5G Impact on Canada GDP, Environment & Quality of Life

Final Project Report for SYSC 5804
5G Networks
Carleton University

Submitted By:
Liansheng Wang
Sabique Shadman Rafeed
Afonso Kudikila Moniz
Rutu Kirtikumar Gadhiya

Course Instructor:
Jun (Steed) Huang

TA:
Mohammed Abuibaid

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1 Contributions

The following are the contributions of each author of this Final Report. We used citations from different well-known alliances, institutions and authors working in the relevant field.

Chapter 4: Impact on GDP:
4.1 - 4.4
Liansheng Wang, 300275304, lwang365@uottawa.ca
AND
4.5 - 4.9
Sabique Shadman Rafeed, 101244513, sabiqueshadmanrafeed@cmail.carleton.ca

Chapter 5: Impact on Energy consumption:
Afonso Kudikila Moniz, 300335214, amoni019@uottawa.ca

Chapter 6: Impact on Quality of life:
Rutu Kirtikumar Gadjiya, 101250900, rutukirtikumargadhiy@cmail.carleton.ca

2   Abstract

In comparison to previous generations, 5G wireless network technology offers faster, more dependable, and more effective connectivity. It is designed to support a vast range of applications, including high-speed mobile broadband, ultra-reliable low-latency communication, and massive machine-to-machine communication. This report shows how 5G technology is fostering development across a range of industries, including manufacturing, healthcare, rural areas, and agriculture. the paper also examines how it is impacting Canada's employment market and economic expansion. The paper also takes into account the energy efficiency of 5G networks and how they could support the development of ecologically friendly systems and smart communities. The final section of the paper looks at how 5G will affect people's quality of life, including how it will open up new possibilities for social interaction and entertainment and improve access to healthcare and education. Overall, this paper emphasizes the potential advantages of 5G technology and offers details on its potential effects on society, industry, and the environment. Overall, the impact of 5G on GDP is expected to be significant, with some estimates suggesting that it could add millions of dollars to the global economy over the next decade. Not only that it will also have a significant impact on the environment and people's quality of life.

3   Introduction

The introduction of 5G technology has been hailed as a significant development for the telecommunications industry. This latest version of wireless technology is expected to provide faster and more dependable connectivity, opening the door to new applications and services.
We examined the effects of 5G technology on the GDP, environment, and quality of life in this research paper. We reviewed many of the existing literature reviews done by various renowned organizations, alliances and authors on the subject and then based on the information at hand tried to analyze it. Our study will shed light on the potential advantages of 5G technology and give suggestions for policymakers and industry stakeholders.
We started by looking at how 5G will affect GDP. We looked into how 5G technology is promoting development across a range of sectors, including manufacturing, healthcare, rural area and agriculture. We also examined how

5G affected the job market and how Canadian economic growth is related to investment in 5G technology.

Second, we looked into how 5G will affect the ecosystem and looked at how much more energy-efficient 5G networks are than earlier wireless technology generations and investigate how 5G might help the creation of smart communities and environmentally friendly systems that are good for the environment. Finally, we examined how 5G will affect people's quality of life. We found how 5G is facilitating new entertainment and social engagement opportunities, enhancing access to healthcare and education

4   5G Impact on Canada GDP

5G technology is expected to have a very significant impact on GDP in Canada. In this section we will discuss Canada's GDP growth driven by 5G technology from a variety of aspects, including the government and private sector's investment in 5G technology, 5G impact on labor market, the manufacturing sector benefitting from 5G technology, IoT facilitation in forms of smart devices and infrastructure. We will also focus on the benefits of 5G in the agricultural sector, and its impact on rural areas, healthcare, entertainment, and the retail sector. It is anticipated that 5G technology will promote Canada's economic growth in a range of industries but mainly focused on the above areas and tried to find out what are the current and potential benefits in these sectors.

4.1   5G Investment

Industry Overview: Canada's public sector spending weighed 21.7% approximately of the total Canadian GDP in 2021, which ranked fourth in G7 countries [1]. The Government's investment accounts for over one-fifth contribution to Canada's GDP composition. Nowadays, all levels of government, federal and provincial, are facing the Fourth Industrial Revolution varieties of challenges and opportunities. That is one driving force for the Canadian government to invest in 5G networks, as we have known that 5G is the next generation of wireless network technology. 5G network deployment, must exert profound influences on industrial, social, and environmental development. Investment from public and private sectors in the 5G network could create direct contributions to GDP increase. Private sectors of Canadian

facilities-based carriers have made significant investments in Canada's wireless, which makes Canada be the leader in telecommunications. The companies include Bell, Rogers, TELUS, Shaw etc.

5G network requires a greater amount of capital investment compared to previous generations. One aspect is that a high density of backhaul infrastructure installations is required to reach full coverage over Canada. Another aspect is due to the more expensive operation and maintenance expenditure rooted in the data traffic. Canada's government should maintain a healthy telecommunications industry and act as an investment catalyst to keep pace with global peers [2]. There is a limited assessment of 5G network construction cost and relevant spectrum purchase cost, and those assessments undertaken vary substantially depending on whether they are on a per capita or per area basis. On a per-person or per-base station basis, these data suggest that the costs of building the network could be around $2 billion to $27 billion. On 9th April 2021, the Minister of Innovation, Science, and Industry announced an investment of $14 million in Redline Communications. The investment will support a $39.5 million project allowing Redline to design a 5G wireless solution [3]. An estimation says that $26 billion investment will spend specifically in 5G network infrastructure for carriers in Canada from 2020 to 2026 [4]. The investment consists of that of different segments, for instance, R&D institutions, infrastructure, energy consumption, etc.

The investment will boost Canada's innovation in 5G technologies and benefit a variety of industries. With the cutting edge of wireless technologies, Canada's industrial companies keep competitive worldwide, which will largely contribute to Canada's GDP. The investment will speed up the innovation of products and solutions. The Canadian government needs to encourage the private sector's long-term investment in 5G networks by establishing a supportive policy environment because 5G deployment is more expensive than previous technologies. The capital expenditure is a composite of the purchase and installment of telecommunication equipment. The macro cells and small cells will increase by 3% and 25% in numbers by 2025, respectively. That will result in the growing demand for backhaul infrastructure. All in all, telco capital expenditures are estimated to increase by 210% from 2018 [2]. The expected CAPEX increase due to 5G is shown in Figure 1. The scale of investment is explosively driven by the 5G network need. The Canadian government, federal and provincial, must cooperate with carriers to make investments in 5G deployment solutions providing the broader and higher performance of 5G coverage shown in Figure 2. Dark green indicates 5G
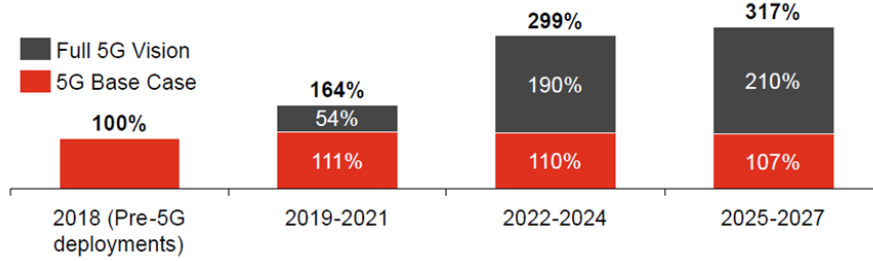
Figure 1: Expected CAPEX increase for network operator relative to 2018 due to 5G [2]

coverage in 2020 and light green is the distribution for 2021. It tells that the 5G deployment in the west of Canada is forward compared to Canada's eastern provinces.

There occurs a positive trend of revenue growth trend starting from 2020 [6], that indicates 5G investment affects Canada's GDP positively. The demand for mobile data has been strongly growing over the past few years in Canada along with the 5G investment expansion. The federal government raised $8.9 billion in a license auction for a key band of 5g wireless 3.5 GHz spectrum. Rogers declared that their 5G investments can benefit 34 million Canadians from their 5G service [7]. The Canadian government and Nokia announced a $340 million project which will help Canada successfully transmit to 5G wireless technology [8]. Bell's network acceleration program speeds up investment in 5G, fiber and rural network infrastructure up to $14 billion from 2020 to 2022 [9]. With the investment enhancement of 5G deployment, 5G adaption will begin to accelerate shown as in Figure 3. 5G applications will eventually exceed 4G and take the most significant contribution to Canada's GDP in the wireless sector.
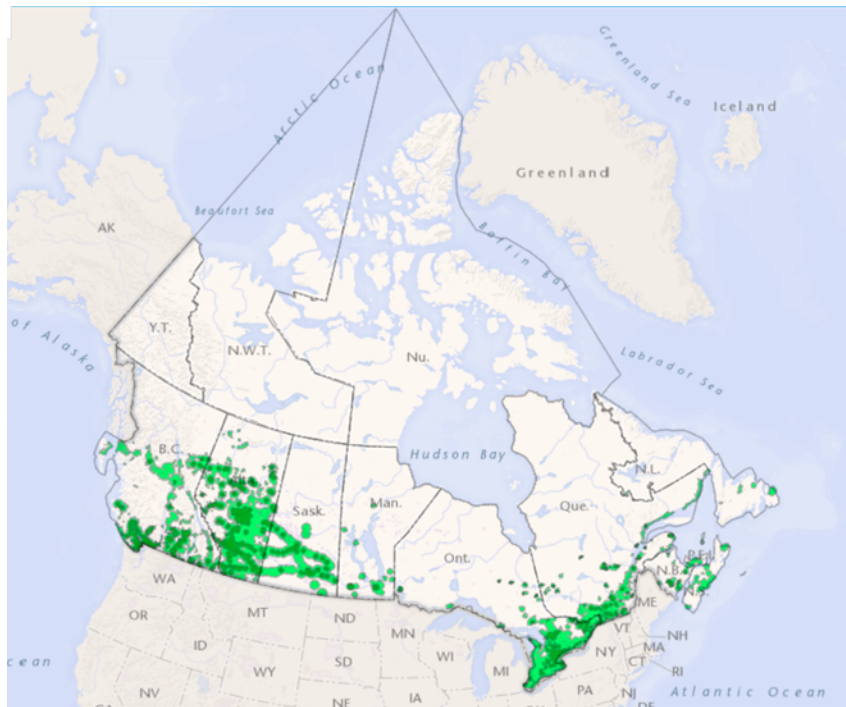
Figure 2: Figure 2. 5G coverage in Canada [5]
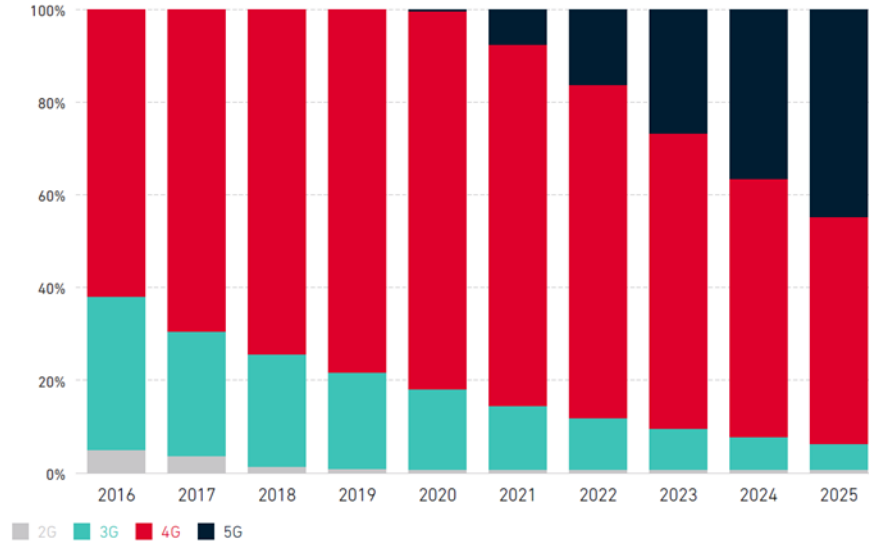
Figure 3. Mobile technology evolution in Canada, 2016-2025

