement 5G in a rapid fashion, Canada can lead by example in the fight against climate change.

WIRELESS IN CANADA

33.2 MILLION
wireless subscriptions

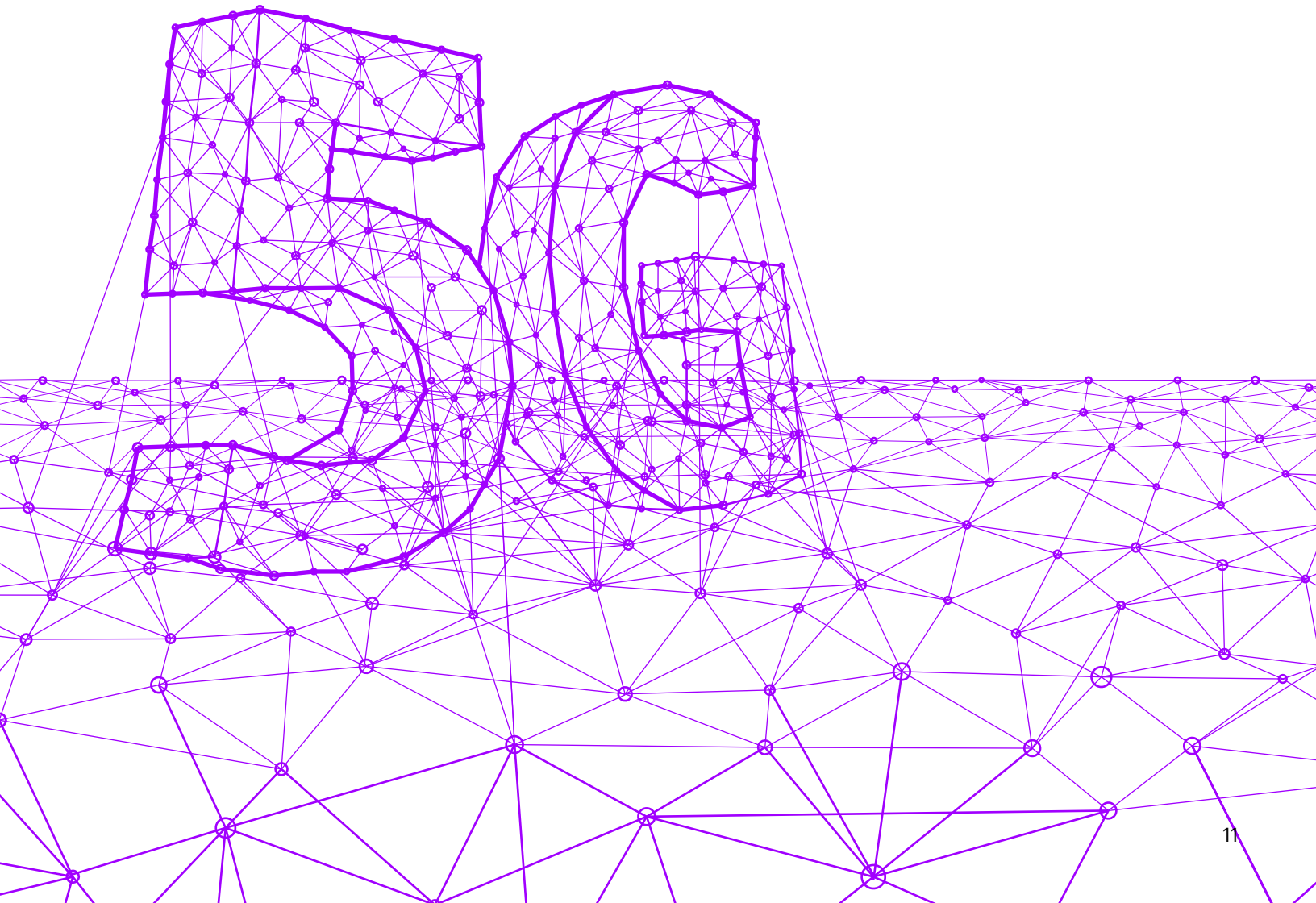
90.18%
of Canadians have a mobile phone

$48.2 BILLION
total contribution to Canadian GDP

> **"We believe leveraging technology, such as digitalization and 5G, will be fundamental to halve emissions every decade"**
>
> **-Börje Ekholm; CEO, Ericsson[12]**

EXISTING INDUSTRY RESEARCH

The impact the communications industry has on the environment has been the subject of previous research. However, at the time this paper was written most existing research has focused on current generation wireless technologies (4GLTE and below), or network efficiencies gained from 5G. The following papers by industry experts have been critical in shaping our perspective on this topic.

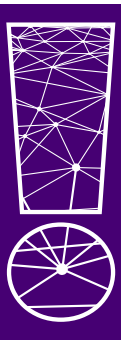


GeSI Mobile Carbon Impact Report, 2015[14]

In 2015 the GeSI, the Global e-Sustainability Initiative, released a report on the abatement enabled by mobile technologies. The GeSI took a conservative approach to estimating the abatement from mobile technologies, studying 100 potential mechanisms. This ultimately boiled down to showing the carbon abatement enabled by machine to machine (M2M) and consumer behavior changes.

The GeSI found that as of 2015, mobile networks enabled a 5:1 abatement ratio, saving 180 $MtCO_2e$ of GHG emissions in Europe and the United States. This means that the technologies enabled by mobile networks were abating (or reducing) 5X more emissions than the mobile sector emits. 70% of this abatement comes from the use of M2M technologies, and 20% comes from changes in consumer behavior.

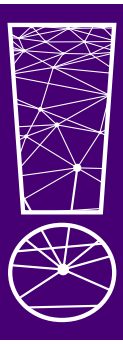
The GeSI broke down mobile technology enabled abatement into ten categories. These categories included: (1) Connected Agriculture (2) Connected Buildings (3) Connected Cities (4) Connected Energy (5) Connected Health (6) Connected Industry (7) Connected Living (8) Connected Transportation (9) Connected Working (10) Physical-to-Digital. Connected buildings and connected transportation made up most of the abatement, accounting for 29% and 28% of total abatement respectively. The GeSI points out that as other use cases become more feasible and widely adopted, it is possible to see the abatement enabled grow 3-5x larger by 2020. This will be through further advancements in sectors like healthcare and agriculture, where the impact of mobile technologies has not yet reached full maturity.



In 2015 mobile networks enabled 5x more abatement than their total sector emissions, saving 180 $MtCO_2e$ of GHG emissions in Europe and the United States.

GSMA – The Enablement Effect, 2019[15]

In 2018 the global mobile industry helped abate 2,135 $MtCO_2e$ in emissions, a 10:1 ratio to its own emissions. Following up on the work of the GeSI, the GSMA Enablement Effect paper focuses on analyzing the impact of mobile technology on fighting climate change. It concludes that enabling the creation or deployment of more efficient technologies, the mobile industry will have a major part to play in reducing emissions and environmental pollution. The GSMA shows that the total emissions from the mobile industry is roughly 220 $MtCO_2e$, which accounts for only 0.4% of global emissions. However, the GSMA found that in 2018 the mobile industry helped to abate 2,135 $MtCO_2e$, a positive impact of 10:1. Notably, this ratio of enabled abatement to sector emissions is double that recorded by the GeSI in 2015. The report states further developments and denser IoT connections could see the doubling of the industry's enablement savings, doubling the impact by 2025. The GSMA breaks down the enabled use cases from mobility into six categories: (1) Smart Buildings (2) Smart Energy (3) Smart Living, Working, & Health (4) Smart Transport & Cities (5) Smart Agriculture (6) Smart Manufacturing. GSMA finds that the largest share of current avoided carbon emissions come from smart living, working, and health, which made up 39% of abated emissions in 2018. Smart transport and cities are a close second with 30% of abated emissions, with the other categories making up the remaining 31% of abated emissions. The major forms of enablement studied were M2M technologies and behavior changes from the use of smartphones.



In 2018 the mobile industry helped abate 2,135 $MtCO_2e$ in emissions, 10x more than the industry's emissions.

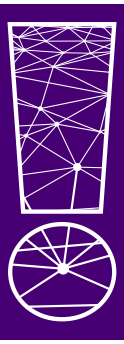
STL Partners: Curtailing Carbon Emissions – Can 5G Help?[16]

STL partners set out to understand how mobile operators can work to decrease their own carbon footprint across the industry. Although 4G networks can help drive some improvements in the energy load (average amount of energy needed for a network to transmit a given amount of data to a device), with the massive expected growth in data volumes over coming years, relying on 4G technology will not be enough to reduce the sector's emissions.

