Deep Dives and Case Studies for TELUS Priority Verticals: Energy

Prepared for TELUS Communications Inc.

Prepared by: Deetken Insight

30 June 2022

Deetken Insight

5.1 Deep Dives and Case Studies for TELUS Priority Verticals

5.1.1 Energy

Key Takeaways

- Key challenges faced by the energy and electric utility industry include increasing energy demand driven by rising living standards in developing countries; growing levels of electrification and utilization of renewable energy creating significant demand side pressures and increasing operational complexity due to the integration of new energy sources; a shift from the traditional utility business model towards a new decentralized model which requires a complex self-driving power system composed of a network of technologies and distributed controls that work together to efficiently match bi-directional energy supply to energy demand; additional ESG and regulatory pressures; energy wastage; competitive pressures from global markets; outdated extraction, generation and distribution plants and processes; increased risk of natural disasters due to climate change; and physical and cyber attacks.
- 5G will enable innovative applications that could optimize energy extraction and distribution operations and infrastructure while also addressing the additional complexities introduced by decentralized grids with multiple energy sources. These digital 5G solutions include AR/VR-enabled diagnostics and worker training; smart grids that leverage AI and predictive analytics to automatically react to changes in power demand; smart meters that provide real-time data on consumption and generation; remote drone surveillance to manage security; supervisory control and data acquisition (SCADA) systems that proactively detect infrastructure faults; and digital workforce management with seamless real-time collaboration.
- These 5G solutions could enable accurate demand predictions and supply adjustments from distributed grids; reduce peak energy demand; optimize energy extraction and distribution operations; reduce downtime through improved diagnostics and maintenance; cut operational expenditures; enhance worker training and safety; streamline end-to-end logistics; reduce electricity theft and wastage along the supply chain; help standardize regulatory compliance through digitization; and improve physical and cyber security.

Industry Overview: In Canada, energy production was equal to 8.3% of total Canadian GDP in the fourth quarter of 2021.[1] The current transformation underway in the energy sector is one of the most important challenges facing humankind. Cumulatively, fossil fuels (petroleum and other liquids, natural gas, and coal) still accounted for 80% of the world's primary energy consumption

[1] Link to report: https://energy-information.canada.ca/en/subjects/energy-and-economy

in 2019. Nuclear energy and renewables accounted for the remainder of energy consumption at 5% and 15%, respectively.[2] The overall demand for energy is expected to continue growing as the global population is anticipated to reach 9.7 billion by 2050.[3] Improving standards of living in developing markets will also play a critical role in the growth of energy consumption in these markets. The U.S. Energy Information Administration (EIA) projects nearly a 50% increase in world energy usage by 2050, led by growth in Asia.[4] By 2050, we will still get approximately 69% of our energy from fossil fuels, 4% from nuclear and 28% from renewables based on estimates from the U.S. Energy Information Administration.[5] The Intergovernmental Panel on Climate Change (IPCC) states that emissions must be reduced by at least 45% from 2010 levels by 2030 and reach "net zero" emissions by around 2050 to limit global warming to 1.5 degrees Celsius and avoid the worst impacts of climate change.[6] This dichotomy puts the energy and electric utility sectors in the centre of a massive energy transition which will last for multiple decades as the world strives to wean itself off fossil fuels.

Given the oil and gas and electric utility sectors' highly diversified and complex operations, processes, infrastructure and technical workforce, as well as the magnitude of their economic and environmental footprint, it is expected these industries will drive the migration from Industry 3.0 to Industry 4.0 using 4G-LTE and 5G lite enabled digital solutions.[7] Widespread use of digital technologies in the oil and gas sector could decrease production costs between 10% and 20%, including through advanced processing of seismic data, the use of sensors and enhanced reservoir modelling.[8] Technically recoverable oil and gas resources could be boosted by around 5% globally, with the greatest gains expected in shale gas.[9] The International Energy Agency (IEA) estimates that the overall savings from these digitally enabled measures could reach approximately US$80 billion per year from 2016 to 2040, or about 5% of total annual power generation costs.[10] This would extend the lifetime of all power assets in the world by five years and defer close to US$1.3 trillion of cumulative investment between 2016 and 2040, or about 7% of total power sector investment, according to the IEA.[11]

Challenges faced by the energy and electric utility industries:

1. **Increase in energy demand from population growth and rising living standards in developing economies:** As the global population continues to grow, it will drive increased energy demand from emerging markets and developing economies. Across all fuels and technologies, emerging markets will be instrumental in shaping global trends in the coming