4.2 Labour Market

5G will affect the labor market in direct and indirect ways. 5G technology wireless have to impact the labor market by creating new job opportunities, which involve new technology applications, services, deployment, etc. Research estimates a total of 154K temporary, direct, indirect, and induced jobs will be generated from 2020 to 2026 in Canada at its peak of 28K. it is estimated that nearly 250K permanent jobs will be added by 2026. Accenture estimates that the broadband penetration will increase by 100K jobs benefiting from 5G networks [4].

Figure 4. Temporary job creation from 5G network build-up

Figure 5. Sectors distribution benefiting from 5G networks

A recent study shows the deployment of 5G will benefit different sectors

in Canada and create a variety of job opportunities in those industries shown in Figure 5 [10]. The implementation of 5G technology requires a significant amount of infrastructure development, including the installation of new cell towers and optical fibers, which could create the most immediate demands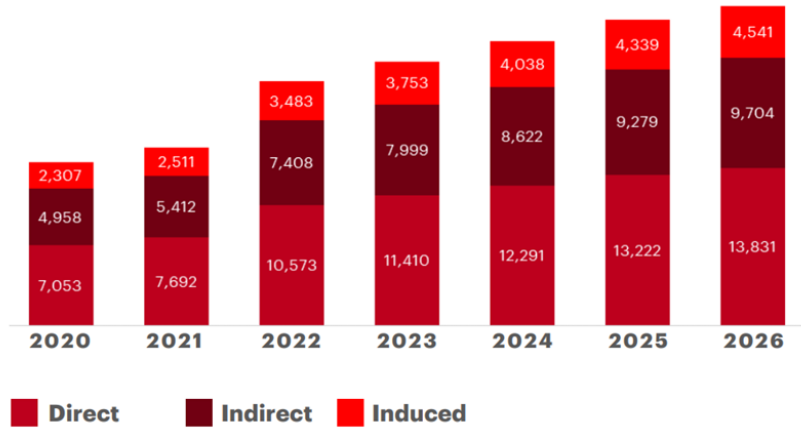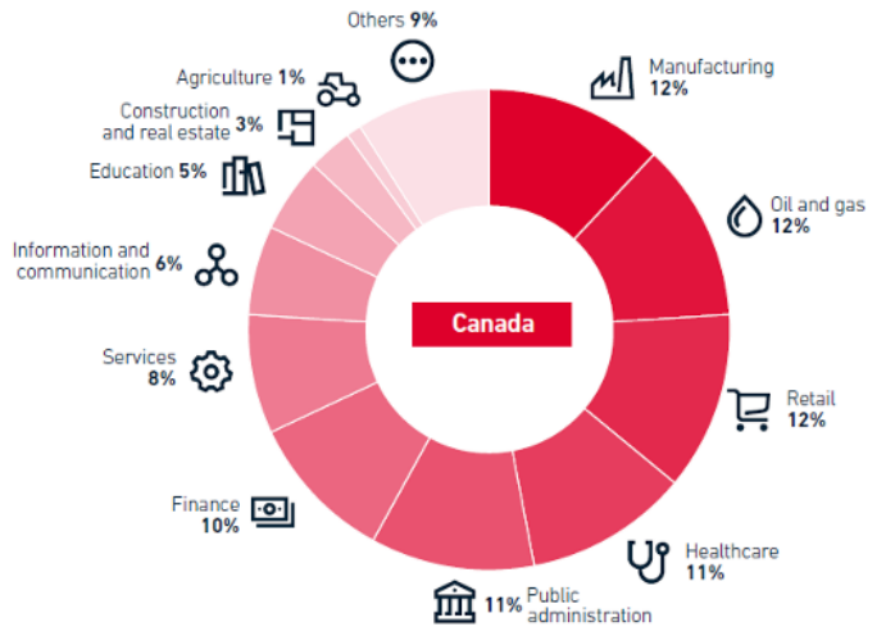 in construction and related industries. 5G network deployment will require skilled workers to design, configure and maintain the technology, this will create a number of jobs such as network engineers, IT technicians and other technology-related roles. In addition, the high data transmission rate and lower latency advantages of 5G networks will create opportunities for developers to innovate applications and services. This could lead to the creation of new jobs in the technology sector. The implementation of 5G networks could expand existing businesses, which could bring new job opportunities in a variety of industries. All the new opportunities in the labour market will bring positive impacts on Canada's GDP. For instance, the ENCQOR 5G program contributes to the maintenance or creation of more than 1800 high-level research and development jobs in Quebec and Ontario [10].

From another perspective, we can see that 5G will affect the labour market. As we know, the pandemic has had a significant impact on people's work attitudes. Home-based work has become more and more acceptable and popular. The preference for a remote work environment is growing during and post-COVID-19. The 5G mobile broadband access provides more creative and flexible work arrangements. Employers don't have to consider where the potential employees live, which will draw more people to enter the labour market. for instance, people can make a better balance between work and family. 5G networks will provide flexible options to people due to their technical properties, with high speed, low latency, and strong security. 5G creates impacts on the employment sector in another direction in a particular way, specifically in rural areas. The lack of healthcare and education systems in rural areas is a fact. The people living there are facing challenges to hire healthcare workers. Meanwhile, the government services and transportation systems are not provided well. With 5G technology deployment, professionals in urban areas can work with the potential workforce who cannot conduct services independently. This method will create new employment opportunities in rural areas. This will partially or potentially solve those challenges which the locals are experiencing.

Statistics Canada releases that the wired and wireless telecommunications industry employed 101,546 people in 2021, and more than 41.8% of the employees held a bachelor's degree or above [11]. Empirical studies have found

that the employment increase in networks industries mostly comes from new graduations [12], which indicates the broadband industries, 5G currently and soon are emerging more job opportunities. In terms of the education industry, In Canada, the education sector accounts for approximately 6% of total Canadian GDP [1]. The education sector should make an adaption from its current models to support the labour market of the future. The challenges include inaccessible environments, lack of funding, poor quality of instruction, etc. 5G provides solutions to those challenges, such as real-time digital solutions, and video meetings, enabling the education sector to be more responsive to the needs of the current labour market [13].

4.3 Manufacturing

The manufacturing industry accounts for more than 10% of Canada's total GDP [1]. The manufacturing industry will benefit the most from 5G technology due to the large size of the manufacturing industry vertical. Canada's average labour productivity in 2018 was $50 GDP per hour worked. GDP per capita can be evaluated by labour productivity growth. As shown in Figure 6, other countries can produce more output than Canada [14]. 5G technology deployment will significantly improve labour productivity. With 5G advanced mobile technology, businesses will be better capable of providing information and services, and customers will be able to get entertainment services while 'on the go' [15]. The improved reliability, speed, and latency provide better communications within companies as well as production network stability. That increase in efficiency will result in labour productivity improvement, which will contribute to Canada's GDP increase. With manufacturing model updating, it becomes more important to have the ability to make a quick change in the production process, 5G technology satisfies fast production alternation requirements. Sufficient bandwidth and reliable speeds allow machines to upgrade fast and reduce downtime. The core incentive in the manufacturing sector is looking to improve labour productivity and reduce costs and keep the competitive stage. 5G deployment provides a solution to achieve the goal. 5G has unique attributes compared with previous-generation mobile networks. The high data rate, lower latency, and massive device connectivity are all these properties that can improve manufacturing processes. The disruptive supply chain pushes future companies to consider reconfiguration of different production lines corresponding to a sharp demand shift. 5G can help realize this model by establishing a modular fac-

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tory, where machinery can be quickly reconfigured to optimize production [16].
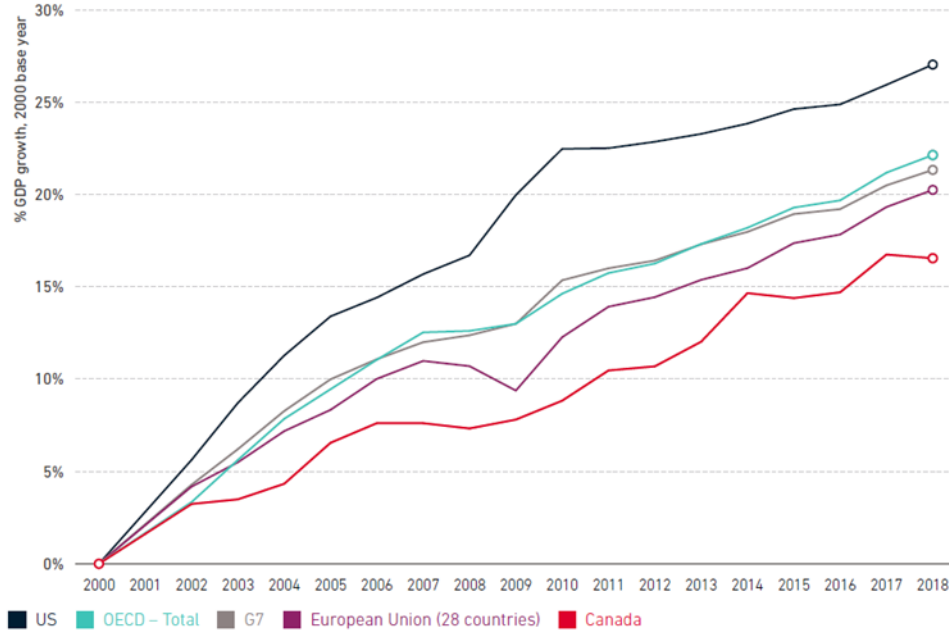
Figure 6. Comparison labour productivity growth