STL evaluated the impact of 5G on the mobile network's emissions. Without any 5G roll-out, global emissions from mobile networks will be roughly 600 $MtCO_2e$ in 2030, nearly three times higher than 2018. However, a base-case rollout of 5G networks results in global emissions from mobile networks of 260 $MtCO_2e$ in 2030*, saving 340 $MtCO_2e$ compared to the scenario with no 5G. A rapid 5G rollout saves another 80 $MtCO_2e$ in carbon emissions in 2030. Networks are examined in two portions: (1) core network and IT, and (2) radio access. Historically, the later accounts for two thirds of a network's emissions.

When talking about improvements to the core network, STL partners state that improvements to optical transmission, more efficient chipsets used in network equipment, and the "cloudification" of network functions will help networks become more efficient in terms of GB/kWh. However, a lot of these improvements are exogenous to the roll-out of 5G networks. Thus, 5G will only offer a modest improvement to the core network infrastructure.

For improvements to radio access, STL partners has isolated three main improvement areas: New Radio (NR) technology; new spectrum and higher array massive MIMO antennas, and mmWave spectrum. A roll out of mmWave spectrum along a middle ground density scenario could, by 2030, lead to a 98% reduction in energy consumption per bit of data transmitted compared to 4G.



A roll out of mmWave spectrum along a middle ground density scenario could lead to a 98% reduction in energy consumption per bit of data transmitted compared to 4G by 2030

* This analysis focuses primarily on network operation because installation has been shown to be <5% of a sites carbon footprint over its life cycle. It is also assumed that the installation emissions between 5G and 4G networks will be comparable over the next 10 years.

5G ENABLES SUSTAINABLE GROWTH IN DATA TRANSMISSION

Canadian carriers have made phenomenal progress toward climate targets. However, as demand for data continues to steadily increase, they will need to realize technical efficiencies to continue improving. 5G provides this opportunity by offering the potential to allow a 98% reduction in energy consumption per bit of data transmitted.[17]

Canadian Service Providers

Canadian facilities-based service providers take their environmental footprint very seriously. Service providers recognize they have an important role to play in reducing their own environmental footprint, for the good of the country and the world. Each of the three national carriers tackle their emissions in different ways, with various emissions targets and actions to lower their scope one (direct emissions under the control of an organization), scope two (energy purchased and used by the organization), and scope three emissions (all other indirect emissions).[18] Bell Canada has set an objective to lower their ratio of scope one and scope two emissions to network usage by 75% of 2014 levels by the end of 2020. As of 2018, Bell had already accomplished a 73% drop.[19] Rogers is attempting to reduce their scope one and scope two emissions by 25% and reduce their energy use by 10% of 2011 levels.[20] TELUS set the target to reduce their GHG emissions by 25% of 2011 levels, an objective which they had already achieved by 2018.[21]

Canadian service providers are all working to ensure that the electricity they consume is largely generated by renewable sources. In 2018, 53% of the electricity that Bell consumed was from renewable sources. The Bell network generated 170,000 kWh of renewable energy from solar and wind sources.[22] In 2018, TELUS purchased 22,407 MWh of renewable energy.[23]

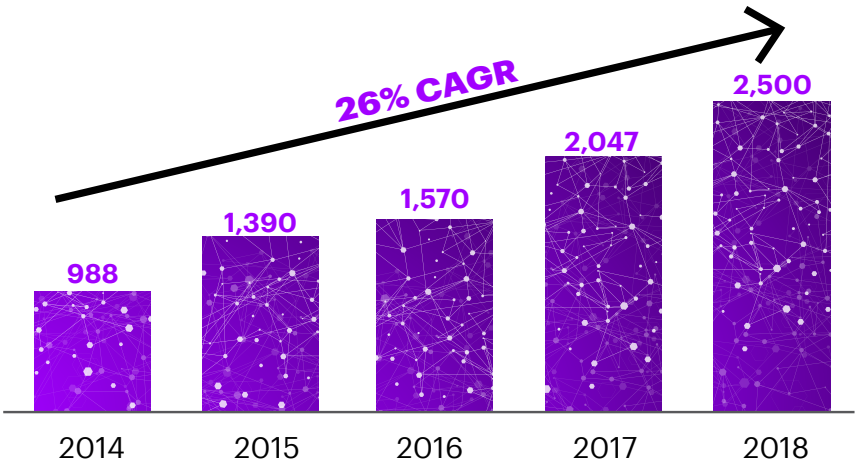
Regional facilities-based carriers are also working to ensure that their environmental footprint is as low as possible. After all, achieving consensus across the industry is critical to ensuring environmental value. In 2019 SaskTel was named one of Canada's Greenest Employers by MediaCorp Canada Inc. SaskTel received this honor for the 10th consecutive year.[24] Shaw has implemented route optimization software which has resulted in a 25% reduction in distance travelled/ service order, and has also installed high efficiency mechanical equipment to reduce power consumption in its facilities and data centres.[25] In 2018, 84% of the energy used by Quebecor (Videotron) came from renewable sources.[26]

Technical Efficiency Gains from 5G

Mobile data usage in Canada is growing rapidly. As of 2018, 75% of Canadians had a mobile data plan. LTE covers 99% of Canadians and 96% of rural communities.[27] Average data consumption per subscriber with a mobile data plan in Canada has been rising steadily at a 26% compound annual growth rate (CAGR) between 2014-2018, reaching 2.5GB by 2018.[28] [29]

Overall data consumption is forecasted to continue increasing at a 34% CAGR between 2017 and 2022. This growth will be driven by increasing demand for new high bandwidth services, such as streaming HD video. As data consumption increases, there is a risk of significant increases in GHG emissions, particularly in countries that are heavily dependent on fossil fuels.[30] Current 4G technology cannot support substantial increases in data consumption without significant densification.[31] [32] Densification would traditionally result in more energy consumption. To support increased data use in a practical and environmentally friendly way, operators need to look beyond 4G.

Average Data Consumption per Canadian Subsciber with Data Plan (MB/Month)



5G WILL LEAD TO MORE DEVICES & MORE DATA PER DEVICE[33]

602.2MBPS average 5G speed in Canada by 2023

77MBPS average 4G speed in Canada by 2023

39.6MBPS average 4G speed in Canada in 2018

270.9 MILLION M2M DEVICES in Canada by 2023, up from 11.4 million in 2018

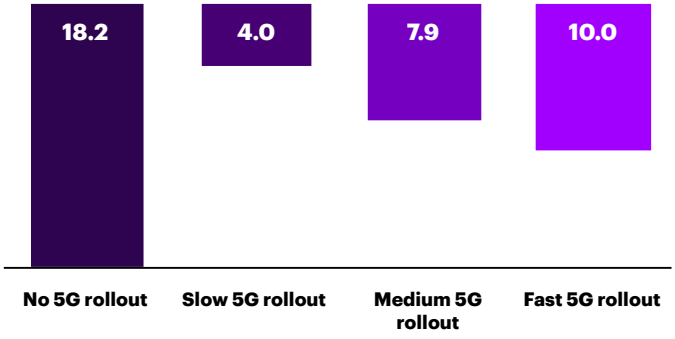
With 5G, not only will new use cases like 4K streaming, VR enablement, or autonomous vehicles lead to more data demand, the network will support a higher number of connected devices than was possible with 4G. It's natural to assume then, that the combination of more devices supported on the network and more data being consumed per device would lead to more energy consumption. However, there are multiple ways 5G networks will function more efficiently than their predecessors, allowing for net emission savings.

