# 5G, the digital economy, and Canada's global competitiveness

November 2021

pwc

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# Executive summary

The deployment of 5G is important for Canada, as it is a core enabler of the digital economy. The digital economy represents the end-to-end digitization of business processes and every-day activities, and is achieved by integrating connectivity, software and hardware. The improvements in connectivity delivered by 5G are expected to accelerate the growth and impact of the digital economy. The growth of the digital economy is forecasted to deliver significant economic, environmental and societal benefits, including:

- **Economically,** an estimated increase in Canadian GDP of $94B annually by 2035.[1]
- **Environmentally,** 5G-enabled technologies will be used to optimize operating conditions and inputs of existing industrial processes to reduce emissions and water consumption.
- **Socially,** 5G-enabled technologies will impact the quality of life of Canadians by improving the delivery of key social services such as healthcare, education and transportation.

*The digital economy represents the end-to-end digitization of business processes and every-day activities, and is achieved by integrating connectivity, software and hardware. The improvements in connectivity delivered by 5G will further accelerate the growth and impact of the digital economy, through enabling use cases that will deliver a range of economic, environmental and societal benefits.*

The COVID-19 pandemic has accelerated a number of existing trends that have increased the demand for connectivity and the adoption of the digital economy. These trends include shifts in population centres, in entertainment preferences, in business operating models, in service preferences and in consumer purchasing habits, and a shift to localized and digitized supply chains. These trends further increase the importance of the digital economy and the need for fast, ubiquitous, 5G connectivity.

On 5G coverage, Canada currently ranks fifth among the G7, Australia and South Korea with 50% of the population covered, despite a later start date due to 5G spectrum allocation.[2] While this places it on par with many peer countries in coverage, Canada's exclusive reliance on low-band networks results in it being in a weak position, ranking 14th among a group of 25 leading countries in download and upload speeds (see Exhibit 1), as it has yet to deploy mid- and high-band 5G networks.

For example, download speeds on high-band networks in the US range between 245 Mbps (AT&T) and 618 Mbps (Verizon)[3], while in Canada, which is reliant on low-band networks, 5G download speeds range between 105 Mbps and 175 Mbps.[4] Moreover, Canada's 5G coverage has yet to fully extend to regional and rural areas which constrains its potential impact. In contrast, 5G coverage in the US has been expanded to cover less densely populated areas, including 92% of interstate highway miles.[5]

1 PwC Analysis
2 Data from GSMA Intelligence, for Q2 2021.
3 OpenSignal. July 2021. "Quantifying the mmWave 5G experience in the US".
4 OpenSignal. 2021. "Canada 5G Experience Report August 2021".
5 Harrigan, M. 2021. "Continuing to Deliver; Management Committed to 5-Year Targets". The Benchmark Company (Analyst Report)

The primary factors causing this are (i) Canada's slow spectrum allocations, (ii) complex regulations for accessing the passive infrastructure that is needed for network deployment, and (iii) competition from multinationals in the digital economy.

**Exhibit 1: Canada's 4G and 5G performance relative to 25 leading 5G countries (Dec 2020 - Feb 2021)**

| Category | 4G Rankings | 5G Rankings |
|---|---|---|
| Download speed (Mbps) | 2nd | 14th |
| Peak download speed (Mbps) | 1st | 16th |
| Upload speed (Mbps) | 7th | 14th |

Source: Open Signal

Compared to global peers in the G7, Australia and South Korea, Canada's 5G spectrum allocations are years behind for mid- and high-band frequencies. Canada is the last country among global peers to issue mid-band spectrum and one of only three countries (the others being France and the UK) that have yet to issue high-band spectrum. For 5G to fully enable the digital economy, all three bands of 5G are needed to ensure the right connectivity for select technology use-cases and innovation, and deliver near-ubiquitous geographic coverage to enable applications that are not employed solely in high-density areas such as autonomous vehicles and process automation in mining and agriculture.

Beyond spectrum allocation, factors such as the cost of 5G will impact network deployments. 5G is forecast to be more expensive than previous generations of network connectivity, with the total cost of ownership (TCO) estimated to be up to 71% higher relative to 4G networks.[6] This increase in TCO is primarily driven by three factors:

- 5G requires greater capital investment than previous generations due to the large number of installations required (macro cells and small cells which are expected to grow 3% and 25%, respectively, until 2025[7]) and the increased need for and cost of backhaul infrastructure.
- 5G networks need to reach near-ubiquitous coverage throughout the country (both rural and urban areas) to fully enable the broader digital economy.
- 5G networks will be more expensive to operate due to increased energy costs associated with increased data traffic, and other costs such as maintenance.

Peer countries recognize the importance of 5G for enabling the digital economy, and the additional costs and complexities involved with its deployment. As such, a number of peer countries have undertaken measures to facilitate 5Gs deployment. For example, select peer countries have reformed their regulatory regimes to provide fast and affordable access to passive infrastructure.[8] Notably, the Federal Communications Commission (FCC) in the US has instituted caps on review periods by states and municipalities for small cell installations ranging between 60 to 90 days (depending on the type of small cell installation).[9] Other examples of regulatory reform to promote 5G deployments include Spain's doubling of the length of spectrum license leases from 20 years to 40 years for the 700MHz band[10], and cutting reserve prices on the auction by 12.5% to 20%.[11]

6 GSMA. 2019. "5G-era Mobile Network Cost Evolution"
7 GSMA. 2019. "The 5G Guide"
8 CD Howe. 2021. "C.D. Howe Institute Telecommunications Policy Working Group, Communiqué #2: Governments Must Cut Through Their Red Tape to Build 5G".
9 FCC. 2018. "FCC 18-133: Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure Investment"
10 Laudette, C. 2021. "Spain cuts prices, eases conditions ahead of July 5G spectrum auction". *Reuters.*
11 Wieland, K. 2021. "Spain doles out 700MHz spectrum for $1.1B". *LightReading.*

These actions are within the backdrop of the competitive landscape of the digital economy, where value is increasingly accruing away from connectivity and network operators towards a broader ecosystem of hardware, software and service competitors. For example, companies that provide 5G-enabled solutions, such as large multinationals (e.g., service providers like IBM, software providers like Amazon, and hardware providers like ABB) are forecast to capture around 89% of the value from 5G-enabled technology use-cases, with connectivity's share of the total being only around 11%. These large multinationals' global scale (for example, Apple generates more than 14 times the annual revenue of the largest Canadian Telco), and concentration of financial and human capital allows them to dominate the markets they compete in, making it difficult for local network operators to compete, despite investing in the telecommunications networks that enable the creation of market value in the digital economy. In addition, the telecommunications industry is facing significant disruptions from technologies such as embedded SIM (eSIM) technology which can be used by equipment manufacturers to disintermediate telecom operators, and low earth orbit (LEO) satellites which are a potential alternative method to deliver connectivity to consumers and businesses.

The digital economy, Canada's global competitiveness and the rollout of 5G are intertwined. As a result, Canada should aim to maintain a healthy telecommunications industry, where large scale operators are able to generate the cash flow required to fund the deployment of 5G, including mid- and high- band networks. This is required to support the needs of the growing digital economy and keep pace with global peer countries in 5G performance.

To ensure a healthy telecommunications industry, Canada should aim to create an environment that has:

1. The appropriate level of market incentives that drive improved customer value and investment in innovation.
2. A predictable and fair set of regulations that promote competition, investment and network security, while providing sufficient flexibility to adapt with the changing needs of the digital economy. For example, simplifying regulations that govern access to passive infrastructure for 5G deployments.
3. An industry view that acknowledges the broader impact and benefits that come from connectivity enabling the digital economy, and the new competitive landscape within it.