Extended reality (XR) is taken as a promising technology, including virtual reality and augmented reality where digital objects appear and could be operated in reality. XR technology may create an important effect in the manufacturing sector under 5G technology deployment circumstances because 5G technology can offer the capacity for high volumes of data. Manufacturing plants could accomplish 5G to install predictive maintenance to reduce downtime and improve productivity and performance.
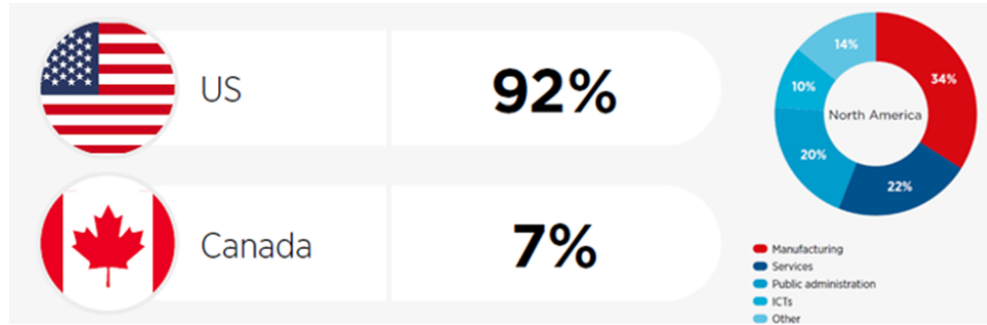
Figure 7.GDP contributions by mid-band 5G spectrum, 2020-2030, by sector
At the country level, Canada is predicted to account for 7% of North America's overall contribution to GDP from mid-band 5G. in terms of economic sectors, 5G mid-band applications will primarily benefit manufacturing [16]. 5G will increase Canada's annual GDP by $94 billion by 2035 according to estimation. 5G technologies will gain labour productivity and keep Canadian businesses competitive in the agriculture and manufacturing sectors [17]. In primary industries of Western Canada, 5G-enabled use cases are estimated to increase about $16.4 billion of value by 2035, including smart mining, smart automated construction and automated mobile robotics benefiting from 5G technology deployment [18].

4.4   Internet of Things (IoT)

The 5G technology will provide Canadians required speeds and bandwidth to develop the Internet of Things by providing real-time digital solutions and complementary. The Internet of Things (IoT) and 5G will enable productivity improvements and a competitive edge for businesses, which will increase Canada's GDP. The 5G technologies and IoT applications blend to create enterprise resource planning (ERP) systems and generate better smart supply chains. The establishment of the 5G ecosystem will bring value for customers due to the transmission speeds improvement. Therefore, businesses and consumers can get benefits from IoT and 5G implementation. The true change of the IoT with 5G technology is coming from the fully new things using wireless and IoT technology devices, such as autonomous vehicles, traffic engineering systems, the smart grid of energy management systems, etc. As shown in Figure 8, the 5G IoT market in North America, only US and Canada

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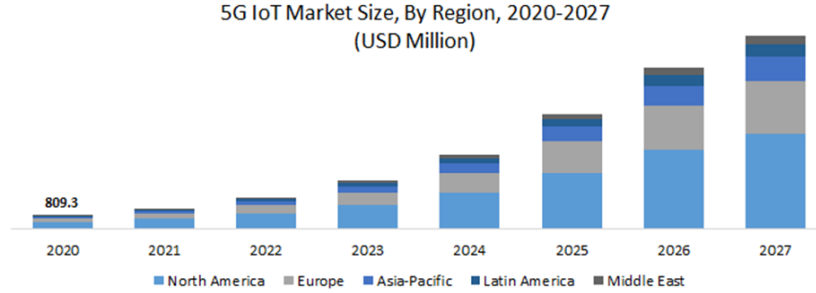included, is increasing rapidly compared to other regions [19].

Figure 8. 5G IoT market size by region 2020-2027

The Internet of Things (IoT) and 5G will improve labour productivity for businesses, and the new applications can increase work efficiency. The core of IoT is connectivity. IoT is a system consisting of inter-correlated computing devices, sensors, data centers, objects, etc. The system has the ability to make an arrangement based on data analysis, even without commands from people. IoT is growing rapidly as much more devices can communicate with each other and new applications are developing. In 2019, there were $2.7 billion IoT connections in North America, and the figure is mapping to increase to $5.9 billion by 2025 [12]. The augmented reality of the 5G network can connect more devices, and decrease the communication delay through the network. All facts indicate that the IoT industry will continue growing current and future.

From the consumer perspective, the true promise lies in the totally new thing that 5G and IoT can bring. Firstly, wearable devices for monitoring the patient's body data can transfer those data to the healthcare provider directly, such monitoring devices include heart rate monitors, fall detection equipment for old people, etc. There is an estimation showing the healthcare industry IoT can bring hundreds of billions in market share. Secondly, people are talking about the autonomous vehicles of the future, the realization relies on the telecommunication system, and 5G networks can make driving smarter. Because hundreds of sensors in cars must monitor and analyze the gathered information and make a decision in real time, which requires high-speed and low-latency communication systems. There is a foreseen estimated twenty-one million autonomous vehicles in the US by 2030, which is a big opportunity for car manufacturers. The autonomous vehicle technologies involved can be used to administrate the traffic system to mitigate or avoid traffic congestion.

Thirdly, the IoT system will consume a lot of energy, but the smart grid system will manage the electricity distribution dynamically to reduce the electricity cost. In addition, the smart grid with 5G technology can help the government manage the public lighting system to save the public budget. As for the smart home with IoT technology, it is forecast to be a $43.7 billion market by 2023 [12]. As shown in Figure 9, the impact of 5G on a variety of sectors is heavily dependent on the IoT's successful deployment [14].
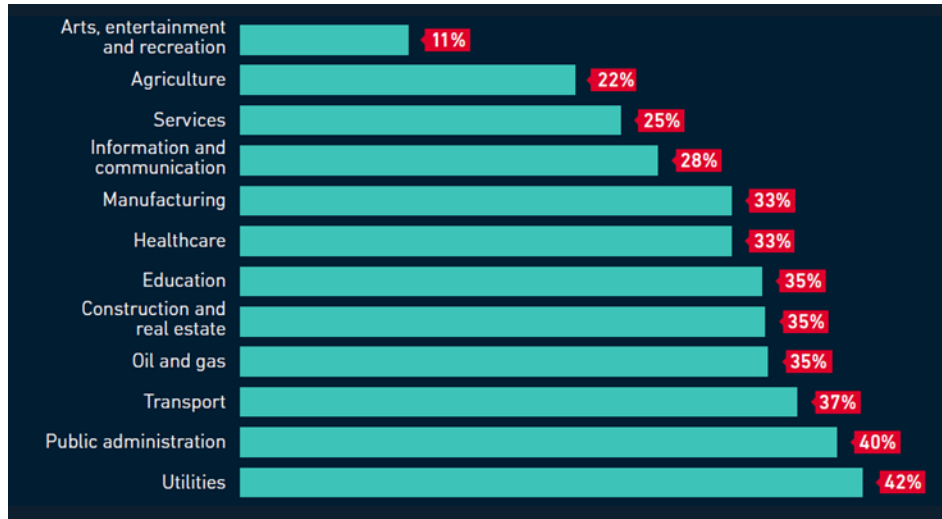
Figure 9. mIoT-driven share of 5G benefit by industry, 2020–2040

4.5   Agriculture

The introduction of 5G technology is anticipated to have a substantial effect on a variety of Canadian industries, including agriculture. Canada is a major agricultural producer, and the agricultural industry contributes significantly to the country's gross domestic product (GDP). However, the sector currently faces significant challenges ranging from environmental issues (including droughts, storms, and global warming that contribute to the emergence of new crop pests and diseases), a growing population, unpredictability of commodity prices, and an aggressively competitive global market. The fifth-generation wireless network is quicker and more dependable than its forerunner, 4G, allowing for the transmission of more data in real-time. This rise in connectivity

is anticipated to revolutionize the agricultural industry, positively impacting the sector's gross domestic product.

The adoption of precision agriculture (or "smart farming"), a system that integrates modern information and communication technologies into agriculture, is one of the innovative approaches being pursued by the industry in response to these diverse challenges. A variety of technologies, including satellites, drones, and Internet of Things (IoT) devices, are integrated into smart agricultural systems. Due to technological limitations, the complete benefits of smart farming have not yet been realized. For instance, drones are used for crop inspection, but the captured data is usually not retrieved and evaluated until after the drone has landed due to transmission limitations while the drone is in flight. A survey of Western Canadian farms identifies "Internet speeds and/or cellular data coverage" as the second most difficult obstacle to precision agriculture adoption. [20] This data can be analyzed using artificial intelligence and machine learning algorithms, allowing farmers to make data-driven decisions about their farming practices. For example, farmers can use this data to determine the optimal time to plant crops, apply fertilizers, and water their fields. This can help farmers optimize their yields, reduce waste, and save costs, resulting in a higher GDP for the agricultural sector.

In Canada, 5G can overcome obstacles preventing the widespread adoption of precision agriculture. It can provide accessible Internet with faster speeds and reduced latency, allowing massive amounts of data gathered on farms to be transmitted in real-time. This will allow video feeds, high-resolution images, remote drone control, and the spread of sensors and other IoT devices across farms. 5G technology will allow farmers to make real-time management decisions, opening up new approaches that will benefit Canada's agricultural sector.

Another way in which 5G technology can impact agriculture in Canada is through the automation of farming equipment. With 5G connectivity, farming machinery can communicate with each other and with central control systems in real-time. This allows for more precise and efficient farming practices, reducing the time and labor required for planting, harvesting, and other tasks. Automation can also reduce the risk of errors, resulting in higher crop yields and a more significant contribution to the sector's GDP.

Furthermore, 5G technology can also enhance food safety and security in Canada. Real-time monitoring of crop and livestock health can help detect potential disease outbreaks and prevent their spread, reducing the risk of

foodborne illnesses. This can improve consumer confidence in Canadian agricultural products and contribute to the sector's GDP.

The United Nations predicts that food production will need to double by 2050 to satisfy the needs of a growing global population, and that innovative strategies will be required to achieve this goal [21]. nearly 7%, or $111.9B, of Canada's GDP coming from the agriculture and agri-food system [22]. By reducing input costs by $24.50 USD per acre and increasing output by $42 USD per acre22, large farms of 5,000 acres or more can anticipate substantial economic gains. By applying these numbers to fields of comparable size and scale in Canada, the agricultural industry could realize economic gains of $3.3 billion CAD, with approximately $1.2 billion attributable to input price reductions and approximately $2.1 billion attributable to yield increases [22]. The installation of remote sensors in agricultural regions has led to a 70% reduction in water consumption in Chile. [23] Farmers and researchers were able to watch the conditions of the soil and the plant's needs due to the placement of soil sensors. Thus, farmers were able to optimize their irrigation procedure to use less water while increasing crop yields. As one of the most widely cultivated crops in Canada, blueberries are a sector of agriculture with a high potential for smart irrigation. Based on an Accenture analysis [22] of acreage of blueberry farms at the provincial level, plant type, growing days, and current water requirements, it is estimated that blueberry farmers in Canada could save 74.3 billion imperial gallons of water annually, resulting in approximately $270 million CAD in annual, recurring cost savings.