5G networks will be more efficient than previous wireless technologies. Various new technical capabilities will allow operators to reduce the emissions per unit of data associated with providing service to their customers. Innovative hardware that combines multiple radio technologies in single pieces of equipment can lead to energy efficiencies on a per site basis. Technologies like network function virtualization (NFV), software defined networking (SDN) and network slicing will allow operators to gain a higher degree of control over their networks than was previously possible. The more control operators have, the better they can monitor their energy consumption, scaling up or down to meet demand as necessary.[34]

With this combination of new technologies, it's projected that a rapid rollout of 5G will enable up to 10 million tonnes of CO_2 equivalent reduction from Canadian MNOs between 2020-2030.[35] This massive reduction will mainly be the result of the greater efficiency of 5G networks, which is driven by improved data efficiency per unit of data transmitted. *The STL Partners research shows that for a general 5G cell site, energy used in data transmission will be 8-15% of what is currently is for a similar 4G cell site and mmWave technology can drop it to 1-2% of a 4G macro site. These figures represent relative performance, as optimal energy loads may not scale across the entire network.[36]

This is a result of 5G being substantially more energy efficient, despite the increased volume of traffic on the network. It is predicted that 5G will support a thousand-fold traffic increase in the next 10 years, but the full network's energy will be half the current levels. This implies an energy efficiency increase of 2,000 times over the coming decade.[37]

Cumulative Carbon Emission Reduction from Mobile Networks in Canada, 2020-2030 ($MtCO_2e$)



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Network Function Virtualization (NFV) & Virtualized Ran (vRAN)

Network function virtualization (NFV) refers to the process of decoupling software from hardware.[38] This process will be key to enabling functionality such as network slicing, a technology central to multiple key 5G use cases. Different virtualization techniques will help make operators core network more efficient. Improvements brought by the cloudification of network functions will generally improve the core's energy efficiency. However, the core network accounts for only one third of the total network's energy consumption on average, so virtualization of the core will only have a modest impact on these emissions. Early 5G networks will likely utilize 4G cores, meaning the net difference from the leap to 5G will initially be minimal.[39]

Virtualized Radio Access Networks (vRAN) are inspired by the central tenets of NFV. vRAN is when baseband functions are virtualized on commodity server hardware.[40] Below we capture the critical evolution of the RAN between 4G and 5G. The shift to vRAN will allow for more energy efficiency from the RAN, and less emissions from regular maintenance like truck rolls.

Distributed Radio Access Network (DRAN)

- Upon the introduction of 4G, RAN shifted to DRAN
- Latency if data operations reduced by moving the Radio Network Controller (RNC) to the Evolved Node B (eNodeB)
- The eNodeB consists of the baseband unit (BBU) and the remote radio Unit (RRU) connected by a lossless, short fiber

Centralized Radio Access Network (CRAN)

- As the number of cells and the complexity of a 4G network increases, there is a need to save resources by pooling BBUs into hubs
- This is accomplished by separating the BBUs and RRUs, and moving the BBUs away from the eNodeB entirely
- The common Public Radio Interface (CPRI) acts as fronthaul between the BBUs and RRUs
- Allows for better scaling of resources and power savings due to tight coordination possible across BBUs

Virtualized Radio Access Network (vRAN)

- In vRAN, the hardware BBU is replaced with a software based BBU deployed on COTS servers
- Since BBUs are entirely independent of underlying hardware, capacity can be spread across multiple RRUs
- vRAN allows maximum flexibility in sharing resources for baseband processing
- vRAN allows carriers to improve their capacity and spectral efficiency by drawing from a pool of BBUs that share signals among cells.[41]

Ultra-Lean Design & Smart-Sleep Mode Technology

Aspects of the 5G New Radio (NR) technology, a new radio access technology developed by 3GPP for 5G mobile networks,[42] will help lead to improved energy efficiency, even in the face of network densification.[43]

One contribution will be the new ability for sites to enter a "sleep state" based on the current traffic demands. In its current state, LTE technology consistently consumes a great deal of energy, even though there are gaps in energy demand throughout the day. Base stations still consume power when there is no demand, because they must always remain active to transmit idle mode signals (e.g. synchronization signals, reference signals, and system information). With 5G NR, base stations will be able to "sleep" when there is no traffic to serve, consuming less energy.[44] Ericsson has found that deploying a dense network using NR can offer both high performance and capacity, while ensuring low energy consumption.[45]

Massive MIMO

Massive MIMO (multiple-input multiple-output) technology involves the use of arrays with many more antennas at each base station.[46] This results in an increase in the amount of hardware per base station. However, massive MIMO allows the use of a transmission technique referred to as spatial multiplexing (SM). With SM, multiple antennas are used to carry multiple data streams simultaneously and with the same frequency band.[47] This allows for significantly improved spectral and energy efficiency. Industry experts have explained that if you were to spatially multiplex 10 users and need to spend twice the energy to do so, you would still be five times as energy efficient as prior to utilizing massive MIMO.[48]

mmWave Spectrum

Millimeter wave spectrum (mmWave) refers to spectrum above 24 GHz. Utilization of mmWave is expected to allow for more data to be transmitted for less energy and to transmit that data on smaller and easier to power cells. mmWave 'overlay' cells will make existing 3G/4G/5G macro cells more efficient. The ability to overlay will help to ease the problems of running both a 5G network and earlier generations of network simultaneously.

5G IS KEY TO ENABLING FURTHER WIRELESS INDUSTRY ABATEMENT

Without updates to the network infrastructure Canadian service providers run the risk of increasing carbon emissions from network functions as the demand for data increases. **A fast, comprehensive, and effective rollout of 5G technology across Canada can help mitigate these effects.**

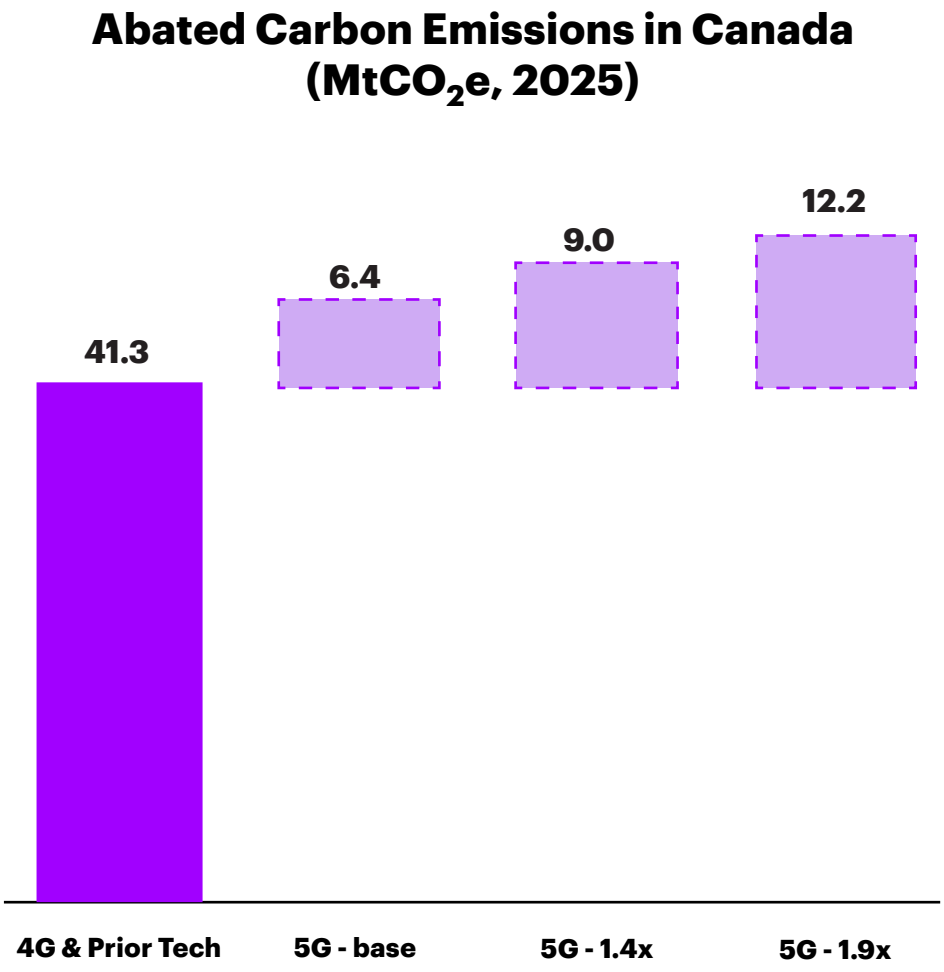
Measuring 5G Enabled Abatement Across Industries

We have developed a quantitative model to estimate the abatement impact of 5G on enabled use cases in Canada. The estimates indicate that 5G has potential to reduce cross-industry emissions in the range of 6.4 to 12.2 $MtCO_2e$ by 2025, which translates up to 13% to 23% of total wireless technology abatement respectively in baseline and best-case scenarios. This is in addition to the estimated 41.3 $MtCO_2e$ reduction from current wireless technologies.