Through enabling a healthy telecommunications industry, Canada will ensure that network operators have the ability to make the significant investments needed to deploy 5G at pace and close the gap with global peers for mid-band and high-band networks. This will enable the continued growth of Canada's digital economy, support Canada's global economic competitiveness, and support the realization of the many forecasted environmental and societal benefits from 5G.

# 1: The digital economy enabled by 5G will support Canada's post-COVID recovery and global competitiveness

As a core enabler of the digital economy, the deployment of 5G is forecasted to deliver significant economic, environmental and societal benefits for Canada. 5G is also critical for Canada's post-COVID recovery and global competitiveness.

With the transition to the digital economy, Canada is in an enviable position, having a strong economy and expertise in foundational technologies of the future. Canada should prioritize the deployment of 5G networks to enable its researchers and businesses to continue innovating and improve its relative global competitiveness.

## 5G connectivity is a core enabler of the digital economy

The digital economy, powered by connectivity, is revolutionizing how businesses operate and how people interact with each other. It represents the end-to-end digitization of business processes and everyday activities, and is achieved by integrating connectivity, software and hardware. While the transition to the digital economy is already underway, 5G will further accelerate its growth and impact. This ongoing transition is evidenced by the expected growth in the number of M2M/IoT devices, a key technology component of the digital economy[12], which are forecasted to increase by approximately 131% from 2018 to 2023, while all other connected devices (e.g., tablets, smartphones) are expected to grow by approximately 19% over the same time period.[13]

***5G is the next generation of connectivity that is expected to deliver faster connections (up to 20 times the speeds of 4G and 10 times the connection density), increased network capacity (up to 100 times the traffic capacity of 4G), ultra-low latency and improved reliability (up to 10 times lower latency than 4G), and enhanced security with improved security protocols.***

In the digital economy, the deployment of 5G connectivity will enable a number of solutions that are forecasted to deliver economic, environmental and societal benefits. Examples of the solutions include cloud robotics, connected autonomous vehicles, augmented reality and virtual reality applications, and remote monitoring of industrial operations. The digital economy technology stack (Exhibit 2) on which these solutions are based is composed of:

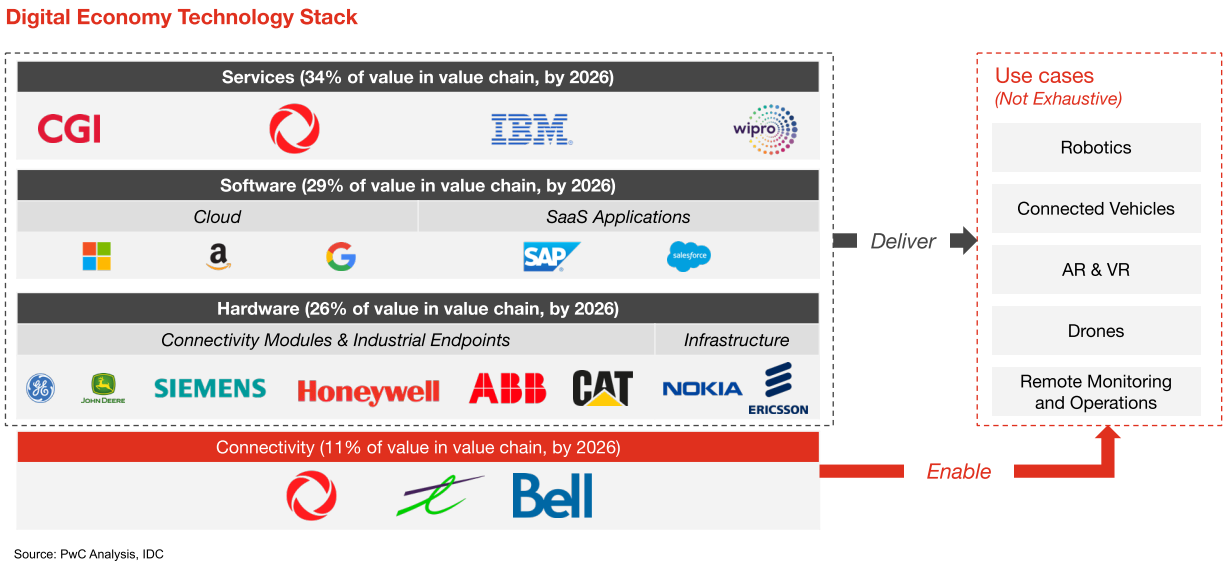
- *Services:* The initial IT and installation services (e.g., project-based services, consulting, systems integration) and ongoing services (e.g., managed services, support and training and related network interfaces). Examples of leading companies in this market include IBM, Oracle and CGI.

12 United Nations Conference on Trade and Development. 2019. "Digital Economy Report 2019, Value Creation and Capture: Implications for Developing Countries"

13 PwC Analysis, based on data from Cisco. 2020. "Cisco Annual Internet Report (2018–2023) White Paper".

- *Software:* Programs used to enable solutions such as data processing applications to organise and access information, data analytics software, and software required for end-user input. Examples of leading companies include Amazon, Microsoft and Google.
- *Hardware:* Solution endpoints (e.g., sensors, IoT devices), computing hardware (e.g., edge computing hardware) and telecommunications infrastructure. Leading companies of hardware vary by application and industry. For example, in the automotive industry, large OEMs such as Mercedes, Volvo and General Motors are building autonomous vehicles. In the industrial sector, companies such as Siemens and ABB provide smart sensors that offer a range of capabilities including temperature, proximity, image, light, pressure and humidity monitoring.
- *Connectivity:* Enables the digital economy technology stack by allowing for the transfer of large amounts of data between all points in the stack including sensors, gateways, routers, applications and platforms. The improvements in connectivity that 5G delivers will allow for larger and faster data transfers while connecting a larger number of devices together, thereby enabling advanced solutions. In Canada, connectivity is primarily provided by the largest three mobile network operators: Rogers, Bell and TELUS, as well as a number of regional MNOs.

**Exhibit 2: Connectivity enables the next generation of digital economy applications and tools**




Source: PwC Analysis, IDC

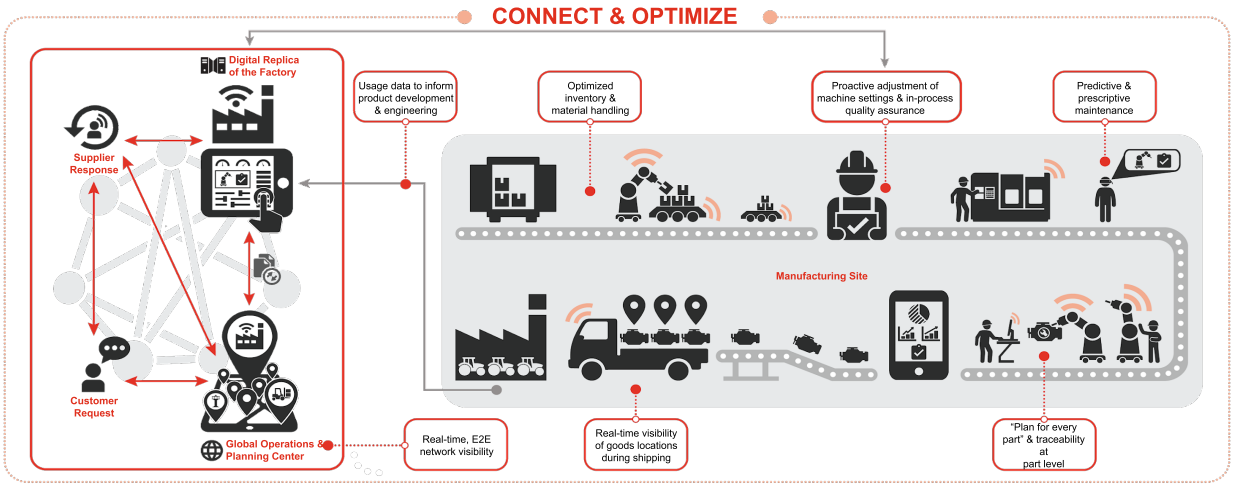
The automotive industry provides an example of where connectivity and the digital economy can provide productivity benefits and help businesses meet pressing challenges. Key challenges such as greater customer expectations regarding customization, the shift towards shorter model lifecycles, the evolution away from the internal combustion engine and uncertainty in supply chains is forcing automakers to change how they think about the traditional assembly line. Automakers will have to adopt digitally-enabled and flexible processes that leverage the combined power of fast data collection, communication and computation to cope with these challenges.