Canola, one of Canada's most important crops, which is exported to 90% of the world's markets [24], is a prime example of 5G's potential benefits. In 2018, Saskatchewan gathered over 12 million acres of canola and produced over 10.9 million tons [25].

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 [26] A study conducted by the European Parliamentary Research Service found that early, accurate detection and localized pest and disease treatment has the potential to reduce pesticide costs by up to 85% [27] In addition to increasing overall yield through targeted application and the additional health and environmental benefits of decreased pesticide use, this represents yearly savings of up to $360M CAD for the canola industry in Saskatchewan. Once 5G networks

are established and additional regulations are in place to enable precision agriculture technologies to flourish in Canada, the average oilseed farmer in Saskatchewan can anticipate yearly savings of more than $40,000 [25].

In a recent "Digital Vineyard of the Future" pilot project, Halifax-based VineView partnered with Global UAV Technologies to launch a 4G-enabled drone over a Nova Scotia winery to perform real-time analysis of vineyard conditions [28]. The aerial disease detection powers of VineView can assist in identifying and isolating Grapevine Leafroll Disease, one of the most prevalent viruses affecting vineyards. This virus could reduce yield by up to 30 percent on a typical 50-acre Okanagan vineyard. If undetected and untreated via targeted vine replacement in a timely way, this would result in an average annual economic loss of $18,000. A 5G-enabled communications network enables increased volumes of data and imagery to be transmitted in real-time for farmers to act quickly to improve their crop yields.

The city of Ottawa has financed an automated smart farm with soil tracking, automated vehicles, and drone surveillance. The automated farm has increased product yields, enhanced efficiency, and decreased operational inefficiencies. As a result, the farm has achieved increased profits [29].

The impact of 5G technology on the agricultural sector's GDP in Canada is expected to be significant. Canadian farmers can optimize their yields, reduce waste and inefficiencies, and increase their incomes. The adoption of 5G technology is, therefore, crucial for the future growth and development of the agricultural sector in Canada.

4.6   Rural Area

One of the main advantages of 5G technology is its ability to provide faster and more reliable connectivity. This is particularly beneficial for people living in rural areas who may currently struggle with slow internet speeds and poor connectivity. With 5G, rural communities could have access to the same level of connectivity as their urban counterparts. Internet Factbook of the Canadian Internet Registration Authority (CIRA) mentions that 86% of Canadians have access to broadband internet [30]. The government of Canada, through Budget 2019, has set a target of achieving 95% broadband coverage for homes across the country by 2026, and 100% by 2030 [31].

Broadband Internet access can have substantial economic benefits. Internet connectivity allows businesses to access national and international labor

markets in order to capitalize on efficiencies and skills. It also allows rural residents to engage in the workforce remotely. According to surveys [30], 20% of Canadians with dependable home internet frequently work from home. In addition, highspeed internet improves access to services associated with greater economic prosperity, such as e-commerce, e-learning, and improved infrastructure, and access for educational services.

According to studies, a 10% rise in broadband penetration can result in an increase of 0.9% to 1.5% in GDP growth. Applying these numbers to rural areas in Canada reveals substantial economic benefits. 75% of households in Saskatchewan, a province with 296 rural municipalities and 33% of the people residing in rural areas, have access to broadband services. In the event that Saskatchewan achieves the Canadian government's goal of 95% broadband service availability, the province's GDP could rise by up to $1,2B. Comparatively, Nova Scotia and Newfoundland and Labrador have remote populations of 43% and 42%, respectively. Increasing the availability of broadband service in Nova Scotia and Newfoundland and Labrador from the current levels (79.1% and 78.1%, respectively) to government goals could result in a GDP increase of up to $520 million and $420 million, respectively as shown in Figure 10. [25]

As the economic benefits of increased broadband penetration are not limited to rural areas only, all Canadian provinces and territories can anticipate significant impacts on GDP as 5G technologies open up new paths to achieving greater broadband service availability. As shown in the chart below, achieving the government's goal of 95% broadband availability across all Canadian provinces and territories could have substantial effects on GDP. The effects on provincial GDP vary based on the present availability of broadband service and the GDP of the various Canadian provinces and territories. [25]
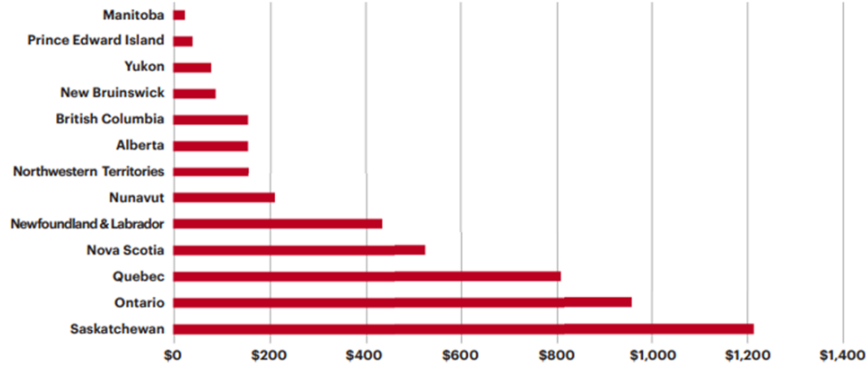
Figure10: Expected GDP Uplift by 2026 across different provinces [25]

4.7 Healthcare

5G technology has the potential to transform the healthcare industry by enabling faster and more reliable communication between healthcare providers and patients. On average, each person in Canada spends around $6,839 annually on medical care. In 2018, the Canadian government allocated more than $240 billion to healthcare. The total spending on health makes up about 11.3% of Canada's GDP. [32]

The rapid growth of telemedicine during the COVID-19 pandemic provides a glimpse into the future of healthcare, but remote care is only one area where 5G can facilitate cost savings and improved health outcomes. 5G will vastly improve doctor-patient communication by enabling it to be continuous and real-time both inside and outside of hospitals. This will allow physicians to utilize their time more effectively, improve patient outcomes, and reduce hospital stays.

5G-powered mobile health platforms will expedite and improve the accumulation and exchange of health information among health systems, healthcare providers, and patients. It may also allow physicians to use surgical robots or scanners remotely controlled over 5G to assist in patient care or surgeries.

A drone equipped with 5G could deliver a defibrillator to the patient four times quicker than an ambulance could. Additionally, drones can deliver medications, blood, and vaccines over long distances and at high speed, as

well as collect and convey blood or tissue samples to a central laboratory for analysis.

The combination of higher speed and efficiency with lower latency makes 5G better able to support remote, real-time interactions between physicians and patients than previous generations of mobile technology. In addition, healthcare providers will be able to receive remote surveillance data from a large population of patients in real-time, typically via 5G-connected wearable devices and supplemented by cloud analysis and processing (termed the "Internet of the body"). These advantages imply that 5G will increase the reach and efficacy of remote health surveillance and telemedicine initiatives, including in rural areas with limited hospital access.[33]
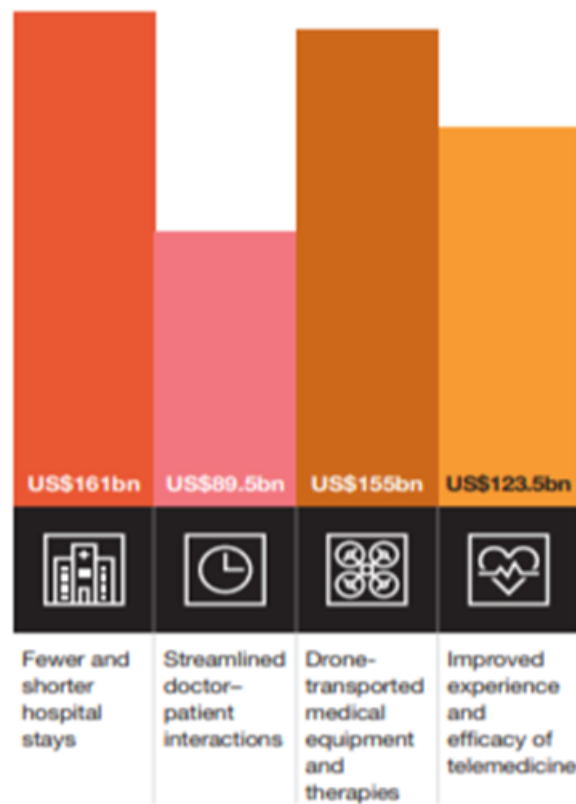
Figure 11: Net contribution to global GDP by 2030[33]
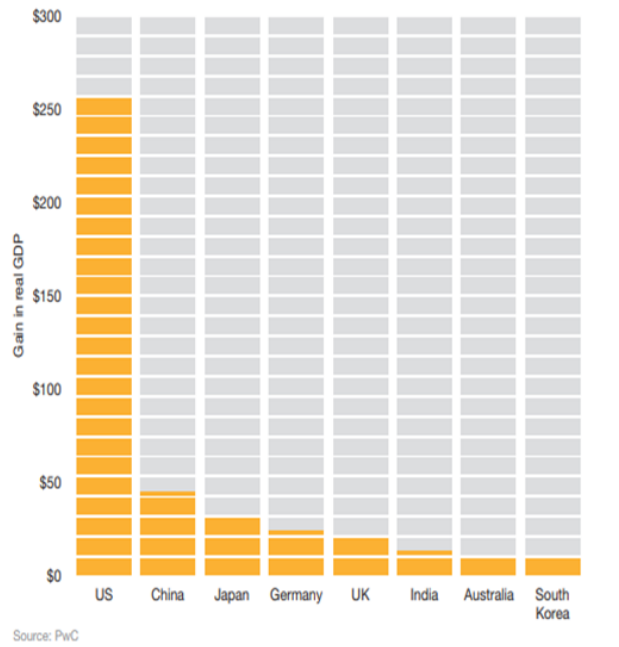
Figure 12: 5G boost to healthcare by country by 2030 in US $bn[33]

Doctors in China have already successfully conducted remote surgeries over a distance of more than 2,000 kilometres. The patient underwent a three-hour procedure that included a deep brain stimulation implant performed by a physician from a different city named Dr. Zhipei. This is made possible by 5G's extremely low latency, which makes remote surgery nearly as effective as traditional surgery. [34]

Ambulatory services in Canada are an integral component of the overall patient care process and the entry point for a number of citizens into the hospital care system. 5G's enhanced mobile broadband and low latency characteristics can enable a "connected ambulance" that will serve as a mobile emergency room with medical equipment and wearables, allowing for the storage and real-time streaming of patient data to emergency department teams at the hospital. Continuous collection of patient data and real-time video transmission can enable Emergency Department staff to remotely monitor patients for conditions that are otherwise difficult to detect, thereby assisting paramedics in making better treatment decisions for patients en route.[35]