Canada represents ~1.6% of global GHG emissions, although it is one of the highest per capita emitters. In 2017, Canada's GHG emissions were 716 $MtCO_2e$, showing a net decrease of 15 Mt or 2.0% from 2005 emissions.[49] Canada was one of the first parties to sign and ratify the Paris Agreement, adopted under the United Nations Framework Convention on Climate Change (UNFCCC). In 2016, the Government of Canada and eleven provincial and territorial governments adopted the Pan-Canadian Framework (PCF), the first climate change plan to include individual and joint commitments by federal, provincial and territorial governments. It is the country's overarching framework to reduce emissions across all sectors of the economy to meet Canada's Paris Climate Accord target of 30% below 2005 levels by 2030, stimulate clean economic growth and build resilience to the impacts of climate change.[50]

Mobile communication technologies enable real-time communication between machines. The use of connected devices brings change in consumer behavior and these changes could lead to numerous industry cases of enablement of carbon emissions reduction. As per Accenture model analysis leveraging GSMA "The Enablement Effect" methodology, mobile technologies have the potential to mitigate emissions estimated to range from 47.7 $MtCO_2e$ in the base case to 53.5 $MtCO_2e$ in the best-case scenario in Canada by 2025. Our model shows that 41.3 $MtCO_2e$ is forecast to come from 4G and prior wireless technology, with a range of 6.4 to 12.2 $MtCO_2e$ driven by 5G, representing a range of 18% to 23% of total wireless technology enabled abatement by 2025. The Canadian government has set a target to bring down GHG emissions to 30% below 2005 levels by 2030.[51] Therefore, there is a need to achieve a net decrease of 205 $MtCO_2e$ from 2005 emissions. Mobile technologies including 5G have the potential to achieve 48 $MtCO_2e$ of reduction by 2025, which is equivalent to 23% of the emission reduction target for 2030.

As mentioned above, Accenture plotted three future scenarios based on possible incremental efficiencies of 5G over previous wireless technologies. In our base case scenario, we assume that 5G is equally efficient to 4G and prior technology at enabling abatement. In the base case scenario, the potential of 5G in reducing carbon emissions would be 13% of total mobile enabled abatement, or 6.4 $MtCO_2e$. Then, for incremental improvement scenarios, Accenture developed a "5G multiplier" that was applied to use cases that will be positively impacted by 5G, leading to incremental abatement above the base case scenario. In the second scenario, using a 1.4x multiplier on 5G use cases we found that 5G enables 18% of total abatement, or 9.0 $MtCO_2e$. Because of the incremental improvement of 5G this use case adds an additional 2.6 $MtCO_2e$ of abatement to the base case scenario bringing total abatement up to 50.3 $MtCO_2e$. In the third scenario, using a 1.9x multiplier on 5G use cases we found that 5G enables 23% of total abatement, or 12.2 MtCO2e. This represents an additional 5.8$MtCO_2e$ over the base case scenario causing a total abatement of 53.5 $MtCO_2e$.



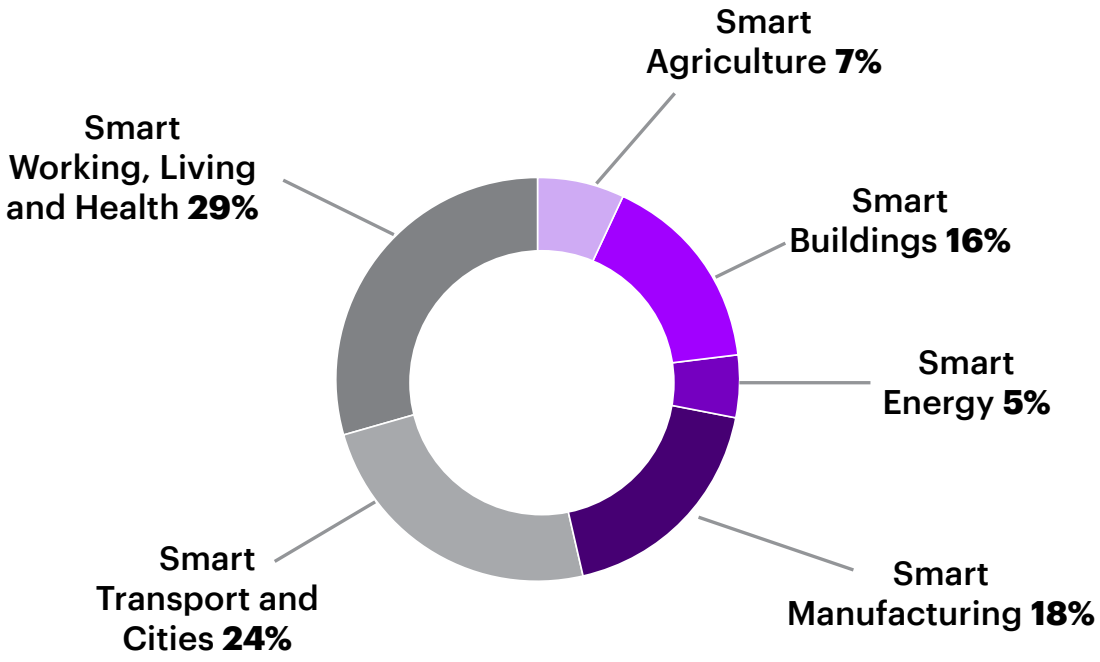
The abatement effect differs for various use cases which are clustered under six main categories. **In Canada, smart working, living, health, smart transport and buildings together account for more than 70% of the carbon abatement.**

5G will serve as the foundation of smart cities, working and living. In a smart city, data, sensors and connected devices help improve government services and residents' quality of life through analytics, artificial intelligence and, automation. Offering a major step-up from 4G networks, 5G offers huge upgrades in terms of speed and latency, enabling a new generation of platforms and services.

The most significant use cases are considered under each category. Although this approach is not exhaustive, it captures a large portion of the abatement potential. We have also analyzed additional groundbreaking new use cases where 5G may have an impact in the future.

Please see the appendix for further details on the methodology underlying this model.

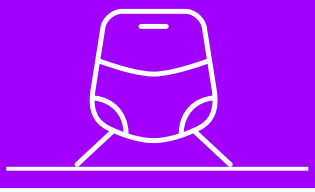
Abated Carbon Emissions by Category/Industry in Canada ($MtCO_2e$, 2025, all mobile technologies, all scenarios)



Groundbreaking 5G Enabled Use Cases

In addition to modelling benefits, we explore several use cases in detail to understand the impact of 5G-enabled use cases in driving carbon abatement. Some of these use cases include bottom up abatement estimations on top of what is already included in the model. Here, we explore three categories across connected infrastructure: connected transportation, connected living, and connected agriculture.

Connected Transportation



Greenhouse gas (GHG) emissions from the transportation sector accounted for almost a quarter (24%) of all GHGs in Canada in 2017, making it second only to the oil and gas sector as the largest source of GHG emissions in the country.[52] Passenger and freight vehicles are responsible for the majority of transportation emissions. This is the result of the need to move people and goods around Canada's vast landmass.

According to a new report "Traffic Index 2019", traffic congestion is on the rise in almost every major Canadian city, with drivers in Vancouver and Toronto facing the longest delays. Vancouver topped the charts with a congestion level of 39%, meaning the average trip there takes 39% longer than it would if traffic was flowing freely. Conditions worsen at rush hour; drivers with a 30-minute commute each way will spend an extra 17 minutes in their car in the morning and an extra 21 minutes in the afternoon. Traffic is increasing in most Canadian cities, increasing the cause for concern.[53]

Local governments, traffic and road authorities are seeking new technology solutions to reduce carbon emissions, traffic congestion and casualties in Canada. In late 2019, the City of Vancouver launched a hackathon called "Decode Congestion", with the aim of developing technological solutions to some of the city's most pressing transportation issues.[54] Local government and traffic authorities are already implementing technology-based solutions to ease road congestion. For instance, the City of Edmonton in Alberta has become the first Canadian city to deploy an adaptive traffic signals corridor as part of the city's smart transportation initiative to reduce delays and travel time.[55] The adaptive traffic signals manage vehicle and pedestrian traffic by monitoring and changing traffic signal timings to become more responsive to variable traffic demand. The real-time camera data is fed into the traffic management platform to control signal timings based on demand.

Mobile technology has the potential to play a major role in the monitoring and management of traffic congestion in cities. It can also help create positive behavioral change in commuters, by improving the availability and functionality of advanced network connectivity enabled applications. For instance, communication between traffic lights can optimize wait times at junctions, improve traffic flow and allow drivers to maintain a more consistent speed. This helps to reduce fuel consumption and emissions. While the current pandemic will slow down the advantages of ride sharing and public transit, together with navigation apps all three will ultimately reduce the number of vehicles on the road over the medium term.