While connectivity enables the integration of the digital economy technology stack and the delivery of these solutions, it will only account for 11% of the value pool enabled by 5G, by 2026. Conversely, services will account for 34%, software for 29% and hardware for 26% of the value (see Exhibit 2). The implications of these dynamics are:

1. The companies investing in 5G networks and providing connectivity are not capturing a significant portion of the value they are generating. While connectivity is a core enabler of the digital economy technology stack, it only accounts for a small share of the value pool.
2. The services, software and hardware categories are dominated by large multinational companies, which have the financial and human resources to compete at a significantly larger scale than local telecommunications providers.

An example of the digital economy is a "smart factory" illustrated in Exhibit 3. In this example, the factory has been digitized end-to-end. This is enabled by the integration of hardware capable of capturing and communicating vast amounts of data, software capable of analyzing the data and driving decision-making, and ultra-fast, ultra-reliable connectivity that connects all layers.

**Exhibit 3: The smart factory archetype is an example of the new digital economy**




Source: PwC Analysis

These types of capabilities underpinned by connectivity are important in industries such as car manufacturing, which has challenges such as greater customer expectations regarding customization, the shift towards shorter model lifecycles, and uncertainty in supply chains. These challenges are forcing automakers to change how they think about the traditional assembly line. To cope, automakers are adopting digitally-enabled and flexible processes that leverage the combined power of fast data collection, communication and computation.

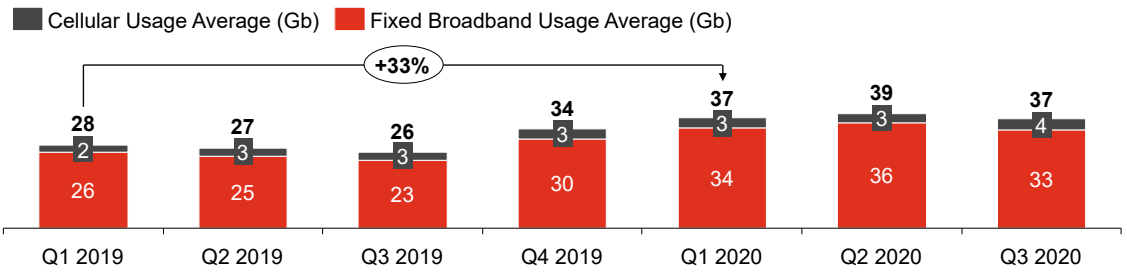
## In focus - The flexible plant

One example that leverages "smart factory" capabilities and embeds flexibility in the process is the *flexible plant.* In this flexible factory, automated guided vehicles (AGVs) safely carry around chassis, parts and sub-assemblies to different areas to complete tasks in an optimized sequence. In contrast to the more traditional assembly line where cars are assembled on a fixed, predetermined sequence, the sequences in the modular plant are determined based on resource availability (e.g., workers, robots, parts) to optimize inputs. To achieve this, machines in the process must be connected and communicate a vast amount of information in real-time. That information can be gathered into a central *Data Lake* to drive the optimization.[14,15] This embedded flexibility, enabled by fast and reliable connectivity, can support automakers in coping with the significant disruption facing the industry. Automakers such as Mercedes and Porsche are already implementing some of these concepts in their factories. This type of modular plant is a good example of how the different components of the digital technology stack are integrated to deliver enhanced solutions. In this application, software is needed to analyze the data captured by sensors on each machine; the sensors, AGVs and the computing infrastructure represent the hardware; and the associated services include the cloud computing services to store and process data. The whole solution is underpinned by connectivity that enables the continuous transfer of vast amounts of data between each layer.

The growing importance of the digital economy and connectivity has been accelerated by the COVID-19 pandemic, with data consumption increasing by 33% year-over-year between Q1 2019 and Q1 2020 (Exhibit 4).[16] This is a result of six trends that have been accelerated by the pandemic:

1. **Shifts in population centres:** An increase in remote working and learning will push for greater video usage, while network coverage will need to be geographically expanded.
2. **Shifts in entertainment preferences:** Growth in gaming, digital events, video streaming and the rise of AR/VR will all increase bandwidth consumption.
3. **Shifts in business operating models:** Business processes are increasingly being digitized and rely on vast data transfers.
4. **Shift to localized and digitized supply chains:** Connected supply chains solutions will improve competitiveness, but will require greater bandwidth as the number of connected endpoints increases.
5. **Shifts in service preferences:** Preferences for digital services lead to an increase in substituting physical interactions for digital ones in industries such as healthcare.
6. **Shifts in consumer purchasing habits:** An increase of content on eCommerce channels and an increased demand for digital services require greater bandwidth.

**Exhibit 4: Monthly average data usage in Canada (Gb) – Fixed Broadband and Cellular**




Source: OpenSignal Data, PwC Analysis

14 Strategy&. 2021. "At the end of the line".
15 Ericsson. "Safer vehicle production with 5G".
16 PwC Analysis, OpenSignal data

## 5G connectivity will bring economic, environmental and societal benefits to Canada

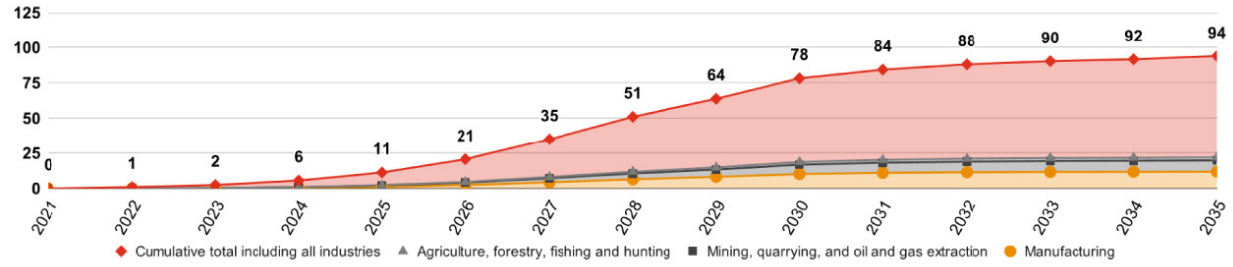
The accelerated transition towards the digital economy and the deployment of 5G connectivity will have significant economic, environmental and societal benefits for Canada, including:

- *Economic benefits:* By 2035, the introduction of 5G connectivity in Canada is expected to increase GDP by approximately CA$94 billion annually[17], with all major Canadian industries benefiting.
- *Environmental benefits:* 5G-enabled technologies work to optimize inputs and process operations to reduce emissions and water consumption.
- *Societal benefits:* 5G supports numerous use cases in areas such as education, healthcare and transportation that can improve the delivery and efficiency of these services.