This will help reduce the congestion encountered by many emergency rooms

today by remotely determining an alternative course of treatment for patients who may not require urgent care but who have requested ambulance services. The collection of patient data and real-time video transmissions can reduce emergency department wait times for patients who require urgent care, as medical personnel will have patient data available before the patient arrives. Approximately one million patients are transported annually in Ontario by land or air ambulances. 57,915 patients were admitted as stroke patients [36]. Accenture estimates that if connected ambulance technology could be provided to these patients, the mortality rate could be reduced and over 7,303 Ontario stroke patients would benefit. There are approximately 100,000 critically ill patients requiring emergency transportation in Ontario and tens of thousands more in the remainder of the nation. If improved treatment in the ambulance could result in a 20% reduction in the average length of hospital stay for even 10% of patients presently transported in an ambulance, the healthcare system could save $140 million. [35]

4.8   Entertainment Sector(VR/Gaming/Education)

During big entertainment events in high-density event venues, the average consumer will have the ideal chance to experience 5G's superior network throughput and capacity. With 5G enabling a 100x increase in traffic capacity and network efficiency compared to 4G, immersive fan experiences based on High Definition (HD) mobile video, Augmented Reality (AR), and Virtual Reality (VR) hardware, content, and features will become commonplace in the near future. No seat is undesirable due to the drastically reduced latency and high-performance computing done at the network's edge. The ability to view the action from multiple viewpoints on demand also enables a potentially monetizable, enhanced experience for fans watching from home, whether through VR or a large-screen television concurrently streaming the main action with a synchronized overlay locked on your favourite players. Meta launched more than 50 live NBA games in virtual reality (VR) on Meta Quest, including five in immersive, 180-degree VR [37]. If this type of feature was added to Hockey Night in Canada, the service provider could generate an additional $17 million.

British Columbia (B.C.) is a hub for augmented reality (AR) and virtual reality (VR) businesses seeking to shape the future of entertainment, education, healthcare, and other fields. Vancouver is a leading VR/AR ecosystem in the

world, second only to the Bay Area/Silicon Valley, with over 260 immersive technology firms [38]. B.C. immersive technology companies generated $2.3B in annual revenues which is 35% of all AR/VR revenue activity in Canada.[38] The pandemic of COVID-19 has resulted in a dramatic change in the manner in which many Canadians work. Statistics Canada reports that 39.1% of Canadians worked from home during the final week of March 2020 due to physical distancing requirements[39]. Aternity's analysis of data from more than 500 Global 2000 businesses revealed that Canadians have experienced a 170% increase in remote work since the implementation of work-from-home policies, resulting in a 25% increase in overall productivity [40]. While current telecommunication services already play a large role in enabling remote work, 5G will dramatically expand its possibilities.

Not only the workplace, but 5G will also revolutionize classrooms with AR/VR technologies. Unlike the video conferencing calls we currently use for classrooms, virtual reality classrooms may enable more dynamic engagement by shifting from static, 2D video to digital 3D representations of participants. Microsoft recently demonstrated its Mesh framework for developing augmented reality (AR) and virtual reality (VR) applications. In one of Microsoft's demonstrations, participants interacted in a virtual environment where they could speak, gesture, and exchange digital objects. 5G will be essential for enabling these kinds of live, digital interactions to be seamless due to its low latency and other advantages [41]. AR exploration is yet another method by which 5G could significantly enhance educational encounters. AR allows students to examine objects in ways they may not be able to in reality. Google already has a handful of existing augmented reality (AR) teaching tools. For instance, Google's AR Search function enables users to research animals and examine life-sized 3D models using AR. In addition, Google's 'Arts and Culture app enables virtual tours of renowned museums and cultural locations. Although these instruments already exist, 5G will assist in their improvement and expansion [41].

With VR and high-definition graphics, gaming will become more immersive, social, and realistic. Access to the Internet with a high level of speed and responsiveness will allow players to enjoy new VR games anywhere, without the expense or inconvenience of carrying specialized hardware. "Cloud-based gaming will be improved by 5G; users will be able to engage with others over the Internet without relying on ultra-fast home broadband connectivity [42].

4.9   Retail

With 5G technology, retailers in Canada can offer faster download and upload speeds, lower latency, and higher network capacity to their customers. This can enable them to offer more immersive and interactive shopping experiences, such as AR/VR experiences, and faster and more convenient checkout options. This enhanced shopping experience can lead to increased customer satisfaction and loyalty, and in turn, drive revenue growth.

DressingRoom by Gap is an application designed to assist customers in virtually trying on clothing. Customers can select a Gap style they're interested in purchasing and one of five body types to see how an outfit will appear on them. Nike Fit is a scanning app that uses a combination of computer vision, data science, machine learning, artificial intelligence, and recommendation algorithms to measure the complete shape of a user's feet and determine which Nike shoe style is the best fit. [43]. At H&M in Berlin, employees wear bracelets connected to the Azure cloud to receive inquiries for assistance from customers in fitting rooms or at the cash register. Sobeys, a leading Canadian grocer, initiated a proof-of-concept (PoC) in June 2021 for a smart cart that allows customers to scan, weigh, and pay for items using a self-service register scanner, thereby eliminating payment lines, one of the largest customer experience issues for grocers. Walmart and Verizon will test the deployment of 5G in two locations, integrating engagement applications for auto check-in to its new medical clinics. [44] These are some examples, and more and more companies are adapting to AR/VR for added customer experience which would bring new dynamics to retail stores and 5G will help them to achieve this.

Overall, 5G technology deployment will create new values from a number of sectors of Canada's economy. An estimated 16% of GDP growth will be improved by the delivery of 5G networks and corresponding applications. And all the sectors discussed above have huge potential and are expected to have a very significant contribution to the country's economy.

5 5G impact on energy consumption, carbon/ greenhouse gas footprint, Climate Change

5G network structure diverges meaningfully from 4G in terms of networking means, produce forms, and performance parameters. The power consumption of 5G hardware is between two and four times greater than 4G, affecting unprecedented trials for site infrastructure creation. It demands systematic research and innovative 5G energy solutions to meet the energy challenges brought by 5G. The 5G era will be a completely mobile, fully associated smart era. It will see the development of networks and communication between people, between people and things, and between things and things. With the number of global connections set to surpass 100 billion by 2025, 5G will engender a greater variety of situations and service necessities.

5.1 The 5G impact on Climate Change

It is important not to forget the daunting threat of climate change. Without meaningful action, climate change is probable to cause noteworthy, long-term, and potentially permanent hurt to the environment, the economy, and people's way of life.

In the Evolving Policies Scenario, Canadians decrease their energy consumption and adopt lower carbon sources. Total primary energy usage reduction of 21% from 2021 to 2050. Unabated fossil fuel combustion (fossil fuel combustion without carbon capture and storage) falls 19% from current levels by 2030, 45% by 2040, and 62% by 2050. The Canadian's plan contains worthy endeavours, such as retrofitting buildings and delivering more energy-efficient transit options. Nevertheless, what the strategy does not address is how a fast and effective deployment of 5G wireless technology is central to reaching Canada's carbon emission reduction commitments. 5G will allow substantial GHG emission decreases in the maneuver of mobile networks and across high-emitting Canadian industry sectors.
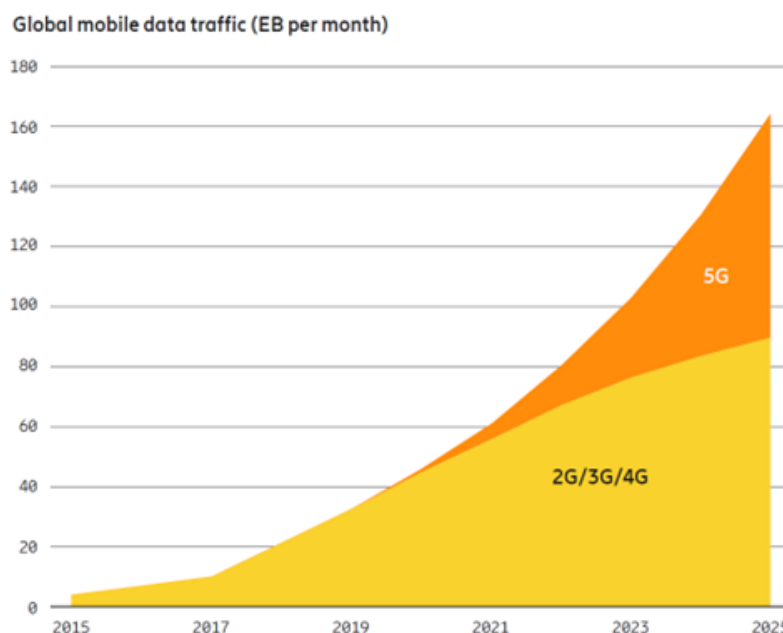
Figure 13. Canadian government plan to reduce energy consumption [3]

Despite the predictable explosive evolution in mobile data consumption, 5G networks will be more effective than previous wireless technologies. For instance, some studies estimation is that a 5G cell site will use only 8-15 percent of the energy of a current 4G site, whereas energy consumption by a mmWave 5G cell site could be as low as 2 percent of that spent by a 4G macro site. Besides, industry experts have estimated that 5G could support up to a thousand-fold growth in mobile traffic while by means of only half the energy of existing networks. These outcomes in an estimated energy productivity increase of 2,000 times.

Also, wireless technologies offer high-emitting trades the skill to decrease their own GHG emissions. Worldwide, it has been revealed that the usage of present and preceding wireless technologies across manufacturing sectors has resulted in GHG reductions 10 times greater than the cellular industry's own emissions. The implementation of 5G, cellular technologies will allow between 48-54 million (metric) tons of carbon dioxide emission (MTCO2e) to drop in Canada by 2025. That is the comparison of taking 10.5 million passenger vehicles off the street for a complete year. Likewise, it would account for up to 23 percent of Canada's current emission-saving targets by 2025. Smart cities, adjusted buildings, streamlined transport networks, and amplified efficiency

of inventory stocks and manufacturing are all becoming viable to adopt 5G. Examples of 5G-enabled technologies that will aid diminish GHG emissions include smart transportation answers that optimize vehicle traffic patterns and diminish congestion, extended reality (XR) technologies that deliver remote work and machine procedures, and more sophisticated and extensive use of connected building technology to control and systematize edifice HVAC and lighting systems.