Many of the current generation networks provide sufficient connectivity to support some connected vehicle applications. Yet the higher data rate, lower latency and improved capacity provided by 5G New Radio (NR) access make 5G systems the ideal choice to maximize the safety, efficiency and decarbonization of road transportation. 5G has the capability to help

reduce traffic congestion by optimizing routing and improving city-traffic management with real-time information and videos. At an advanced stage, 5G will support the "platooning" of connected vehicles. According to the recent study by ERTICO, platooning can reduce CO_2 emissions by up to 16% from the trailing vehicles and by up to 8% from the lead vehicle.[56]

Electric vehicles (EVs) show tremendous promise in reducing emissions in the longer term. However, they currently only occupy a small market share in Canada. Metro Vancouver's public transit authority TransLink recently revealed their plan to replace half of the diesel, diesel-hybrid, and natural gas buses entering retirement with new zero-emission, electric-battery bus models. The authority has set itself a goal of reducing its greenhouse gas emissions by 80% by 2050, with an interim target of 45% by 2030. To support the new electric-battery bus fleet, TransLink will need to ensure that its planned Marpole Transit Centre is 100% electric charging ready when it opens in 2023-24. The related enablement comes from the facilitation of charging points for electric vehicles.[60]

With 5G's low latency and capacity to accommodate a dense network of vehicles, the technology can enable communication between electric vehicles, charging stations and energy grids, which will help in real-time monitoring and regulation of electricity demand and supply at a charging station.

At an advanced stage, 5G can become the foundational technology to power an all-electric, autonomous transport ecosystem. 5G's high-capacity and low-latency will be cornerstones of future transport solutions, providing the connectivity and reliability needed to safely introduce autonomous cars and trucks onto public roads, and paving the way for the resulting reduced CO_2 emissions.[61]

REDUCTION IN EMISSIONS & COMMUTER TIME SAVINGS IN THE THREE BUSIEST CANADIAN CITIES

Commuters in the busiest three Canadian cities (Toronto, Montreal, Vancouver) lose an average of 113 hours in traffic congestion per year, and authorities are continuously looking for ways to ease traffic congestion.[57] More than 20 municipalities in Canada have implemented by-laws that require drivers to turn off their ignition after three consecutive minutes idling in a 60-minute period. According to National Resources Canada, annual CO_2 emissions could be reduced by 1.4 million tonnes if Canadian motorists avoided idling for three minutes every day of the year.[58]

This would be equal to saving 630 million liters of fuel and equivalent to taking 320,000 cars off of the road for the entire year. Research has shown that implementing 5G technologies has the potential to reduce traffic congestion by 10%.[59] With implementation of 5G use cases, **this translates into estimated time savings of 11.3 hours per year for an average commuter and an associated annual ~0.83 million tonnes of CO_2 emissions reduction in Canada.**

> **"While basic internet access allowed work to be done remotely, XR and 5G will allow work to be done truly virtually"**
>
> **Omar Abbosh & Paul Nunes[62]**

Enhanced Remote Working

The COVID-19 pandemic has resulted in a dramatic shift in the way that many Canadians work. Physical distancing requirements has forced many workers to work from home, with Statistics Canada reporting that as many as 39.1% of Canadians worked from home during the last week of March 2020.[63]

For many, working remotely was a new experience, but due in large part to the resiliency of Canada's telecommunication networks, most Canadians having to transition to this new reality have done so successfully. Aternity's analysis of data from over five hundred Global 2000 companies found that Canadians experienced a 170% increase in remote work since work from home measures were implemented; which resulted in an overall increase in productivity of 25%.[64]

The move to more remote working is unlikely to be a short-term phenomenon, even if a vaccine and effective therapeutics for the COVID-19 virus are created. Many companies have discovered the cost-saving and productivity gains of having some or a majority of their workforce working from home. In Canada, OpenText Corp. announced that it is considering closing half of its office space after the COVID-19 pandemic to allow more employees to work from home,[65] while Shopify announced that it is moving to a "digital by default" model where most of employees will work remotely on a permanent basis.[66] In the U.S., companies such as Facebook[67] and Twitter[68] have made similar announcements.

While the recent transition to remote work is the result of a sudden health crisis, remote work also has obvious long-term environmental benefits. The daily commute to and from work contributes greatly to GHG emissions. As an example, in a previous Accenture study[69], it was estimated that a 10% reduction in traffic congestion in the cities of Montreal and Vancouver would result in reduction of CO_2 emissions of 130K tonnes and 55K tonnes respectively, which is the equivalent to taking 29,000 cars off the road in Montreal, and 12,500 cars off the road in Vancouver. These reductions would be much higher if the current trend towards more remote work becomes permanent across Canada.

Notwithstanding its health safety and environmental benefits, remote work is not feasible for everyone. Statistics Canada estimates that today only 4 in 10 Canadians work jobs that can plausibly be performed from home.[70] While current telecommunication services already play a large role in enabling remote work, 5G will dramatically expand its possibilities.

5G will enable new extended reality (XR) technologies. Extended reality works to combine VR, AR and mixed reality innovations. Through VR and remote devices operation, many jobs that traditionally required the worker's physical presence will be able to be performed from home or from alternate locations using telepresence, teleoperation, and telerobotics.[71]

Imagine a world where an employee can be trained for a job remotely, using a virtual reality headset to see, feel, and hear the office space that they would generally work in. Not only could the quality of training be improved by allowing full control over the immersive situations that an employee is put through, but emissions are avoided as employees no longer need to travel to a training center.

This could be expanded past training to day-to-day work. Using virtual reality technology and the creation of "digital twins" of various locations, workers will be able to collaborate utilizing "telepresence", which simulates being physically together even when separated by large distances. This would allow for a factory supervisor to remotely inspect her lines, or for a group of executives to meet in the same meeting room face-to-face, but virtually. Teleoperation is a similar concept that allows for the remote operation of a machine. If we combine telepresence and teleoperation, we enter the realm of telerobotics. With telerobotics, use cases like remote surgery are made possible.

Doctors in China have already successfully performed remote surgeries from distances over 2000 kilometers between patient and doctor. The patient underwent a three hour procedure that included a deep brain simulation implant from a doctor, named Dr. Zhipei, who was in a different city. This is made possible by 5G's incredibly low latency, which allows remote surgery to be performed nearly as effectively as traditional surgery. Remote surgery of this kind is sometimes referred to as "telesurgury".[72] Remote work will not only reduce GHG emissions by reducing travel necessary but will allow for increased safety for employees across various industry verticals.

With the advent of 5G networks more jobs will be capable of being done remotely thus reducing GHG emissions.

VR Conferences & Trade Shows

According to MeetGreen, the average 1,000-person, three-day event translates into 530 metric tonnes of CO_2e.[73] These conferences and meetings lead to massive amounts of domestic and international travel, creating large amounts of emissions and waste. Much of the typical carbon footprint for one of these events is formed by travel-based activities. If travel were removed from a conference, 92% of the carbon footprint could be avoided.

With 5G, virtual reality (VR) could be used to decrease travel for events such as conferences. 5G's capacity for enhanced mobile broadband (eMBB) and ultra-low latency communication (URLLC) use cases will enable new capabilities around accessing VR and AR capabilities. Lower latency will decrease the delay between action and response, especially with actions like head movements, making the technology more useable for the average consumer.[74]

When we look to business travel, conferences and trade shows, 5G could enable participants to attend virtually, without losing the value gained from being physically present. Utilizing VR technology, attendees could walk around event halls, attend lectures, and even network virtually. A lot of the value of conferences is gained from sales and networking. If this can be facilitated virtually, even for a small percentage of attendees, it would have an enormous effect on carbon abatement.

Conferences are already working toward virtual capabilities. According to American Express 58% of North American meeting organizers planned to use virtual/hybrid meetings in 10% of meetings. We believe that with modest levels of increased adoption due to 5G (5-15% of attendees), Canadian conferences can reduce their emissions by cumulative 7,000 metric tonnes CO_2e* over five years.[75] This abatement would be driven entirely by the reduction in hotel room stays and travel emissions from attendees at Canadian conferences. One example of a business already doing this successfully is Multiphoton Optics, who reduced their annual trade show carbon footprint by 98.5% using AR and VR. This was due to reducing the amount of equipment they ship back and forth between events and utilizing AR & VR to allow them to be shown remotely.[76]

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* **Methodology:** Typical conference attendee creates 176.76 KG CO_2e (1, MeetGreen), Canada had 49,538 business event attendees in 2017 (2, Events Industry Council, Oxford Economics), Average length of a conferences is 3 days in North America (3, CWT Data). Therefore, total estimated Canadian emissions is 26,269,011 KG CO_2e. Roughly 92% is travel related (1, MeetGreen) leaving 24,167,490 KG CO_2e of addressable travel emissions/year. Using VR for a 3-day 5,000-person conference creates 124,416 KG CO_2e of emissions (4, Educatorsinvr.com) or 82.9 KG CO_2e/ person/ day. Net per person per day abatement is therefore 93.8 KG CO_2e. Assuming that due to the enhanced experience with 5G an incremental 5% of of attendees shift to virtual reality after year one ramping up to 15% in year five (5, Accenture Analysis based on American Express data), a total of 6,971 metric tonnes would be abated. See endnotes for source details.