## Enhanced 5G connectivity will benefit Canada's economic development

Forecasted economic benefits of approximately CA$94 billion will be delivered across Canadian industries by the deployment of 5G-enabled technologies. Exhibit 5 shows a stacked area graph that details the expected annual GDP impact of deploying 5G networks, breaking out three key goods-producing industries in Canada for which illustrative 5G use cases and their impact are listed further below.

**Exhibit 5: Annual impact of 5G on the Canadian economy and for select industries (CA$, Billions)**




Source: PwC Analysis, IHS Markit

Notes: 2020 Canadian dollars

- **Manufacturing**
  - *Autonomic operations* allow manufacturing plants to optimize sequencing and resources to react in real-time to changes such as fluctuations in supply and demand or equipment breakdowns. This type of operation goes beyond current automation capabilities (e.g., robot arms in an assembly line completing tasks in a predetermined sequence) and creates systems that are capable of real-time decision making and flexibility.[18]
  - *Digital twins* allow plant operators to comprehensively track and model plant operations, which enables improved decision making, leading to better plant efficiency (i.e., greater output, reduced waste). For example, digital twins can be used to conduct predictive maintenance, which can reduce downtime, and to optimize operating conditions to improve the economics of a factory.[19]

17 PwC Analysis
18 Menascé et al. 2015. "Autonomic smart manufacturing". *Journal of Decision Systems.*
19 Hartmann and Van der Auweraer. 2020. "Digital Twins". Siemens.

- **Mining and Oil & Gas**
    - *Self-driving trucks for material hauling* can improve efficiency by 10 to 30%[20,21] by optimizing driving patterns to reduce fuel consumption, engine wear and downtime.[22]
    - *Automated drill rigs* can bring efficiencies of up to 40% to the current process by increasing machine operating hours, allowing operators to either increase drilling or reduce the number of machines required. This can also improve the safety of the mine by eliminating the movement of staff through dangerous areas.[23]
- **Agriculture**
    - *5G-enabled precision agriculture (PA)* allows farmers to optimize their input consumption (e.g., water, fertilizer), monitor equipment and improve yields. The use of PA has increased yields by 4% and is expected to further increase them by 6% as the technology becomes more widely adopted. Similarly, herbicide usage is estimated to have decreased by 9% due to the adoption of PA, and can be reduced by a further 15% from current levels as PA technologies are more widely deployed. This means increased revenues and reduced costs for farmers.[24]

## 5G connectivity will support the reduction of environmental footprints through the optimization of inputs

The introduction of 5G-enabled technologies will also help to mitigate environmental concerns and support Canada in achieving its global environmental commitments such as the Paris Agreement and the UN sustainable development goals. By leveraging the vast amounts of data being generated in processes today, improved decision-making and automation can reduce emissions, increase energy efficiency and improve water usage and quality, thereby reducing environmental impacts in Canada.

1. *Reducing emissions and improved energy efficiency:* 5G-enabled technologies can be used to improve decision making around operating conditions with the aim of reducing emissions. For example, better control of the combustion process in boilers installed at chemical plants can improve energy efficiency by 3% to 5% alone.[25,26]
2. *Water Sustainability:* Reducing water consumption is key in ensuring a sustainable freshwater supply in Canada. Care is also needed to minimize water pollution and maintain appropriate water quality. 5G technologies can be used to improve decision making on water consumption and quality. For example, precision agriculture (PA) techniques using soil sensors allow for automated irrigation which optimizes water usage. In North America, PA has already decreased water consumption by 4%, and could lead to another 21% decrease when implemented more broadly.[27] Another example includes deploying smart water sensors as part of smart cities projects to improve water conservation practices through consumption-based feedback for customers.[28] Sensors can also be used to monitor water quality in real time, allowing cities to quickly mitigate quality issues.[29]

20 Accenture. 2020. "Mined Over Matter: The Not-Too-Distant Future of Autonomous Operations".
21 Ericsson. 2018. "A case study on automation in mining".
22 Cisco. 2020. "Wireless Networks enabling autonomous vehicles for underground mines".
23 Ericsson. 2018. "A case study on automation in mining".
24 Association of Equipment Manufacturers. "Environmental benefits of precision agriculture".
25 Energy Star. 2017. "Energy Efficiency and Cost Saving Opportunities for Ammonia and Nitrogenous Fertilizer Production"
26 AT&T. 2021. "Reducing emissions. It's good for the world, and good for business."
27 Association of Equipment Manufacturers. "Environmental benefits of precision agriculture".
28 Cominola et al. 2021. "Long-term water conservation is fostered by smart meter-based feedback and digital user engagement". *NPG Clean Water.*
29 Verizon. 2021. "Technology & Water: How 5G and IoT Can Update Our Water Infrastructure".

## 5G-enabled use cases will improve the delivery of key social services such as healthcare, education and transportation

Finally, enhanced 5G connectivity allows governments and other social enterprises to provide higher quality services on a more cost-effective basis. For example:

1. *Healthcare and Social Assistance:* As Canadians age, the pressures on the healthcare system and the associated costs will continue to grow.[30] 5G-enabled technologies can support healthcare systems by improving patient outcomes while reducing overall costs. Notably, enhanced remote patient monitoring has the potential to reduce the length and costs of hospitalizations by enabling earlier interventions.[31] The use of AI-enabled remote diagnostics can also reduce healthcare resource intensity by freeing up clinician time and improving outcomes through better predictive care.[32]

2. *Urban and rural divide:* 5G also has the potential to support the deployment of broadband to rural communities and support economic development in sectors that are key to rural economies. For example, low and mid-band 5G connectivity with its ability to deliver broadband to a wide area can be used as a more economical method to bridging the rural-urban connectivity gap by bringing broadband connectivity to rural communities through the use of FWA.[33,34,35] This addresses a significant challenge for network operators as the network infrastructure required for broadband delivered by previous generations of connectivity was cost prohibitive.[36] 5G can improve the overall economic competitiveness in regional and underserved communities supporting the creation of more high-tech, high-skill jobs in rural areas, which indirectly create other jobs in the community.[37]

3. *Education:* The growth of online learning before and during the pandemic, and the rise of new online teaching methods to engage students requires improved connectivity. 5G-enabled Fixed Wireless Access (FWA) can help bridge the online learning gap in homes and schools where wired broadband connections are unfeasible (e.g., rural areas). 5G's low latency and increased capacity also allows for more immersive teaching tools to be used such as VR and AR headsets that allow teachers to conduct virtual field trips to sites around the world.[38]

4. *Transportation and infrastructure:* As urban spread increases[39], a trend accelerated by the COVID-19 pandemic, the need for efficient and safe transportation systems becomes more pressing. 5G-enabled applications can improve mobility by improving transportation resource efficiency and safety. For example, the automation of public transit can improve system efficiency and user wait times.[40] The improvement in asset-utilization can allow cities to expand public transit services. 5G can also enable improved infrastructure management by connecting large amounts of sensors to collect data and drive improvements in maintenance practices.[41]

30 The Conference Board of Canada. 2018. "Meeting the care needs of Canada's aging population"
31 Taylor ML et al. 2021. "Does remote patient monitoring reduce acute care use? A systematic review". BMJ Open
32 Ahuja A. 2019. "The impact of artificial intelligence in medicine on the future role of the physician". *PeerJ.*
33 GSMA. 2021. "Vision 2030, Insights for Mid-band Spectrum Needs".
34 Oswald, E. 2019. "Will 5G fix America's rural broadband woes? We asked the experts". *Digital Trends.*
35 T-mobile. 2021. "How 5G Will Bring High-Speed Internet To Underserved Communities". *Forbes.*
36 The House of Commons. 2018. "Broadband connectivity in rural Canada: Overcoming the digital divide"
37 Moretti, E. 2012. "The Multiplier Effect of Innovation Jobs". MIT Sloan Management Review.
38 University of Toronto. "Virtual Field Trips and General VR Content Apps"
39 Global News. 2016. "Census 2016: Urban spread continues — but at what cost?"
40 Zhai et al. 2020. "Assessing the Impacts of Autonomous Bus-on-Demand Based on Agent-Based Simulation: A Case Study of Fuyang, Zhejiang, China". *Journal of Advanced Transportation.*
41 EY. 2019. "Four ways 5G connectivity will make cities smarter".