Carbon dioxide emission drop (2025)	48-54 million (metric) tons
Passenger vehicles off the street	10.5 million

Table 1: Reduction of emission
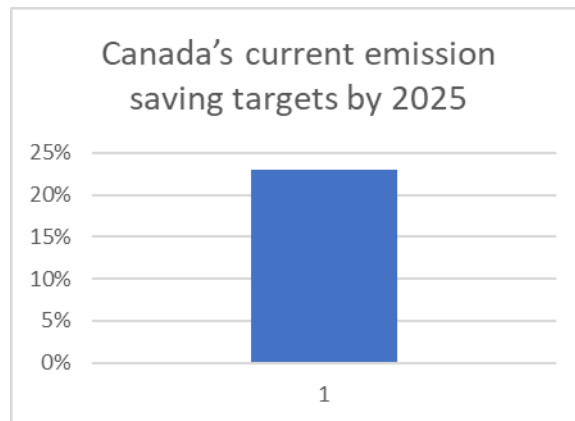
Figure 14: Canada saving percentage

5G and other wireless technologies can also support and diminish other forms of environmental harm that are not linked to GHG emissions. Wireless monitoring technologies can be applied to moderate water wastage from municipal water supply networks and monitor for hazardous waste and oil pipeline leaks. Such technologies will similarly be significant for Canada's farmers, helping to condense their use of fertilizers and pesticides.

The importance of 5G to Canada's financial retrieval and its environment is clear. But to realize these benefits, policymakers must guarantee the right policies are applied. Having invested over,$70 billion on network infrastructure and radio spectrum to build Canada's world-class mobile networks, it is projected that Canada's facilities-based carriers will need to devote another

$26 billion to deploy 5G networks, plus billions more to acquire extra spectrum. This level of investment needs a steady regulatory environment that inspires investment and provides a clear path to rational revenues. The fast and effective disposition of 5G also requires a streamlining of siting approval processes to offer fair, practical, and timely access to publicly owned structures, streetlights, and other street equipment for the installation of wireless apparatus. Lastly, supplementary radio spectrum must be unrestricted on a timely basis.

5.2 Increase data traffic without growing energy consumption

Energy usage is configured to rise intensely if 5G is arranged in the identical mode as 3G and 4G were. This is a dominant subject to resolving. Some communication companies projected to double or increase their energy consumption to achieve the goal of increasing traffic needs while refining their network and systematic 5G installation. This is not supportable from a financial or ecological standpoint.

Applying the 5G standard and more progressive efforts, it is conceivable to meaningfully diminish energy consumption. 5G, which is the most energy-awareness standard, will let the cellular system apply smart sleep methods more efficiently.

and outspread coverage by means of lesser bands while growing capacity and rapidity with carrier aggregation. Fast and effective data communication aids the system to reoccurrence to a little-weight state quicker.
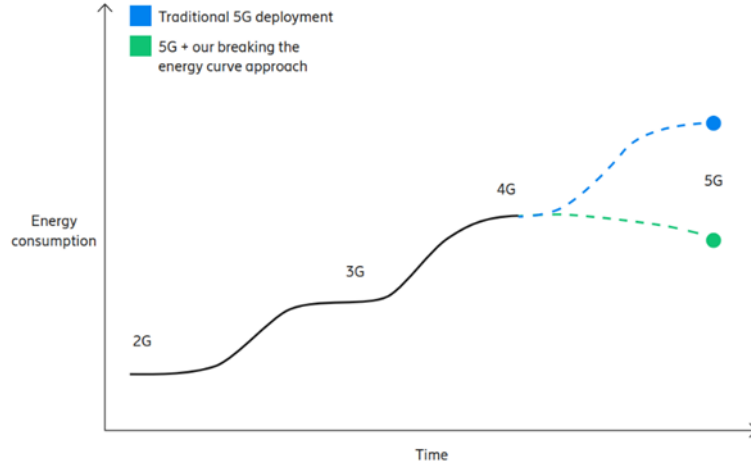
Figure 15: Energy consumption reduction approach [45]

An innovative approach to breaking the energy curve Taking the first step brings immediate savings and provides insights that can be applied later. Where and how to start implementation of our approach depends on each network design and status. Below are the three elements of the approach.

1. Formulate the network
2. Trigger energy-saving software
3. Build 5G with accuracy and Run site infrastructure intelligently.

5.2.1   Formulate the network

By modernizing the network with the latest technology and replacing old equipment, it is possible to realize new business opportunities and, at the same time, create significant energy savings. Previous deployments of mobile generations were often managed by adding new equipment while keeping existing network assets. This practice must change. We have seen that modernization in low-traffic areas can yield a payback period of fewer than three years for energy savings alone.

Preparing for and introducing 5G creates an opportunity to modernize and improve existing networks. Considering the limited capacity of current networks, growing traffic demand creates performance challenges. There are large energy and physical footprint savings to be realized in network

modernization. This can significantly reduce total mobile network energy consumption and make room for a 5G rollout within the same energy budget.

Service providers have different starting points and deployment priorities for their network evolution. We recommend that network modernization encompasses all aspects of site equipment as well as the core, transport, and radio access equipment. For example, upgrading from air-conditioned shelter sites to modern site cabinets and convection-cooled, multi-standard remote radio units in the radio tower will substantially reduce energy consumption.

5.2.2   Capable hardware is essential

New multi-standard hardware platforms offer a reduced physical footprint and the latest energy-reducing technologies that contribute to more energy-efficient networks. Updating with the latest Ericsson Radio System (ERS) solutions and dual mode 5G Core (5GC) provides immediate energy and cost savings, as well as facilitating a swift move to 5G in the future with a software installation.
ERS is a complete platform to build the highest-performing Radio Access Network (RAN) and offers optimal modularity to ensure the lowest total cost of ownership (TCO). All ERS equipment shipped since 2015 is 5G-ready. Having equipment on the ERS platform ensures that the network can migrate to the most efficient technology as soon as devices and services are available.
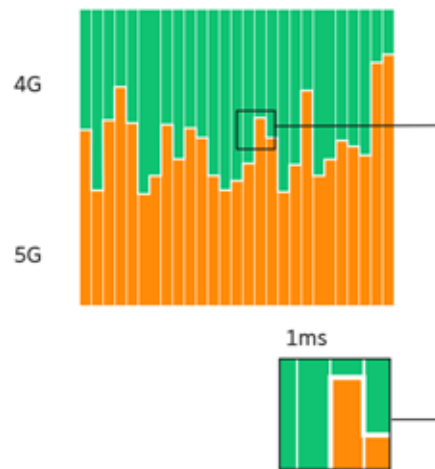
Figure 16: Ericsson Spectrum Sharing's unique 1ms solution [45]

5.2.3   Only one millisecond to switch between 4G and 5G

With Ericsson Spectrum Sharing (ESS), service providers can run 4G and 5G simultaneously on the same frequencies, without adding new energy-consuming hardware. ESS gives both technologies instant access to the same spectrum and assigns resources at a millisecond level to the devices that need them (as shown in Figure 15). The solution is available through a remote software installation on ERS base station hardware.
Spectrum evolution plan – using the most efficient standard.
When preparing for future RAN capacity, it is important to look at the current spectrum assets to create a spectrum evolution plan, assessing how spectrum needs will evolve (Figure 16).

Typically, a service provider has several frequency bands for various radio technologies (2G–4G). Over time, new spectrum bands will provide more capacity, but spectrum reallocation is needed to gradually shift traffic towards 4G and 5G. The network can migrate to the most efficient technology. This may mean implementing a robust 4G platform to monetize existing use cases and to be the basis of addressing the next wave of 5G. We recommend moving 2G and 3G to a joint lower frequency band, combined in an energy-efficient, mixed-mode configuration and, when possible, switching off one or both technologies.

Replacing 2G/3G with 4G will most likely double the capacity for the same spectrum. It also enables the use of more efficient energy-saving functionality, which the 4G standard offers. It is a perfect opportunity to reduce the energy spent on older radio technologies and get ready for implementing future 5G equipment.
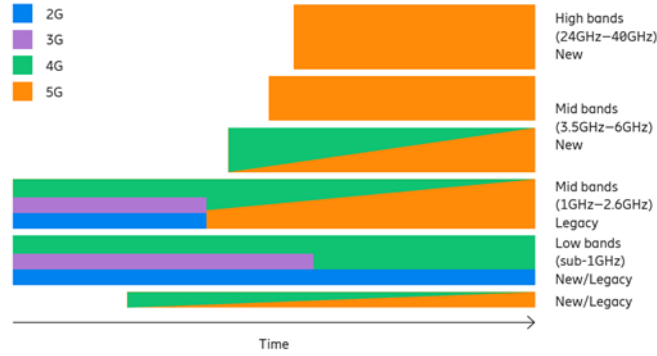
Figure 17: An example of a spectrum evolution plan [3]
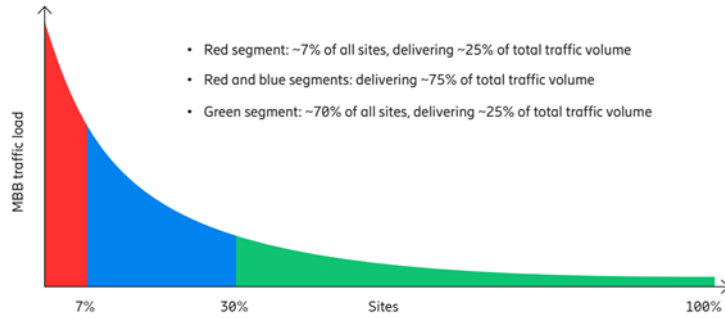
Figure 18: Typical mobile broadband traffic load split into three segments

5.2.4 Network reality

Based on extensive traffic data analysis from networks across the world, it is known that 2G, 3G and 4G have an almost identical traffic distribution over the total number of radio sites (Figure 17).

Sites with high traffic loads tend to have the largest year-on-year growth, while growth is much lower where traffic volumes are already low.

Some dense urban sites experience low traffic volumes due to small cell areas, while some rural sites cover large geographical areas and carry fairly high traffic loads.

This understanding enables service providers to model network evolution to meet expected traffic growth.

Defining quality

Service providers' perceived delivered quality is defined by how well they

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dimensioned the most valuable sites in the red and blue segments above. Traditionally, the focus has been on managing capacity expansion and spectrum efficiency on these sites to protect and handle the increasing mobile broadband traffic.

Defining network energy use

To break the energy curve of total mobile network energy consumption, the green segment above must be addressed. It could be perceived that keeping older equipment on these sites can handle the increased traffic demands. However, introducing the latest ERS equipment will immediately lower energy consumption by about 30% in like-for-like modernization.

Enhanced operational efficiency with dual-mode 5G Core (5GC)

To efficiently prepare for the move to 5G, the core network is rapidly transforming to cloud-native implementations. Our dual-mode 5GC combines network functions from 5G Evolved Packet Core and 5GC architecture into a common cloud-native software platform. This supports standalone and non-standalone 5G, 4G, 3G and 2G access technologies. It delivers high levels of orchestration and automation for operational efficiency and provides up to 20% savings in infrastructure with cloud-native operations[46].

5.2.5 Trigger energy-saving software

Ericsson Radio Access Network (RAN)has these applications available and can be activated immediately. Adding machine learning will bring further savings. Features such as Micro Sleep Tx (MSTx) and the Low Energy Scheduler Solution (LESS) can reduce radio equipment energy consumption by up to 15% while maintaining the same user experience.