Connected Buildings

Buildings accounted for 12% of total greenhouse emissions (85 $MtCO_2e$) in Canada in 2017. They are therefore a key focus area for reducing emissions.[77] A large proportion of emissions originate from heating, ventilation, air conditioning (HVAC) and lighting systems.

Canadian city planning authorities are working on roadmaps for achieving zero emissions from buildings. In Toronto, City Planning has partnered with environmental consulting firm Integral and a stakeholder advisory group, The Atmospheric Fund (TAF), to develop a Zero Emissions Building Framework to achieve near zero emissions in all new buildings by 2030.[78] In 2016, Vancouver created a Zero Emissions Buildings (ZEB) plan to make near-zero emissions homes and buildings the norm in Vancouver by 2030.[79]

In a connected building a network of sensors, actuators, and microchips collect and analyze data about the building's operations. Mobile technology then enables communication between the various points in the network. M2M connectivity allows for the automation and monitoring of building systems remotely. This could allow systems to be switched on and off depending on occupancy or temperature levels. Leveraging IoT-powered temperature sensors, dashboards for buildings can show real-time information such as the number of people using different spaces and the temperature and air quality inside each space. Analytical tools can be used for predictive maintenance and more sophisticated building control policies, such as adjusting heating according to the weather forecast and historical data. 5G can transmit information in real-time which will make connected building systems more efficient, ensuring these buildings produce net zero energy, or even that they are energy-positive (structures that generate more electricity than they consume).

Canadian operators are increasingly looking to forge partnerships with niche connected buildings technology companies. Bell has collaborated with GridPoint to deliver smart energy management solutions, with the aim of improving energy usage and management in buildings across Canada.[80] The smart building solution provides critical insights into equipment, health and performance, allowing users to make timely and more-informed decisions with real-time monitoring across all their assets – including HVAC, lighting, refrigeration and more. The solution collects and displays data in real-time through a software platform and mobile application, empowering users to understand their building's energy patterns and adapt their operations to maximize savings.

For a full list of energy solutions please see Bell's website: https://business.bell.ca/shop/medium-large/resource/gridpoint-overview

ENABLEMENT BY IMPROVEMENT OF HVAC (HEATING, VENTILATION, AND AIR CONDITIONING) CONTROL SYSTEMS

Heating, ventilation and air conditioning (HVAC) are critical building systems that account for approximately one third of a building's energy usage. In connected buildings, M2M assisted automated monitoring and control of HVAC systems is currently one of the biggest enablement mechanisms. Direct and real-time communication between systems allows them to respond without manual intervention, enabling the reduction of carbon emissions. As per the GSMA Enablement report, these advanced HVAC systems enabled avoidance of ~103 million tCO_2e in 2018, out of which ~40% is attributed to North America. Globally, **this translates into an equivalent 235 TWh of energy savings in buildings in 2018.** [81]

TELUS signed a deal with a Vancouver based clean tech firm - Universal mCloud - to offer solutions for monitoring the performance of HVAC units in connected buildings.[82] HVAC equipment is connected using IoT technology to mCloud's cloud-based platform. On the platform, real-time data is received, monitored and analyzed for trends and patterns. When performance issues arise, mCloud's solution diagnoses the problem and suggests any possible fine-tuning or maintenance requirements. Property management can then dispatch their designated HVAC service technician, preventing unnecessary energy consumption, asset downtime, and costly repairs.

These solutions are currently run on current generation communication technologies. However, the arrival of 5G will allow for even more sophisticated and widespread use of connected building technology by unlocking new use cases within this domain. This takes place by allowing for higher density of devices and decreasing latency in data transmission, allowing information about a buildings energy usage to be delivered in real time. In the near future, smart homes with enhanced connectivity will allow us to control appliances, heating and cooling remotely, while real time, robust consumption dashboards will make us much more aware of our energy consumption. With more awareness about energy consumption, we can change our behavior to reduce our carbon footprints.

Connected Grids

The electricity sector accounted for 10.3% of total GHG emissions in Canada, equivalent to 74 $MtCO_2$ in 2017.[83] The Pan-Canadian Framework on Clean Growth and Climate Change set forth an ambitious target of reducing carbon emissions to roughly half the current emissions from this sector by 2030.

The use of clean energy sources will be a major factor for reducing emissions in the electricity sector, as will more widespread use of smart grids and meters, which have the potential to reduce energy losses at both the grid and consumer levels. As of Dec 2018, over 82% of meters in Canada are classified as smart meters.[84] Given the prevalence of smart meters, operators in this sector have a major opportunity to offer enhanced connectivity for IoT applications. Two-way communication meters help to optimize the generation and transmission of energy to meet consumption needs. Through improved real time monitoring, energy supply and demand can be better matched to avoid excess generation. Peak consumer demand can be reduced overall due to better real-time monitoring, driving reduced overall and peak generation needs (i.e. load shaping). Transmission and distribution (T&D) losses can be mitigated due to more efficient distribution network. We can identify points of loss, specific issues in the grid, allowing for preventive and rapid repairs. Microgrids can be facilitated which can increase customer-owned renewable generation capacity. Connected grids represent a massive opportunity for reduction of GHG emissions.

Globally in 2018, M2M enabled electric network management in smart grids resulted in an 11 $MtCO_2$ emission reduction and associated energy savings of 18 TWh.[85] 5G can play a significant role in enhanced communication between smart grids and smart meters. Moreover, 5G's ultra-low latency enables the millisecond-level response time that's required for granular control over grid systems. This will help ensure better matching of energy supply to demand, especially where renewable sources are significant. 5G-enabled smart grids will ultimately improve monitoring, analysis, control and communication within the supply chain. This will help improve efficiency, reduce energy consumption and cost, and maximize the transparency and reliability of the energy supply chain.

ONTARIO TO HOST NORTH AMERICA'S LARGEST SMART GRID SYSTEM

In February 2019, Sault Ste. Marie in Ontario province announced its plans to host the first of its kind and largest smart grid system in North America. It aims to create value for both utility providers and customers, by increasing energy efficiency, reducing outages and outage duration and reducing customer bills by between 2-4%. The smart grid system will allow the integration of electric vehicle charging and distributed renewable energy resources, both of which will lower the utility's operational costs and customer bills. The smart grid will also have a "self-healing" capacity, allowing the system to open and close switches during outages.[86]

Government and local authorities in Canada have been taking steps to increase the use of smart meters and invest in technology-based energy solutions to improve energy efficiency and reduce emissions from the sector. In 2018, the Government of Canada launched the "Smart Grid Program" and announced $100 million in funding towards utility-led projects to reduce GHG emissions, to better utilize existing electricity assets and to aid the development of smart grid integrated systems.[87]

In 2019, the Canadian government announced a $650k investment in the Yukon Energy Corporation (YEC). Under this partnership, the Residential Demand Response Program is expected to make the electrical grid more efficient by equipping ~400 customer homes with demand response devices, controllable from YEC's system control center. This will enable YEC to shift participating customer's loads off critical peak electricity demand periods.[88]

Recently, the Canadian government invested $2.43 million in an Ottawa based startup called BluWave-ai which develops AI software to monitor energy usage across a variety of sources and users, feeding operators information to help predict energy demands.[89]

Connected Water

In Canada, the annual water consumption per capita stood at 883 cubic meters, compared with an average among select countries of 585 cubic meters in 2017.[90] This is the second greatest consumption per capita, second only to the United States and more than twice as much as European countries such as Poland, Germany and France.

Residential water use accounts for half of the drinking water produced annually in Canada. The residential sector was the primary water user, averaging 220 liters per person per day in 2017. This worked out to 2,445 million cubic meters or 50% of the drinking water produced.[91] A recent study showed that metered Canadian cities use about 40-45% less water per person compared to non-metered cities.[92]

Two-way communication meters improve interaction between the utility and customers resulting in new capabilities. Real-time water usage monitoring will be enabled with IoT monitoring which can enable accurate billing and elimination of estimated billing. Sensors can help identify water leaks immediately resulting in better management of water leakage loss and water theft. Finally, better management of water quality testing procedures can help improve the quality of water.