[2] Link to report: https://www.eia.gov/todayinenergy/detail.php?id=41433
[3] Link to report: https://www.un.org/en/global-issues/population
[4] Link to report: https://www.eia.gov/todayinenergy/detail.php?id=41433
[5] Link to report: https://www.eia.gov/todayinenergy/detail.php?id=41433
[6] Link to report: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/#:~:text=Global%20net%20human%2Dcaused%20emissions,removing%20CO2%20from%20the%20air.
[7] Link to report: https://www.frost.com/frost-perspectives/5g-a-critical-enabler-for-digitalization-in-oil-and-gas-emerging-use-cases-and-opportunities/
[8] Link to report: https://www.pwc.com/ca/en/media/release/digitization-decrease-production-cost-for-oil-and-gas-companies.html
[9] Link to report: https://iea.blob.core.windows.net/assets/b1e6600c-4e40-4d9c-809d-1d1724c763d5/DigitalizationandEnergy3.pdf
[10] Link to report: https://iea.blob.core.windows.net/assets/b1e6600c-4e40-4d9c-809d-1d1724c763d5/DigitalizationandEnergy3.pdf
[11] Link to report: https://iea.blob.core.windows.net/assets/b1e6600c-4e40-4d9c-809d-1d1724c763d5/DigitalizationandEnergy3.pdf

decades. According to the IEA's Stated Policies Scenario (STEPS)[12], oil demand in these economies will be 12 mb/d higher in 2030 than in 2020 (an increase of nearly 30%), gas demand will be higher by 520bcm (a near 25% increase), and coal demand will be higher by 160Mtce (a 4% rise)[13]. Demand for fossil fuels in advanced economies is falling in the Announced Pledges Scenario (APS),[14] but announced pledges do not bend projected demand trends across most of the developing world.[15]

2. **Shift from non-electric sources of energy (fossil fuels) to electricity:** Electrification is a major emerging trend in energy markets around the world. Driving this trend are a collection of newly improved electric end-use technologies (e.g., vehicle fleets; appliances; heating, ventilation, and air conditioning systems; industrial machinery; and other types of energy-consuming equipment), engaged consumers and manufacturers, and a variety of policy objectives in different jurisdictions. As energy and electricity impact every other sector of the economy, electrification has the potential to significantly affect actors across the entire landscape.[16]

3. **Shift away from the traditional utility business model, in which monopolist power companies distribute their energy from large power plants to the end-user:** Decentralization of the energy utility market will look like a distributed energy network with a democratic business model in which energy consumers manage their own energy portfolios. Decentralization requires several technologies with different implications for the grid: distributed generation from renewable sources (primarily photovoltaic solar), which reduces demand during sunny hours of the day; distributed storage, which collects electrical energy locally for use during peak periods or as backup, flattening demand peaks and valleys; energy efficiency, which allows for reduced energy use while providing the same service, reducing overall demand; and demand response, which enables control of energy use during peak demand and high pricing periods, reducing peak demand. As more distributed energy resources (DERs) come online, demand response programmes may become even more flexible and, by some estimates, could reduce necessary annual investments in U.S. grid infrastructure by 10%.[17] Demand flexibility also creates value for customers and the grid by shrinking customer bills (by as much as 40%), reducing peak demand and shifting consumption to lower prices and off-peak hours.[18] This new decentralized model when fully scaled should not only reduce transmission and distribution costs (and losses) but also optimize the use of renewable energy, especially

[12] Definition: Sector-by-sector look at what measures governments have actually put in place, as well as specific policy initiatives that are under development which are then depicted in IEA's Stated Policies Scenario (STEPS).
Link to report: https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf
[14] Definition: The Announced Pledges Scenario introduced this year aims to show to what extent the announced ambitions and targets, including the most recent ones, are on the path to deliver emissions reductions required to achieve net zero emissions by 2050. It includes all recent major national announcements of 2030 targets and longer term net zero and other pledges, regardless of whether these have been anchored in implementing legislation or in updated NDCs. In the APS, countries fully implement their national targets to 2030 and 2050, and the outlook for exporters of fossil fuels and low emissions fuels like hydrogen is shaped by what full implementation means for global demand.
[15] Link to report: https://www.iea.org/reports/world-energy-outlook-2021/executive-summary
[16] Link to report: https://www.nrel.gov/docs/fy18osti/71500.pdf
[17] Link to report: https://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf
[18] Link to report: https://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf

when hundreds of local generators of renewable energy connect to a smart grid. In the centralized model, more power is generated and distributed when demand peaks. In a decentralized system, demand response is used to manage distribution and grid stability. However, the number of energy consumers, equipment, and demand patterns that must be coordinated is enormous.[19,20]

4. **Digitalization, which allows devices across the grid to communicate and provide data useful for customers and for grid management and operation:** Smart meters, new smart/IoT sensors, network remote control and automation systems, and digital platforms that focus on optimization and aggregation, allow for real-time operation of the network and its connected resources, and collect network data to improve situational awareness and utility services.