The energy-saving software functionality automatically switches equipment on and off to follow traffic demand as it varies over time. Experience from networks across the world shows that these functions could significantly reduce energy costs without any need for additional hardware investments. The solutions enable the optimization of energy-saving functionality across service providers' networks. It provides a helicopter view of energy use, an assessment of possible energy savings and myriad Radio Access Network (RAN) energy-saving functionality for all mobile generations[47].

5.2.6 RAN sleep modes will reduce energy consumption at minimal effort

Most energy is consumed in the RAN. We can help service providers automatically make use of low-traffic periods and deactivate capacity when it is not required. Through advanced measurements that predict traffic patterns and load, and end-user needs, from cell to subframe levels, and can dynamically activate.

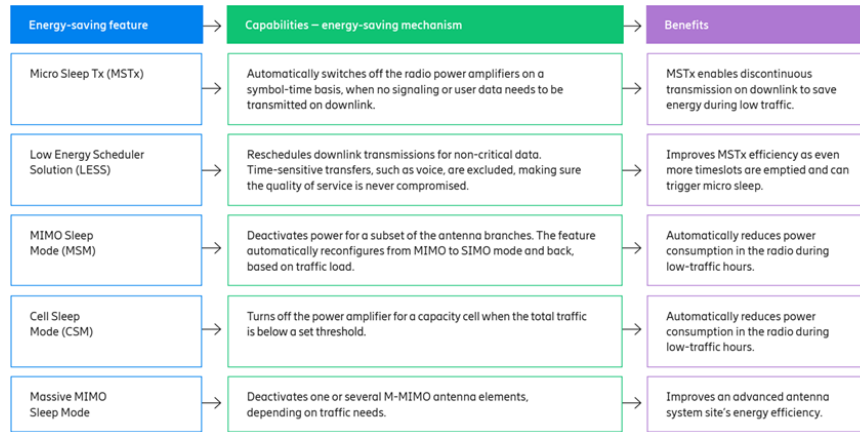| Energy-saving feature	Capabilities – energy-saving mechanism	Benefits
Micro Sleep Tx (MSTx)	Automatically switches off the radio power amplifiers on a symbol-time basis, when no signaling or user data needs to be transmitted on downlink.	MSTx enables discontinuous transmission on downlink to save energy during low traffic.
Low Energy Scheduler Solution (LESS)	Reschedules downlink transmissions for non-critical data. Time-sensitive transfers, such as voice, are excluded, making sure the quality of service is never compromised.	Improves MSTx efficiency as even more timeslots are emptied and can trigger micro sleep.
MIMO Sleep Mode (MSM)	Deactivates power for a subset of the antenna branches. The feature automatically reconfigures from MIMO to SIMO mode and back, based on traffic load.	Automatically reduces power consumption in the radio during low-traffic hours.
Cell Sleep Mode (CSM)	Turns off the power amplifier for a capacity cell when the total traffic is below a set threshold.	Automatically reduces power consumption in the radio during low-traffic hours.
Massive MIMO Sleep Mode	Deactivates one or several M-MIMO antenna elements, depending on traffic needs.	Improves an advanced antenna system site's energy efficiency.

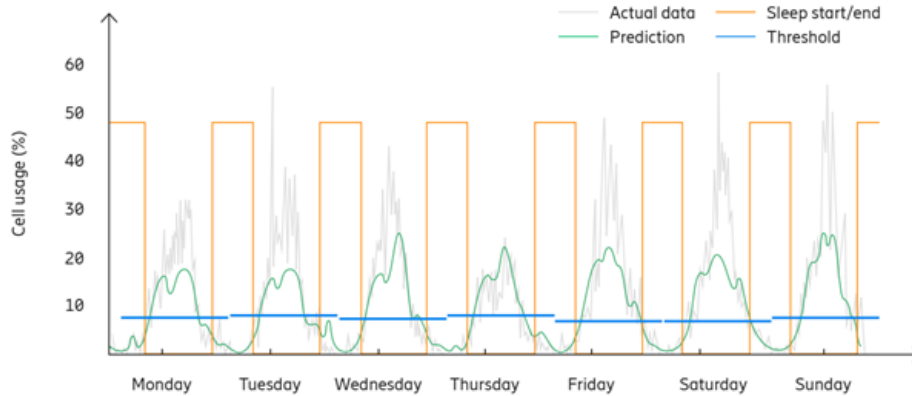Figure 19: Examples of our 4G and 5G energy-saving features

Figure 20: Traffic prediction using machine learning for augmented MIMO Sleep Mode.

RAN Compute and radio equipment. This will achieve the lowest possible

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energy consumption with maintained network performance.

By activating energy-saving features, such as Micro Sleep Tx (MSTx) and the Low Energy Scheduler Solution (LESS), service providers can achieve immediate savings (Figure 6). In 4G, MSTx and LESS can reduce the energy consumption for radio equipment by up to 15% while maintaining user experience. From 5G, MSTx will always be activated.

5.2.7 Augmented MIMO and Cell Sleep Mode enhance traffic-aware power savings

Machine learning (ML) will be applied to energy-saving functionality to enhance efficiency and make the features more autonomous. MIMO Sleep Mode (MSM) and Cell Sleep Mode (CSM) are among the first energy-saving features where ML will be used.

Data traffic patterns can change due to environmental variations, such as new buildings and roads. ML utilizes real-time traffic predictions to augment existing functionalities (Figure 19). For augmented MSM in a cell with 4x4 MIMO, the ML algorithms analyze traffic continuously. It will then predict when to use all four radio antenna branches or just one branch to transmit, and when to change back to make sure the features never compromise user experience and associated key performance indicators (KPIs). In a trial cluster, field data showed an average of 14% savings in energy consumption per site while KPIs were maintained.

The savings will increase as this functionality is deployed in 5G networks. The 5G radio interface enables longer sleep periods for the radio power amplifiers due to more generous discontinuous reception cycles in the downlink.

In dense networks, overlaid cells are deployed. With CSM, overlaid capacity cells can detect low-traffic conditions and turn themselves off to save energy, with confirmed support from coverage cells. The coverage cell monitors traffic conditions to turn on the sleeping cells. This is a self-organizing network (SON) capability that adapts to network traffic conditions. When an overlaid capacity cell is turned off, the traffic load existing in the cell is offloaded to the coverage cells.

5.2.8 Build 5G with accuracy and Run site infrastructure intelligently

It is important to have the right equipment in the right place. Building 5G with precision is about optimizing network performance on the new 5G frequencies while keeping Capex and Opex within certain limits. When complemented with unique solutions, such as Ericsson dual mode 5G Core (5GC), Ericsson Radio System (ERS) and Ericsson Spectrum Sharing (ESS), a swift 5G rollout is enabled without adding any further energy-consuming hardware. This means service providers can limit energy consumption growth when introducing 5G.

By using AI, service providers can operate site infrastructure more proactively. Our portfolio offers tools to control passive equipment and enable predictive maintenance and no-touch problem-solving to reduce costs, site energy usage and site visits. Customer cases show that service providers have reduced site energy consumption by up to 15% through intelligent site control solutions.

5.3 Traffic growth demands more on-site equipment and complexity

Site traffic capacity growth will demand more equipment to be hosted and integrated. Available site power budget and space are often limited and, therefore, require solutions to be compact and energy efficient. On top of this, sites incorporate efficient, environmentally friendly technology.

With increasing onsite demand and complexity, service providers face substantial challenges. Among them, decreasing operational efficiencies, fragmented data from "passive" site systems and lack of a holistic view of all sites are a high priority.

Using automation and AI technologies, we enable smart site energy management through accessibility from either the Network Operations Center (NOC) or on a tablet, smartphone or laptop in the field. Using 24/7 data points, service providers can benefit from predictive maintenance, as well as lower operations and maintenance costs, carbon emissions and site power

consumption.

5.4 Digitally integrate site elements with smart connected sites

Ericsson Smart Connected Site with smart enclosures (Figure 21) is an intelligent and unified way to digitalize the site, enabling remote control and monitoring of all site equipment. The visualization can be at network, site and cabinet levels, and accessible from the NOC or field devices.

The Smart Connected Site combines various measurements and alarms from passive infrastructure with the active (radio, baseband and transport) data into one O and M tool: our Ericsson Network Manager (ENM) system. This enables automated and AI-driven data collection and site data analysis, so the service provider can manage the network more efficiently through real-time insights and control. Service providers also benefit from more intelligent site management with 24/7 information on availability, capacity, network performance and energy management, along with unprecedented control over network stability. The result is a drastic reduction in lifecycle costs, site visits and energy consumption, alongside improved network quality.

5.5 AI-powered infrastructure operations

Our Energy Infrastructure Operations (EIO) is a data-driven service offering that delivers energy-related Opex and Capex savings, as well as operational efficiencies to substantially reduce carbon emissions.

EIO is a multivendor, focusing on gaining energy efficiencies from the passive infrastructure, as well as active radio and transmission equipment on site. While there are many features available for optimizing active site elements (i.e., radio equipment), passive elements supporting the Radio Access Network (RAN) are often overlooked, even though they could represent over 50% of the overall site power consumption.

Figure 21: AI-powered infrastructure [48]

Hence, we have developed EIO as an end-to-end energy management solution to address and manage all site elements impacting the site energy consumption, utilizing AI and data analytics.

The offering is based on data from Ericsson Smart Connected Site's smart enclosures or separately deployed site controllers, connected to all relevant passive infrastructure (battery, diesel generator, rectifier, HVAC, solar, etc.). This enables all site elements to be visible, measurable and controllable to enable remote and intelligent site management. Powered byAI and supported by over 30 fully automated efficiency cases, EIO:
• collects and measures all relevant passive and active infrastructure data
• analyzes it in real-time and proactively
• automatically initiates trouble tickets and work orders based on enriched alarms and performance measurements.

EIO also provides recommendations to improve site energy efficiency, site visit optimization, network performance and, ultimately, to significantly reduce the site's total cost of ownership. This solution is unique as it comes with an innovative business model, where value delivered through the overall energy savings is offered with an attractive return on investment profile. This service provides the following indicative benefits:
• 15% decrease in energy-related opex
• 15% reduction in passive infrastructure-related site visits.
• 30% decrease in energy-related outages.

5G Power efforts on enlightening energy and E2E productivity at the module, site, network, and service level, consuming zero watts when there are zero bits. 5G Power's groundbreaking technology cuts the cost of 5G network progress and enhances energy efficiency by around 9 percent. Moreover, the solution's energy-storing modular expansion ability wires of power operations services and the frequency and peak flake services for the power grid give an extra 8 percent return.

5G Power will attend as a significant reference for future 5G network deployment and growth around the ecosphere. It will benefit global operators save on-site retrofitting and power costs and increasing energy conservation and emissions reduction in sites, helping shape a sustainable and green target power grid for the 5G era.