Two-way communications between the utility provider and the consumer requires two components: the smart meter itself and a reliable connection to make the communication possible. The government and municipalities in Canada are laying the groundwork to increase the use of smart water meters. In 2017, the Public Utilities Commission of the Chatham-Kent municipality in Ontario, working in collaboration with Neptune Technology, set out a plan to upgrade its analogue meters with smart water meters. To facilitate this, they implemented a $10 million project to replace 36,000 analogue meters with smart meters. Similarly, the city of St. Albert has begun a $6.4 million initiative to replace 21,292 analogue meters with digital water meters.[93]

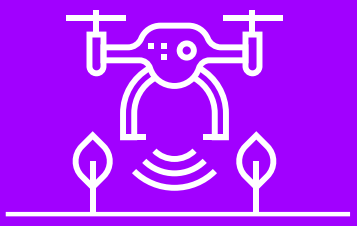
Narrowband-IoT (NB-IoT) is well-suited to connecting water meters, as the technology can provide remote coverage across a wide range of hard-to-reach water meter locations, which are often underground. It offers excellent power efficiency, allowing devices to run on batteries for ten years or more without the need for charge. The technology is built on low-cost communications hardware. Its low bandwidth requirements mean that most use cases require just a few bytes of data to be transmitted per device, per day. NB-IoT is being used by utilities providers to monitor rainwater tanks and pipe flow, as well as to guard against unauthorized entry to sewers.[94]

Last year, Rogers Communications revealed plans to roll out a NB-IoT network across Canada to support IoT applications and use cases. NB-IoT is complementary to Rogers' national LTE and LTE-M networks, which are available to IoT customers across Canada, with additional sites being added.

The Canadian operators are driving several IoT initiatives around the prevention of water leakage loss and water quality management. For instance, Bell Canada has partnered with Echologics, a developer of water infrastructure diagnostic technologies for water loss management, to launch an IoT Smart City solution over Bell's wireless network for the City of Medicine Hat, Alberta.[95] The smart nodes, which are placed on Medicine Hat's network of existing fire hydrants, collect data and monitor water infrastructure for leaks. In this way, the IoT solution wirelessly monitors the city's water pipeline network to help reduce water loss and mitigate the cost of infrastructure failure. By combining Echologics' leak detection technology with Bell's wireless network to transmit data, municipalities can make smarter decisions about their water infrastructure, save time and money, and help ensure their citizens continue to have access to safe, clean drinking water. Bell is also undertaking a Water leak detection initiative as part of a smart city partnership with the City of Markham. The water leak detection initiative will install sensors on water mains and hydrants to provide real-time information on water system conditions. The smart city partnership also includes initiatives around asset management, storm/ flood water monitoring, environmental monitoring, and energy management, helping to turn Markham into a "frictionless city".[96]

Similarly, Rogers Communications has partnered with Ericsson to pilot a 'Connected Water' solution for water quality testing in the City of Ottawa.[97] The pilot leveraged a combination of IoT, cloud and LTE mobile broadband technologies to gather real-time data to better predict, prevent and respond to potential issues related to water quality, including cleanliness and abnormal temperatures.

Connected Agriculture



The agriculture and agri-food sector accounts for close to 7% of Canada's GDP.[98] In Canada, greenhouse emissions from the agriculture sector stood at 72 $MtCO_2$ in 2017, which accounts for 10% of total greenhouse emissions in Canada that year.[99] The high emissions originate from fertilizer use, irrigation systems, and food waste.

The United Nations Food and Agriculture Program has noted that global food production must increase by 70% by 2050 to meet the demands of a growing population.[100] To increase crop yields and to simultaneously reduce the emissions produced by growing crops, the agriculture and farming industries will need to rely heavily on precision agriculture technology. Precision agriculture technology uses data gathering technologies (e.g., drones, satellite imagery, sensors), big data analytics, and precision application controls (e.g., autonomous tractors) to guide and optimize farm management practices, helping to reduce the environmental impacts of farming. These technologies allow farmers to use water, pesticides, and nutrients more sparingly and in exact quantities. Such hyper-precision farming means fewer wasted resources, less fuel consumed powering equipment, less environmental impact, and fewer GHG emissions.

Many of the benefits of precision agriculture will come from increased access to data from autonomous or remote vehicles. Drones will be used to capture high resolution images and provide real-time data to farmers. Sensors may be placed in fields to capture crop data and evaluate crop health. Precision machinery will use data to determine exact levels of pesticides and other inputs. GPS-guidance will allow for targeted applications of pesticides. All of these will require the transmission of huge amounts of data at very high speeds across a dense network of devices.

REDUCTION IN THE USAGE OF PESTICIDES IN AGRICULTURE

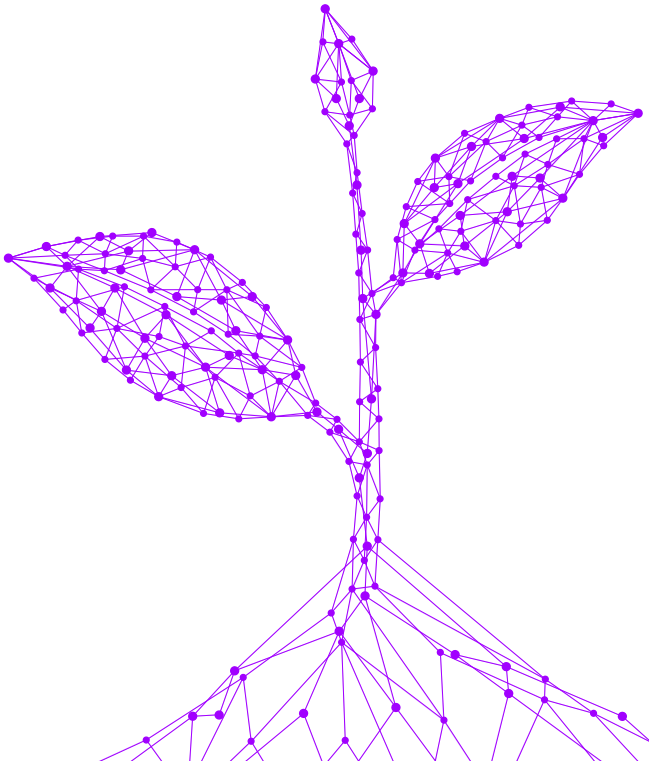
5G will allow farmers across Canada to make huge savings. Once 5G networks are established and further regulations are put in place to allow for precision agriculture technologies to take off in Canada, the average oilseed farmer working in the canola industry in Saskatchewan can expect to save upwards of $40,000 annually.[101] Applying the estimate of $40,000 in savings per farmer to the total number of oilseed farms in Canada, and using the average selling price of one of the key pesticides used in Canola crops (i.e. glufosinate), we can arrive at an estimate for total reduction in pesticide use in oilseed farms in Canada. Based on the above estimations, oilseed farmers across Canada can **reduce the annual usage of pesticides by 20%, leading to a possible 15.6 tonnes of pesticide savings per year in oilseed farming across Canada.**

M2M communication therefore has a huge role to play in precision farming. By enabling access to real-time operational data of all kinds, IoT applications can help improve the production of food resources through managing the location and performance of farm machinery, through the remote analysis of soil samples, field conditions, seeding rate and crop health, and the monitoring of storage and processing operations. With high speed and low latency, 5G can inaugurate an era of connected agriculture. A network of autonomous vehicles and remote devices connected by 5G will lead to substantial carbon abatement by enabling hyper-precision farming, by reducing water, energy and fertilizer use and by reducing the need for and the cost of massive equipment.

Canadian operators, like Bell Canada, have been actively involved in precision agriculture initiatives.

Bell Canada has collaborated with Farmers Edge, a Winnipeg, Manitoba-based precision agriculture company, to offer an IoT solution suite to farmers which includes crop monitoring, digital agronomy, satellite imaging and integrated farm data management.[102] Bell offers an IoT starter kit and proof of concept capabilities, allowing providers to test and verify the effectiveness of their solutions ahead of wide-scale deployment. Additionally, as of 2018, Bell rolled out their LTE-M network to support the rapidly growing use of IoT devices. Bell's LTE-M network will help enable the "Bell MTS Innovations in Agriculture Program" at the University of Manitoba. This program will encourage students to develop innovative IoT technology for agriculture and food science use cases.

IoT devices, potentially enabled by 5G, can help improve the efficiency of irrigation systems. The placement of sensors in the soil will allow farmers and researchers to monitor soil conditions, as well as crop water requirements. According to researchers at Chile's UCSC University, the implementation of remote sensors around farming areas has reduced the volume of water used by 70%.[103] With 5G connectivity, farmers can optimize their irrigation systems by accessing real-time data collected from remote sensors and use it to analyze where, in what volume and for how long their water resources should be deployed.