## 5G connectivity supports Canada's capabilities in leading technologies

Canada is well positioned to benefit from these 5G-enabled technologies. Canada has a strong economy that is 9th globally in nominal GDP[42] and it is a leader in the development and adoption of technologies in many industries including agriculture, healthcare and resource extraction. Canada also enjoys leading connectivity networks and is well-positioned to be an innovation leader, ranking 9th globally in the WIPO global innovation index for innovation input.[43] Notably, in artificial intelligence, Canadian companies and researchers are ranked first globally in AI patents on a per capita basis.[44] Toronto also has the largest concentration of AI start-ups in the world. In fact, the Global AI index ranks Canada 4th in the world in the subject.[45] In Quantum computing research, Canada is among the top six countries in the world[46] with a strong ecosystem of researchers, public funding and incubators.[47] Canada boasts many leading quantum technology companies such as D-wave and Xanadu.[48,49]

The future of some of these leading technologies is expected to be increasingly reliant on enhanced connectivity delivered by 5G. To enable Canadian businesses, researchers and government institutions to continue developing leading capabilities in these key technologies, it is important that 5G deployment is delivered at pace for Canada's global competitiveness.

42 The World Bank. 2020.
43 World Intellectual Property Organization (WIPO). 2020. Global Innovation Index 2020.
44 University of Toronto. 2020. "Canada's AI Ecosystem Report"
45 University of Toronto. 2020. "Canada's AI Ecosystem Report"
46 Rowell, M-C. 2021. "Canada well-positioned as a world leader in quantum technologies". *Global Advantage Consulting.*
47 Gibney, E. 2019. "Quantum gold rush: the private funding pouring into quantum start-ups". *Nature News Feature.*
48 Gibney, E. 2019. "Quantum gold rush: the private funding pouring into quantum start-ups". *Nature News Feature.*
49 Pool, R. 2020. "A new kind of quantum". *The International Society for Optics and Photonics.*

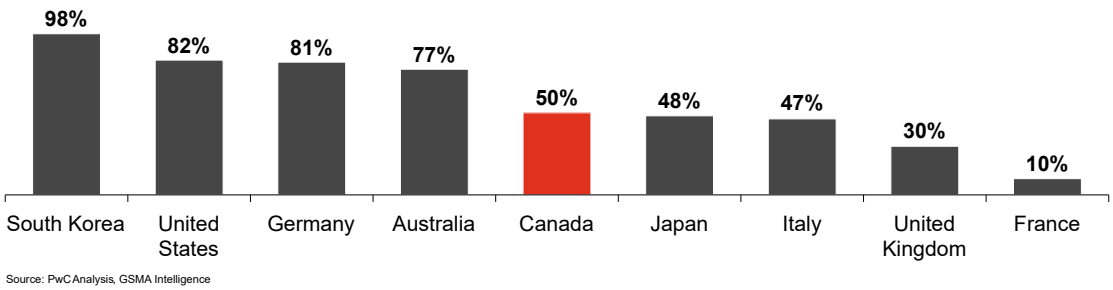
# 2: Canada is lagging global peers in the deployment of 5G

Considering the significant benefits of 5G and the digital economy, building 5G networks should be a national priority. However, not all types of 5G networks are created equal. 5G connectivity comes in three broad categories: low-band, mid-band and high-band networks. To enable the full value of the 5G-enabled digital economy, and bring about the economic, environmental and social benefits promised by 5G, all three types of connectivity are required as each one has trade-offs.

- Low-band networks are ideal for covering large areas and can be deployed to bring connectivity to less densely populated regions. Low-band performance is considered an evolution of current 4G capabilities, and is aimed primarily at consumer applications.
- Mid-band spectrum is highly prized as the networks deployed on these bands combine the positive attributes of low-band and high-band networks, albeit with some trade-offs. They provide high-performance networks to enable some data-demanding applications, while also covering larger areas than high-band networks.
- High-band networks provide the best performance. These types of networks provide orders of magnitude in improvements over 4G performance, with speeds that are up to 20 times faster, and ultra-low latency of down to 1ms (compared to 36 to 48ms for 4G). They are required to enable the most data-demanding, low latency, use cases in the digital economy. However, high-band networks are expensive as they require a large number of small cell installations since their signals do not travel far (less than a few hundred metres) and do not penetrate through infrastructure easily. It is generally economically challenging to cover large areas with high-band 5G networks.

Currently, 5G deployments in Canada have been limited to low-band networks as the economics of low-band 5G networks are broadly similar to 4G networks and low-band spectrum has already been made available. Notably, while Canada lags behind the leaders, Canada's 5G coverage is on par with many peer countries (see Exhibit 6).

**Exhibit 6: 5G network coverage, by population (Q2 2021)**




Source: PwC Analysis, GSMA Intelligence

In contrast to the 4G era however, Canada's relative 5G network performance lags behind peer countries as it lacks mid- and high-band networks (see Exhibit 7[50]). For example, in the US, high-band networks deliver between 245 Mbps (AT&T) to 618.4 Mbps (Verizon) average download speeds.[51] In Canada, current 5G speeds range between 105.1 Mbps to 174.8 Mbps.[52] Although high-band network coverage is still currently geographically limited in the US (average time connected to high-band 5G networks ranges from 0.5% to 0.8% of the time[53]), it enables the full capabilities of 5G and the technologies 5G supports.

**Exhibit 7: Canada's 4G and 5G performance relative to 25 leading 5G countries (Dec 2020 - Feb 2021)**

| Category | 4G Rankings | 5G Rankings |
|---|---|---|
| Download speed (Mbps) | 2nd | 14th |
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Source: Open Signal

Moreover, Canada's 5G coverage has yet to fully extend to regional and rural areas which constrains its potential impact[54], unlike in the US where coverage has been broadened to less urban areas. For example, in the US, T-Mobile's network covers 92% of interstate highway miles.[55]

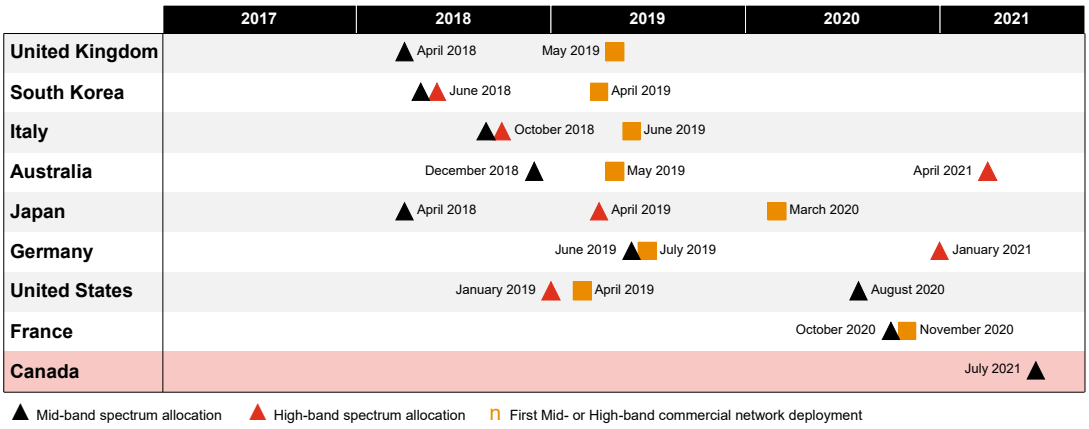
Canada is currently lagging peer countries in 5G performance because of three primary factors:

1. *Canada's spectrum allocation is behind other countries.*

   Canada is the last country among the G7, Australia and South Korea to issue mid-band spectrum and one of only three countries (the others being France and the UK) that have yet to issue high-band spectrum (see Exhibit 8). The first mid-band spectrum auction has only recently concluded (July 2021) and high-band spectrum auctions are not expected until 2024[56], meaning that details on mid- and high-band network rollouts have yet to be announced. Furthermore, the amount of spectrum available for large operators in Canada is also below global industry standards.[57] Canada's mid-band spectrum auction offered only 200 MHz, of which 50 MHz were set aside for small and regional operators. The total of 150 MHz available to Bell, TELUS and Rogers is misaligned with both the International Telecommunications Union's minimum requirement of 100 MHz per provider and global peers' average amounts of spectrum per operator (for example, South Korea averages around 90 MHz per operator).[58]

50 Khatri, H. 2021. "In the 5G era, Canada is losing global leadership due to spectrum challenges". *OpenSignal.*
51 OpenSignal. July 2021. "Quantifying the mmWave 5G experience in the US".
52 OpenSignal. 2021. "Canada 5G Experience Report August 2021".
53 OpenSignal. 2021. "Canada 5G Experience Report August 2021".
54 PwC review of BCE, TELUS and Rogers 5G coverage maps as at 30-Aug-2021.
55 Harrigan, M. 2021. "Continuing to Deliver; Management Committed to 5-Year Targets". *The Benchmark Company (Analyst Report)*
56 Posadzki, A. 2021. "Canadian spectrum auction raises $8.9-billion as telecoms grow 5G wireless services". The Globe and Mail.
57 GSMA. 2021. "5G Spectrum: GSMA Public Policy Position".
58 GSMA. 2020. "5G and economic growth"

**Exhibit 8: Canada's 5G spectrum allocations and its rollouts of Mid- and High-band networks are behind peer countries**




Source: EU 5G Observatory,Analysys Mason, ACMA, CTIA,Ofcom, Korea Economic Institute of America, ITU,Commsupdate, Government of Canada

2. *The return on investment for network operators is more uncertain than previous generations.*

   As value pools shift and network costs increase in the 5G era, a factor accentuated by Canada's geographic dispersion, the return on investment for 5G is uncertain for network operators. While the benefits of 5G are clear, the costs of 5G deployments are higher than previous generations, with the potential to cost up to 71% more than 4G.[59] The evolving market dynamics of the digital economy also favours large multinational companies. As discussed in Section 1, the majority of the value (around 89% by 2026) in the digital economy will be generated in markets (software, hardware, services) dominated by large multinational players such as Google, Amazon and GE. In contrast, connectivity that enables the delivery of solutions will only comprise around 11% of the value in the digital economy by 2026.

3. *The presence of complex regulations regarding access to passive infrastructure.*

   Access to passive infrastructure is a challenge for 5G deployment, as network operators need to install a higher density of telecommunications equipment for 5G. Fast and affordable access to this infrastructure is key in supporting faster and more affordable network deployments.[60]

   To accelerate the rollout, global peers have reformed their regulatory regimes to provide easier access to passive infrastructure. For example, the Federal Communications Commission (FCC) in the US has instituted caps on review periods by states and municipalities for small cell installations ranging between 60 to 90 days (depending on the type of small cell installation).[61] In Canada, efforts are ongoing as the federal government has committed to improving the current process.[62]

59 GSMA. 2019. "5G-era Mobile Network Cost Evolution"
60 CD Howe. 2021. "C.D. Howe Institute Telecommunications Policy Working Group, Communiqué #2: Governments Must Cut Through Their Red Tape to Build 5G".
61 FCC. 2018. "FCC 18-133: Accelerating Wireless Broadband Deployment by Removing Barriers to Infrastructure Investment"
62 Government of Canada. 2019. "High-Speed Access for All: Canada's Connectivity Strategy".

## In focus - The US has accelerated 5G deployment by quickly auctioning spectrum and simplifying network construction regulations

The United States considers 5G a key element for economic competitiveness. President Biden has promised to direct funds towards "new breakthrough technology R&D programs to direct investments to key technologies in support of US competitiveness – including **5G**, artificial intelligence, advanced materials, biotechnology, and clean vehicles".[63] The current Acting Chairwoman of the FCC has stated that "[The United States'] economic recovery and security in a post-pandemic world depends on [the United States'] ability to lead in fifth-generation wireless technologies […]".[64] The legislative branch in the US has also recognized the importance of technology in bolstering competitiveness. The "United States Innovation and Competition Act of 2021" has been passed by the Senate, committing over $250 billion to cutting-edge research, including for research in 5G technology.[65],[66]

To support the deployment of 5G networks, the United States has focused on four key policy levers:

1. *Promoting facilities-based competition:* The US has taken a facilities-based competition approach to encourage innovation, price competition and network investments. The primacy of facilities-based competition is recognized in Federal Communications Commission (FCC) rulings that state that service-based competition measures (e.g., unbundling obligations) are to be mandated only when they are shown to not "frustrate" facilities-based competition.[67] The FCC cites economic studies and multiple decisions from the judicial branch (e.g., the US Supreme Court, the D.C. Circuit) and its own analyses to stress the need for facilities-based competition to promote competition and network infrastructure investments.[68,69]
2. *Accelerating spectrum availability:* The FCC has prioritized rapidly auctioning mid and high-band spectrum. This includes making spectrum previously reserved for federal government operations available for commercial use.[70] The US also continues to release spectrum in desirable bands to enable 5G technology as is evidenced by its 2021 release of spectrum in the 3.45-3.55 GHz band.[71]
3. *Reducing barriers to infrastructure investments:* A number of measures have been instituted by the FCC to facilitate access to infrastructure and speed up regulatory decisions. These include instituting caps on the regulatory review period for the building of new small cell installations and reforming regulations on small cell installations requirements.[72]
4. *Subsidizing deployment of 5G in rural areas:* The FCC has created the 5G Fund for Rural America, which will distribute $9 billion over 10 years to support the deployment of 5G connectivity in rural areas. $1 billion from the fund is earmarked to support the deployment of precision agriculture technologies.[73]

63 Biden Harris Democrats. "The Biden Plan to Ensure the Future is "Made in All of America" by all of America's Workers"
64 FCC. 2021. "Statement of Acting Chairwoman Jessica Rosenworcel regarding Facilitating Shared Use in the 3100-3550 MHz Band, WT Docket No. 19-348; Auction of Flexible-Use Service Licenses in the 3.45-3.55 GHz Band".
65 DLA Piper. 2021. "With the goal of countering China's tech ascendancy, the US Senate approves the US Innovation and Competition Act"
66 McKinnon, J. 2021. "Senate Approves $250 Billion Bill to Boost Tech Research". *Wall Street Journal.*
67 FCC. 2017. "FCC 17-43"
68 FCC. 2020. "Modernizing Unbundling and Resale Requirements in an Era of Next-Generation Networks and Services".
69 Singer, H. 2016. "Assessing the Consequences of Additional FCC Regulation of Business Broadband: An Empirical Analysis". *Economists Incorporated.*
70 FCC. 2021. "Facilitating Shared Use in the 3.1-3.55 GHz Band"
71 FCC. 2021. "FCC Opens 100 Megahertz of Mid-Band Spectrum for 5G: New 3.45 GHz Band Rules Put FCC on Track for 5G Auction This Year".
72 FCC. "America's 5G Future"
73 Ibid.