6 Quality of Life

5G technology has the potential to significantly impact the quality of life in Canada by enabling faster and more reliable connectivity, supporting new applications and technologies, and enhancing various aspects of daily life. Here are some potential ways in which 5G could impact the quality of life in Canada:
1. Enhanced healthcare: 5G technology could enable new healthcare applications and technologies, such as remote monitoring, telemedicine, and virtual consultations, which could improve access to healthcare services and enhance patient outcomes.
2. Improved transportation: With faster and more reliable connectivity, 5G could improve transportation systems by enabling real-time traffic management and more efficient routing, as well as supporting autonomous vehicles and other smart transportation technologies.
3. Enhanced education: 5G technology could improve education by enabling new remote learning and virtual classroom experiences, which could improve access to education and enhance the quality of teaching.
4. Increased economic growth: 5G technology could support economic growth by enabling new industries and technologies, such as smart manufacturing

and autonomous systems, which could create new job opportunities and drive innovation.

5. Enhanced entertainment and media: With faster connectivity, 5G could enhance entertainment and media experiences by enabling high-quality streaming of video and music, as well as supporting new augmented and virtual reality experiences.

6.1   5G enabled Smart hospital

5G technology has the potential to significantly impact smart hospitals by enabling faster and more reliable connectivity, as well as supporting new applications and technologies. Here are some ways in which 5G could impact smart hospitals[49]:

1. Faster and more reliable connectivity: 5G technology is expected to provide faster and more reliable connectivity than previous generations of wireless technology, enabling more seamless connectivity for smart hospital devices and applications[49].

2. Support for new applications and technologies: 5G networks are expected to support new applications and technologies that could benefit smart hospitals. For example, 5G-enabled remote surgery and telemedicine applications could enhance patient care by providing real-time communication between medical professionals and patients[50].
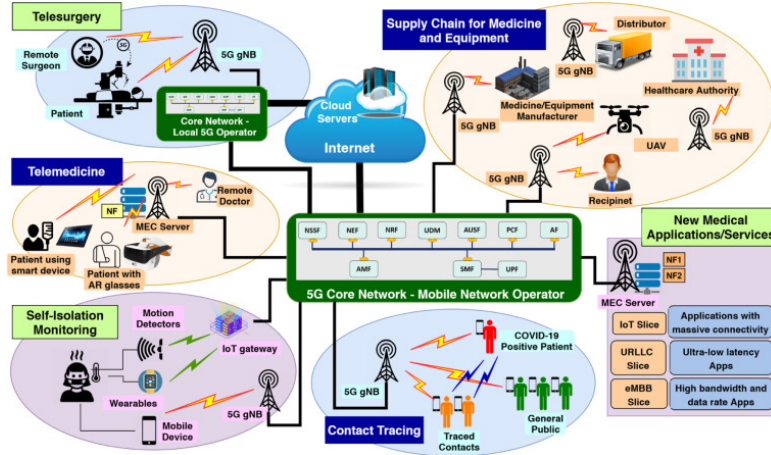

Figure 22: 5G health use cases for the fight against COVID-19 [51]

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3. Improved patient experience: With faster and more reliable connectivity, 5G could improve the patient experience by enabling more efficient communication between patients and medical professionals, as well as improving access to medical records and other important information.

4. Increased use of IoT devices: 5G networks could support a wider range of IoT devices, such as wearables and sensors, which could be used to monitor patient health and improve patient outcomes.

5. Greater flexibility and scalability: 5G networks could provide greater flexibility and scalability for smart hospital networks, enabling hospitals to quickly and easily add new devices and applications as needed.

6. Remote monitoring: 5G technology could enable remote monitoring of patients, allowing medical staff to track patient health and vital signs in real time and respond quickly to changes in their condition[50].

7. Telemedicine: 5G technology could support telemedicine applications, allowing patients to access healthcare services remotely from their homes or other locations, improving access to care and reducing the need for in-person visits.

8. Smart wearables and devices: With faster and more reliable connectivity, 5G could support a wider range of smart wearables and devices, such as smartwatches and sensors, which could be used to monitor patient health and track their progress over time.

9. Real-time data sharing: 5G could enable real-time sharing of patient data between medical staff, improving collaboration and reducing the risk of errors or miscommunication[50].

10. Enhanced imaging and diagnostics: 5G could enable new imaging and diagnostic technologies, such as real-time 3D imaging and AI-assisted diagnostics, which could improve the accuracy and speed of diagnoses and treatment. Overall, 5G technology has the potential to transform smart hospitals by providing faster and more reliable connectivity, enabling new applications and technologies, and improving the patient experience.

6.2 5G impact on transportation

5G technology has the potential to significantly improve transportation systems by enabling faster and more reliable connectivity, supporting new applications and technologies, and enhancing various aspects of transportation. Here are some potential ways in which 5G could improve transportation[52]:

1. Real-time traffic management: With 5G technology, transportation systems

could be equipped with sensors and real-time data analysis capabilities to provide accurate and up-to-date information on traffic patterns and conditions. This could enable real-time traffic management and more efficient routing of vehicles, reducing congestion and improving travel times.

2. Connected and autonomous vehicles: 5G technology could support the development and deployment of connected and autonomous vehicles, which could communicate with each other and with transportation infrastructure to optimize traffic flow and enhance safety[52].

3. Enhanced public transportation: 5G technology could enhance public transportation systems by enabling real-time tracking of vehicles and passenger data, improving efficiency and reducing wait times. Additionally, 5G could enable new features such as mobile ticketing and real-time information displays.

4. Intelligent transportation systems: 5G technology could enable the development of intelligent transportation systems that use real-time data to optimize traffic flow, reduce congestion, and improve safety[52].

5. Freight and logistics: 5G technology could support the development of new freight and logistics applications and technologies, such as real-time tracking and monitoring of shipments, which could improve efficiency and reduce costs. Overall, 5G technology has the potential to transform transportation systems by enabling faster and more efficient travel, enhancing safety, and reducing congestion and emissions. However, it is important to address potential challenges and risks associated with the adoption of this new technology, such as cybersecurity concerns and the need for regulatory frameworks to ensure safety and fairness.

6.3 Smart education with 5G

5G technology has the potential to transform the way education is delivered in Canada, making schools smarter and more connected than ever before. Here are some potential ways in which 5G can enhance the educational experience in Canada[53]:

1. Improved Connectivity: 5G networks offer faster and more reliable connectivity, which can enable students and teachers to access online resources, educational materials, and collaborative tools from anywhere and at any time.

2. Virtual and Augmented Reality: With 5G, schools can leverage the power of virtual and augmented reality to create immersive and engaging learning experiences that go beyond traditional classroom instruction. For example,

students can take virtual field trips, explore complex scientific concepts, and learn in a more interactive and hands-on way[53].

3. Smart Classrooms: 5G can enable smart classrooms that are equipped with intelligent devices and sensors that can collect data and provide real-time feedback to teachers and students. This can help to personalize learning, improve student engagement, and enhance the overall educational experience.

4. Distance Learning: 5G can enable high-quality and seamless video conferencing and remote collaboration, which can facilitate distance learning and enable students to learn from anywhere in the world.[53]

5. Advanced Analytics: 5G can enable schools to collect and analyze vast amounts of data on student performance, learning outcomes, and other key metrics. This can help to identify areas of improvement, optimize teaching strategies, and personalize learning for individual students.

Overall, 5G has the potential to revolutionize the way education is delivered in Canada, making schools smarter, more connected, and more effective at preparing students for the challenges of the future.

6.4   5G impact on mental health

5G technology has the potential to improve mental health services in Canada in several ways. Here are some potential ways in which 5G can help improve mental health in Canada[54]:

1. Remote Consultations: With 5G, mental health professionals can provide remote consultations to patients located in remote or underserved areas. This can help to reduce wait times and improve access to mental health services, particularly in rural or remote communities.[54]

2. Teletherapy: 5G can enable high-quality and seamless video conferencing and remote collaboration, which can facilitate teletherapy and enable patients to receive therapy from the comfort of their own homes.

3. Wearables and Remote Monitoring: 5G can enable the use of wearables and remote monitoring devices to collect data on patients' physical and mental health. This can help to identify early warning signs of mental health issues and enable healthcare providers to intervene before a crisis occurs.

4. Artificial Intelligence and Machine Learning: 5G can enable the use of artificial intelligence and machine learning algorithms to analyze large amounts of data and identify patterns and trends that may be indicative of mental health issues. This can help to improve the early detection and diagnosis of mental health conditions.[55]

5. Peer Support and Online Communities: 5G can enable the creation of online peer support networks and communities where individuals can connect with others who are experiencing similar mental health challenges. This can help to reduce social isolation and provide a sense of community and support for those struggling with mental health issues.

6. Mindfulness and Meditation Apps: 5G can enable the development of high-quality mindfulness and meditation apps that can help individuals manage stress, anxiety, and other mental health issues. These apps can provide guided meditation sessions, breathing exercises, and other techniques to help individuals relax and de-stress.

7. Virtual Reality and Relaxation: 5G can enable the use of virtual reality (VR) to create immersive and relaxing experiences that can help individuals reduce stress and anxiety. For example, VR environments that simulate natural settings, such as a beach or a forest, can help individuals feel more relaxed and calm.[54]

8. Early Intervention and Prevention: 5G technology can enable the use of wearable devices and other remote monitoring tools that can track changes in an individual's mental health status. This can help to identify individuals who may be at risk of suicide and provide early intervention and prevention services before a crisis occurs.

Overall, 5G has the potential to transform the way mental health services are delivered in Canada, improving access, quality, and outcomes for patients.

7 Conclusion and Future Work

5G technology has the potential to bring significant benefits to the economy, the environment, and the quality of life. The higher speeds, lower latency, and increased capacity of 5G networks will enable new applications and use cases that were not possible with previous generations of wireless technology. This, in turn, will create new business opportunities, increase productivity, and lead to job creation.

In terms of the environment, 5G can help reduce energy consumption and greenhouse gas emissions by enabling more efficient and sustainable operations in various sectors. For example, 5G-enabled smart grids and smart transportation systems can optimize energy usage and reduce traffic congestion, respectively.

Moreover, 5G can enhance the quality of life by improving healthcare, educa-

tion, and public safety. Remote patient monitoring, telemedicine, and virtual education can become more accessible and reliable with the low latency and high bandwidth of 5G networks. Additionally, 5G can enable advanced public safety systems, such as real-time video surveillance and emergency response. This report covers some of the impacts that 5G has or will have in terms of GDP, Environment and Quality of life. There may be more impact in different aspects so, additional research is needed to fully understand the economic, environmental, and social impact of 5G. It is a rapidly developing field and it's only the start of this decade where in the end we will see a more evolved 5G in all aspects. With more time more new challenges will come up so all the researchers, stakeholders & policymaker needs to be ready and this report could be a guide to further expand this research work.

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