5G Will Play a Critical Role in Fighting Climate Change

5G's importance to abating emissions in other industries will be critical in helping Canada to achieve its emissions and climate targets. It will play a large role in reducing other types of environmental damage and pollution.

Our research shows that 5G technologies can have substantial beneficial impacts on Canada's environment. Technical network advancements mean that wireless networks will function more efficiently on a per-unit-of-data level. Given the projected increase in data consumption by Canadian consumers without network advancements, wireless industry emissions would be forced upwards by the constantly increasing demand. Due to these efficiencies, a fast 5G rollout in Canada can help save up to 10 $MtCO_2e$ over the next decade, even while data consumption increases.

We have presented a conservative quantitative estimation, expanding on previously published models, which shows that 5G use cases will enable abatement of up to 12.2 $MtCO_2e$ over the next five years. This is on top of what is already abated with 4G LTE and current state connectivity technology. Based on familiar use cases, this improvement will be due to the increased densification and bandwidth that 5G offers, which allows for more widespread sensor deployments, and the corresponding improvement in monitoring, communication, and control that this enables.

Beyond our exploration of familiar use cases with our quantitative estimation, we must recognize that 5G represents a huge leap over previous generations of wireless technologies. The ultra-low latency, massive bandwidth, and mobile edge compute capabilities that this technology brings will enable revolutionary use cases. Because the technologies and use cases are still being defined, meaningful estimations of abatement driven by these use cases is difficult. We have presented examples from the exciting research and advances currently being pursued in the realms of connected grids, transportation, buildings, and other areas. Abatement in transportation driven by networked convoying, or the reduction of physical business travel by deploying VR and AR technologies for conference attendees, are likely to have significant impacts on Canada's total GHG emissions. At the same time, the impacts of more abstract applications such as improved navigation and traffic management, or connected grid load management, are sure to have a positive impact. There may be additional use cases, both for more efficient networks (e.g. more efficient last mile infrastructure) and enabled abatement (e.g. cloud-based gaming or virtual travel).

5G and other wireless technologies have the potential to reduce environmental damage not directly related to climate change. Improved monitoring technologies will help to reduce potable water wastage from leaks in municipal networks, while similar applications can monitor hazardous waste or oil pipelines, ensuring that leaks are caught early. Our discussions with connected agriculture experts revealed that 5G will be important for reducing the overuse of fertilizers and pesticides, which result in excess runoff and contamination of natural water sources.

5G and other wireless technologies will play a key role in the effort to meet our emission commitments. Without the improved abatement and wireless network efficiency driven by these technologies, the gap would continue to grow. We have found a fast deployment can position Canada significantly closer to meeting its emissions targets than a slow deployment. Realizing these environmental benefits requires a recognition by all stakeholders of the importance of 5G to Canada, and the support from federal, provincial, and municipal authorities to remove barriers to deployment of 5G and create an environment that encourages private sector investment in 5G networks.

Glossary

Glossary of Key Terms Used

5G NR 5G	New Radio is the global standard for the air interface of 5G networks
CO_2e	Carbon dioxide-equivalent – for a given mixture and concentration of greenhouse gasses, the amount / concentration of CO_2 that would be equivalent in effect
CRAN	Centralized Radio Access Network
DRAN	Distributed Radio Access Network
Enhanced Mobile Broadband (eMBB)	Data-driven use cases requiring high data rates across a wide coverage area
EVs	Electric vehicles
Fifth Generation Wireless Technology (5G)	The fifth generation of cellular service, coming after 4G LTE. Characterized by much lower latency, and massively increased bandwidth over 4G LTE networks
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GHG	Greenhouse gas
HVAC	Heating, ventilation, and air conditioning
LTE-M	LTE-MTC (Machine Type Communication) is low power wide area (LPWA) technology standard by 3GPP in the Release 13 specification
M2M	Machine-to-machine communications
Massive Machine Type Communication (mMTC)	Type of communication between machines over networks where data exchange and actuation take place with minimal or no intervention from humans
Mobile Edge Computing (MEC)	Network architecture that brings cloud computing and data capabilities to the edge of wireless networks, and thus closer to the end user(s)
NB-IoT	Narrowband-Internet of Things (NB-IoT) is a standards-based low power wide area (LPWA) technology developed to enable a wide range of new IoT devices and services
Network Slicing	5G technology that allows for deployment of multiple virtualized and independent networks on the same physical network infrastructure
Scope One Emissions	The direct emissions under the control of an organization for example the gas consumed by a shipping vehicle or their facilities
Scope Three Emissions	All other indirect emissions from activities of the organization, such as emissions from sources not owned or under their control. These are generally the greatest share of carbon footprint and can include things like business travel and procurement
Scope Two Emissions	Indirect emissions generated from electricity purchased and used by the organization
Ultra-Low Latency Communications (URLLC)	New 5G service category accommodating emerging services and applications having stringent latency and reliability requirements
VR, AR, MR, XR	Virtual reality, augmented reality, mixed reality, extended reality
vRAN	Virtual Radio Access Network

Appendix

Quantitative model methodology: variables and assumptions

Accenture has developed an approach to provide a Canadian overview of the enablement impact that mobile generation communications technologies have on reducing carbon emissions across various sectors. The methodology adopted is an extension of the model and use case analysis established in the GSMA published report "The Enablement Effect"[104]. The objective of Accenture's study is to analyze the impact of current generation mobile technology and the incremental impact of 5G technology in enabling carbon emissions reduction in Canada.

GSMA MODEL METHODOLOGY

AVOIDED EMISSIONS [$kgCO_2e$] = AVOIDED EMISSIONS FACTOR [$kgCO_2e$/QTY] *QUANTITY [QTY]

The analysis covers ~30 use cases where mobile technology has the potential to reduce carbon emissions across six broad categories:
1. Smart Buildings
2. Smart Energy
3. Smart Living, Working, and Health
4. Smart Transport and cities
5. Smart Agriculture
6. Smart Manufacturing

In each use case, a mechanism has been identified that enables carbon emissions to be avoided. The mechanism is either travel avoidance/reduction resulting in avoided travel emissions, or energy use avoidance/reduction resulting in avoided energy emissions. The underlying rationale is based on enhancing mobile connectivity, as well as behavioral changes in consumers aided by availability of improved mobile technologies and smartphones.

To quantify total Canadian avoided emissions, the North America regional results are leveraged from the GSMA report and necessary assumptions are applied to arrive at the breakdown of avoided emissions for Canada. Below are details of assumptions and forecasts utilized in the methodology:

Quantity:

There are two types of use cases that are considered in the analysis: M2M connection based and smartphone user based. Hence, there are respectively two quantities included in the analysis. M2M connections for each use case (in Canada) is calculated by applying the percentage of 5G M2M connections in Canada of total IoT connections in North America in each respective use case reported in the GSMA paper. For smartphone users, smartphone connections (from GSMA) is used as a proxy. Smartphone connections for each use case (in Canada) is calculated in the same way as M2M connections in the above case.

Avoided emissions factor:

For the purpose of quantifying the impact of Canadian carbon emission reduction, Canadian avoided emissions factor is considered equivalent to North America as provided in the GSMA report.

The avoided emissions factor included in the GSMA report pertains to any mobile technology. Considering the report relates to the period 2018, when 5G technology was deployed in a limited way, it is assumed that the reported factor corresponds to 4G and prior mobile technologies.
To estimate the impact of 5G in the forecast period, an additional 5G multiplier is employed in the analysis to calculate 5G-enabled avoided emissions factor.

5G Avoided emissions factor = 4G Avoided emissions factor X 5G Multiplier

Currently 5G is still in an early stage of deployment. The impact of 5G vs. 4G and prior mobile technologies in reducing carbon emissions is dependent on a variety of factors and the evolution of 5G in the future. To account for this impact, a tiered approach is adopted for 5G multiplier as below:

1. Scenario One: The 5G multiplier is considered 1.0x, as the effectiveness of 5G in abatement is considered the same as previous generation 4G
2. Scenario Two: The 5G multiplier is considered 1.4x, as the effectiveness of 5G in abatement is considered to be 40% better than previous generation 4G
3. Scenario Three: The 5G multiplier is considered 1.9x, as the effectiveness of 5G in abatement is considered to be almost double previous generation 4G

As per 3GPP's specification, 5G network equipment and devices will consume only 10% of the energy consumed by 4G network equipment and devices[105], translating the upper limit of scenario 3 at 1.9x.

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