# 3: 5G is different and more expensive than previous technology generations

Impacting the pace of 5G network deployment is the higher cost relative to previous network technology generations (3G, 4G) of 5G, due to greater capital investment requirements, the increased operational costs and the need to reach near-ubiquitous coverage throughout the country (both rural and urban areas) to fully enable the digital economy.

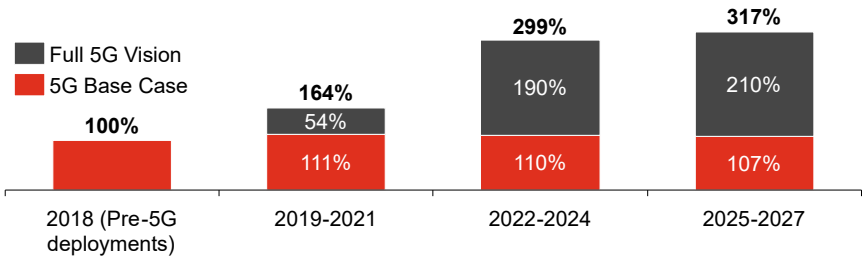
## 5G deployment requires greater capital investments and operational costs than previous generations

Overall, increases in 5G capital and operating costs significantly increase the total cost of ownership (TCO) for network operators. This increase in TCO can range between 23% to 71% relative to 4G networks, depending on how fast and how broad 5G network deployments are.[74]

5G networks are more expensive to deploy and operate than previous generations due to three primary cost drivers.

1. *The capital costs associated with purchasing and installing new telecommunications equipment:* The capital cost of more macro cells and small cells—which are expected to grow by 3% and 25% in numbers, respectively, to 2025[75]—along with the increased need for backhaul infrastructure will be a significant investment for network operators. Overall, by 2025, telco capital expenditures are expected to increase anywhere between 7% to 217% from 2018 levels[76] as shown in Exhibit 9.
2. *The need for near-ubiquitous coverage:* The scale of investment is augmented by the need for 5G networks to provide near-ubiquitous coverage to fully enable applications that are not employed solely in high-density areas (e.g., autonomous vehicles on highways and self-driving trucks on remote mine sites). The wide range in capital cost increases displayed in Exhibit 9 is in part driven by the different deployment scenarios considered by network providers. The more conservative estimate (the base case) accounts only for the capacity expansions required for increasing data traffic. The more aggressive case (full 5G vision) shows the impact of providing broader and higher performing 5G coverage (e.g., mmWave for 25% of the population, high-bandwidth 5G coverage in rural areas).[77]

**Exhibit 9: Expected CAPEX increase for network operators relative to 2018 due to 5G**




Source: GSMA

74 GSMA. 2019. "5G-era Mobile Network Cost Evolution"
75 GSMA. 2019. "The 5G Guide"
76 GSMA. 2020. "Realising 5G's full potential: Setting policies for success".
77 Ibid.

3. *Increased costs to operate 5G networks:* 5G equipment is more energy efficient on a per GB rate; however, the increase in overall data demand will lead to increased energy costs for network operators. The need to densify networks will increase maintenance costs as a greater volume of small cells will need to be continuously maintained and upgraded, while existing infrastructure must also be maintained to support the transition from 4G to 5G.

## 5G-enabled use cases are reshaping the competitive landscape for Canadian MNOs

As discussed in Section 2, the new digital economy has reshaped the competitive landscape, introducing strong competition to MNOs from hardware, software and service providers. This has two main implications for network operators:

1. Value is being disrupted in the digital economy and Canadian network operators are sub-scale relative to multinational digital economy players, whose business models are enabled by connectivity but do not invest in network infrastructure. These multinationals bring significant competitive pressures and there is potential for these multinational players to disrupt current operating models and sources of revenue.
2. Significant technological disruptions are expected to impact MNOs over the coming years. For example:
    a. The deployment of Low Earth Orbit satellites will be used to provide satellite broadband internet. The satellites have the potential to improve connectivity in existing markets and reach unserved markets, allowing satellite providers to compete in the direct-to-consumer market and serve new B2B customers such as shipping conglomerates and governments.
    b. The introduction of embedded SIM (eSIM) technology. The eSIM removes the need to physically swap SIM cards to change the profile on a device. eSIM technology could be used by equipment manufacturers to disintermediate telecom operators—meaning that equipment manufacturers such as Apple would own the customer relationship and dictate revenue splits.

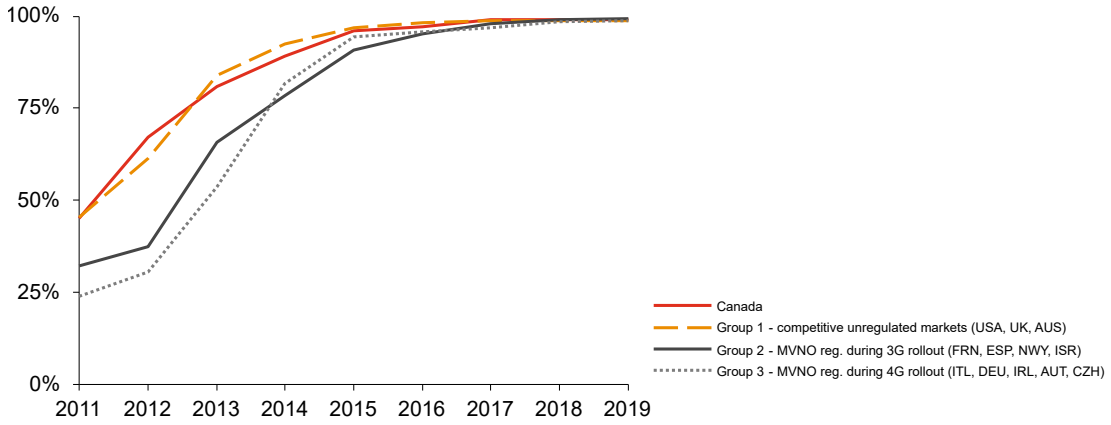
# 4: Canada needs to maintain a healthy telecommunications industry and act as an investment catalyst to keep pace with global peers

Canada needs a healthy telecommunications industry to support the deployment of 5G. As is evidenced by the 4G deployment experience of peer countries, countries where network operators were in poorer financial health had slower 4G deployment and adoption rates. In the 5G era, understanding the importance of 5G for the digital economy, peer countries have already acted. They are ensuring that network operators are incentivized to deploy networks at pace, despite the higher costs, and challenging business case.