5. **Increased variability caused by demand and supply of different energy sources:** New energy sources are and will continue to create complex dynamics between electricity, fuels and storage markets. These complex interactions will generate considerable variability on both the demand and supply sides of the energy equation. The variability of electricity supply will be affected by rising shares of wind and solar photovoltaic (PV), necessitating robust grids and other sources of supply flexibility.[21]

6. **Demanding ESG goals and increased regulatory oversight:** International agencies, governments and policy makers have intensified their scrutiny of the energy and electric utility sectors because of the environmental challenges related to these sectors. The oil and gas and electricity sectors are major consumers and producers of energy and are subject to progressively stringent environmental regulations. These sectors are increasingly confronted with the need to develop and report their ESG targets that align with national and or international regulatory standards. This additional oversight is driving operators to redesign their extraction, production and transportation systems and processes to enhance their operational and regulatory effectiveness. Operators are also required to provide transparency in the environmental management of their activities. These considerations have become critical as these two sectors face accelerating change and increased activism.

7. **Wastage of energy during generation and consumption:** According to the EIA, approximately 60 to 66% of energy used for electricity generation is lost in conversion.[22] It is estimated that of the 66% of energy lost, 54% is due to inefficiencies in the process of converting primary energy to electricity, 5% is lost to the power plant during operations and the remaining 7% is lost during the delivery of electricity through the transportation

[19] Link to report: https://solutions.mhi.com/blog/the-energy-transition-depends-on-these-three-trends/#:~:text=democratic%20energy%20management-,Decentralization,plants%20to%20the%20end%2Duser.
[20] Link to report: https://utilityanalytics.com/2021/08/energy-decentralization-why-its-a-big-deal-for-every-business/
[21] Link to report: https://iea.blob.core.windows.net/assets/4ed140c1-c3f3-4fd9-acae-789a4e14a23c/WorldEnergyOutlook2021.pdf
[22] Link to report: https://www.eia.gov/todayinenergy/detail.php?id=44436

and distribution system. This energy becomes waste heat released into the air due to line losses and conversion losses in transformers and other line equipment.[23]

8. **Reducing costs to remain globally competitive:** One of the major challenges of the energy industry is the high cost to produce crude oil, gas and refined products. Optimizing extraction, conversion and distribution systems and processes is a priority for both energy and utility operators.

9. **Transitioning to renewable energy sources:** Converting the current energy system to one led by renewable energy will require significant flexibility in all parts of the power system from generation to transmission and distribution systems, storage and demand. Production of heat and synthetic gas (e.g., hydrogen) from renewable electricity will also be key for energy system decarbonization in the long-term, and, once in place, it can be a significant additional source of flexibility for the power system.

10. **Increasing operational complexity from distributed smaller scale energy solutions:** The move from centralized to decentralized energy generation is accelerating. As more renewable energy sources connect to the grid, they are creating hundreds or thousands of power generation points and types and are making the power grid more complex to operate. This is resulting in reduced revenue for operators, increased transmission and distribution system costs, and increased risk regarding grid reliability and cyber-security.

11. **Outdated extraction, generation and distribution plants and systems:** Both Canada's and the U.S.'s electric utility sectors face a pressing need to maintain aging facilities, and operators are tasked with integrating more intermittent generation from renewable sources and incorporating smarter grid systems. There are more than 35 electrical transmission interconnections between the Canadian and U.S. power systems with the two systems forming a highly integrated grid. This integration is set to continue expanding, with multiple cross-border transmission projects currently in various stages of development. Every Canadian province along the U.S. border is electrically interconnected with one or more neighboring U.S. states. For utilities, the aged infrastructure is causing frequent tripping and breakdown because of a poor distribution system. The oil and gas sector faces a similar challenge in the form of fugitive emissions that account for approximately 5% of global emissions.[24] Over 60% of fugitive emissions come from leaky valves – and more

[23] Link to report: https://www.enerdynamics.com/Energy-Currents_Blog/How-Much-Primary-Energy-Is-Wasted-Before-Consumers-See-Value-from-Electricity.aspx#:~:text=According%20to%20the%20Energy%20Information,arrives%20at%20the%20customer%20meter.&text=It%20is%20estimated%20that%20of,lost%20in%20the%20generation%20process.