## A healthy telecommunications industry is important for deploying 5G

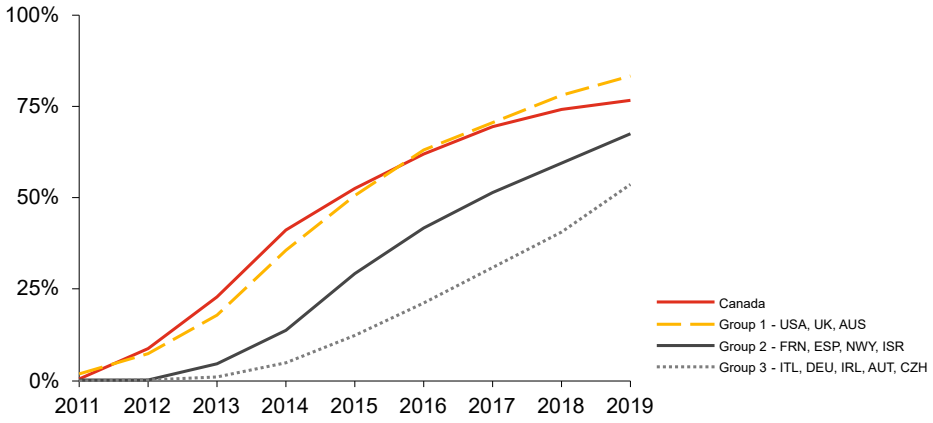
Canada was a leader in the deployment of 4G while other countries fell and remained behind. Countries that lagged behind did so, in part, because of their adoption of service-based competition, which limited the incentives for network operators to invest in 4G deployments. Canada, along with the United States, the United Kingdom and Australia, did not mandate MVNO access, creating an economic environment where network operators were incentivized and had sufficient capacity to invest in 4G infrastructure. This is evidenced by the trends shown in Exhibits 10 and 11 where case studies taken from the PwC report "Understanding the likely impacts of MVNOs in Canada, Part 2: Impact on Canada's Transition to 5G" are provided.

**Exhibit 10: 4G Coverage (% of population, 2011-2018)**




Source: OpenSignal, PwC Analysis

**Exhibit 11: 4G Adoption (4G share of connections, 2011-2018)**




Source: OpenSignal, PwC Analysis

In Canada, the USA, the UK and Australia, the rapid deployment of 4G networks led to a significant gap in coverage when compared to Groups 2 and 3 (countries that mandated MVNO access before or during the rollout of 4G networks). Coverage in Groups 2 and 3 stayed consistently behind until most countries reached near universal coverage. The adoption curves of Groups 2 and 3 also remained behind years later even as 4G coverage was near universal.

As further evidence for the importance of a healthy telecommunications industry, decreases in Average Revenue per User (ARPU) in the telecommunications industries of each country in the case study were correlated with lower 4G adoption. Countries with most significant ARPU decreases were in Groups 2 and 3 where MVNO access was mandated.[78]

The growth of the digital economy, Canada's global competitiveness and the rollout of 5G are intertwined. As a result, Canada should aim to maintain a healthy telecommunications industry to ensure it can meet the connectivity demands of the growing digital economy.

By deploying high-quality 5G networks, Canada can improve its economy, reduce its environmental footprint and deliver societal benefits. To fully capture the associated benefits, Canada should have a regulatory framework that considers the need for 5G networks that enable Canada's economic competitiveness and create high-quality jobs. The regulatory framework also needs to acknowledge the competitive landscape that now includes multinational solution providers (e.g., Google, Amazon, Samsung, etc.). This shift in regulatory approach is needed to ensure that Canada keeps pace with peer countries and avoids falling further behind. Currently, Canada is lagging peer countries in 5G performance as it has only deployed low-band networks while others have also deployed mid- and high-band networks. Notably, future regulatory frameworks should aim to create a business environment that has:

1. The appropriate level of **market incentives** that drive improved customer value and investment in innovation.
2. A **predictable and fair set of regulations** that promote competition, investment and network security, while providing sufficient flexibility to adapt with the changing needs of the digital economy. For example, simplifying regulations that govern access to passive infrastructure for 5G deployments.
3. An industry view that **acknowledges the broader impact and benefits that come from connectivity** enabling the digital economy, and the new competitive landscape within it.

78 PwC. 2020 ."Understanding the likely impacts of MVNOs in Canada, Part 2: Impact on Canada's Transition to 5G".

## Peer countries have taken active roles in supporting the acceleration of 5G rollouts

Globally, regulatory frameworks and attitudes have shifted towards incentivizing and supporting network rollouts. As countries aim to realize the benefits of 5G and address the large costs associated with the deployment of 5G networks, many have acted as investment catalysts and prioritized having a healthy telecommunications industry capable of the investments required. Peer countries have focused their efforts on six policy fronts to support MNOs in the deployment of 5G:[79]

- *Spectrum timing, allocation and costs:* Recognizing that late spectrum auctions are the primary limiting factors for 5G deployments, countries are focusing on rapidly securing and allocating mid and high-band spectrum for 5G purposes (see Section 2 for auction timelines by country) and aiming to reduce spectrum costs for high-priority areas. For example, Japan has assigned spectrum to MNOs at no cost, which reduces the total capital investment required for deployment.[80] In Norway, the Norway Communications Authority (Nkom) is providing discounts (NOK 10-40 million per lot) for operators that commit to providing broadband connectivity in certain rural areas as part of its auction for the 2.6GHz and 3.6GHz spectrum bands.[81] Spain has taken a broader approach to reducing costs by cutting reserve prices by 12.5% to 20% for its 700MHz band auction while also doubling the length of the spectrum license lease from 20 to 40 years.[82,83]
- *Network investment incentives:* Countries are leveraging financial incentives such as direct subsidies, tax incentives and grants to support companies building their 5G network. For example, the Japanese government introduced tax measures that allow network operators to either use a 30% special depreciation rate or a 15% tax credit for 5G network investments.[84]
- *Rural network subsidies:* Countries are providing further tax incentives, subsidies and grants that incentivize businesses to build 5G network infrastructure in rural areas. For example, in the UK, the government has allocated £500 million to match investments made by network operators to encourage rural network build-out.[85]
- *Improving regulatory standards:* Countries are developing legislation and regulations that facilitate 5G infrastructure build-out. For example, in Japan, the Tokyo metropolitan government is making buildings and land lots available for installing 5G infrastructure.[86]
- *Research and innovation funding:* To promote the development of 5G-enabled technologies, governments are funding research projects in research institutions and industry. For example, the German federal government has made €80 million available for research in three priority areas: "reliable wireless communications in the industry", "5G: industrial internet" and "5G: tactile internet".[87]
- *Vertical industry application funding:* To promote the adoption of 5G-enabled technologies and enable the delivery of the benefits of 5G, governments are providing funding for organizations to implement these solutions. For example, the Australian government has allocated AU$20 million in grants to support the deployment of 5G technologies through the Australian 5G Innovation Initiative.[88]

79 PwC. 2021. "COVID-19's impact on connectivity, Canada's post-COVID-19 connectivity needs".
80 GSMA. 2020. "Roadmaps for awarding 5G spectrum in the MENA region"
81 Norway Communications Authority. June 2021. "Award of frequencies in the 2.6 GHz and 3.6 GHz frequency bands: Auction Rules."
82 Laudette, C. 2021. "Spain cuts prices, eases conditions ahead of July 5G spectrum auction". *Reuters.*
83 Wieland, K. 2021. "Spain doles out 700MHz spectrum for $1.1B". *LightReading.*
84 PwC. 2021. Worldwide Tax Summaries, Japan, Corporate - Tax credits and incentives.
85 Rockman, S. 2020. "Shared Rural Network". *UK 5G Innovation Network.*
86 The Japan Times. 2019. "Tokyo Metropolitan Government to make thousands of properties available for 5G base stations".
87 The German Federal Government. 2017. "5G Strategy for Germany".
88 The Australian Government. 2020. "Grants to demonstrate the value of 5G to businesses in Australia".