[24] Fugitive gas emissions are emissions of gas (typically natural gas, which contains methane) to atmosphere or groundwater which result from oil and gas or coal mining activity.[2] In 2016, these emissions, when converted to their equivalent impact of carbon dioxide, accounted for 5.8% of all global greenhouse gas emissions. Most fugitive emissions are the result of loss of well integrity through poorly sealed well casings due to geochemically unstable cement. This allows gas to escape through the well itself (known as surface casing vent flow) or via lateral migration along adjacent geological formations (known as gas migration). Approximately 1-3% of methane leakage cases in unconventional oil and gas wells are caused by imperfect seals and deteriorating cement in wellbores. Some leaks are also the result of leaks in equipment, intentional pressure release practices, or accidental releases during normal transportation, storage, and distribution activities.

than half of a plant's fugitive emissions can be eliminated by servicing, updating and replacing valves through new automation and monitoring technology.[25]

12. **Climate change and the increase in natural disasters:** Accidents like pipeline bursts and natural calamities like floods and earthquakes can also cause interruptions to electricity and energy supplies, as well as major spills and leaks.
13. **Asset protection from physical and cyber attacks:** The economic importance of oil and gas infrastructure means that they are a key target for terrorism and piracy, which can lead to high levels of damage.

Current oil and gas and electric utility business models will use 5G-enabled digital machines, devices, and technologies like AI/ML, BDA, digital twins, blockchain and others to optimize their operations and infrastructure. These new machines, devices, technologies and applications will improve the design, construction, and maintenance methods of oil and natural gas pipelines and electricity generation plants while simultaneously enhancing asset integrity and cost-efficiency and extending service life expectations. These innovative technologies will also further reduce environmental and work and safety incidents.

The proliferation of renewable energy sources will make our energy networks more complex. This increased complexity will be driven by factors, such as multiple energy sources and decentralized grids. To manage this complexity, the energy and utility sectors will require intelligent solutions to monitor and manage fluctuating demand and supply, environmental impacts and operational performance. 5G-enabled digital tools will help energy and utility operators overcome these acute challenges and make the necessary changes.

5G technology enhances critical awareness and decision-making for a variety of situations. As an example, drone-mounted cameras can help monitor seismic changes, fires, and natural disasters more effectively; they can help terminal operators proactively inspect container ships before they even reach the port and operators of wind farms proactively detect problems with turbines. Video analytics could significantly enhance the securit, and efficiency in the field by enabling intrusion detection, automatic fault detection, and control of robots. Similarly, search and rescue operations could leverage camera drones and video analytics to survey remote areas without human intervention.

Potential Digital Solutions Supported by 5G	Types of 5G Capabilities Leveraged
1. **VR, AR and MR (Mixed Reality)**[26] can be used to support collaboration for diagnostics and maintenance, enhance employee training and productivity, and recreate real-life scenarios for workers to safely practice their skills. These digital solutions could even support remote co-working by	1. **Ultra-low and predictable latencies with quality-of-service guarantees (URLLC)** even with a heavy load and many users by using network edge to optimize network traffic flows; Decentralization will drive the need for real-time control of the grid, and low latency requirements, which will also drive the

[25] Link to report: https://www.reuters.com/article/sponsored/capturing-fugitive-emissions-can-create-greener-more-cost-effective-operations
[26] Link to report: https://www.frost.com/frost-perspectives/5g-a-critical-enabler-for-digitalization-in-oil-and-gas-emerging-use-cases-and-opportunities/

allowing collaboration among employees in virtual spaces. Additionally, they could allow interaction with data, applications and the environment in new ways. Digital twins could create a virtual model of an oil and gas or power plant or even an entire grid, allowing employees to model different scenarios, make better decisions and improve efficiencies. 2. **AI and predictive analytics**[27] can be used to accelerate data clean-up and analysis of the massive volumes of data and reports generated by operational processes related to logistics, supply, and production. They can also be used to analyze and predict demand and adjust where power is drawn from on distributed grids. 3. **Smart grids**[28] can detect local changes in power usage and react automatically without the need for human intervention. They allow real-time communication between consumers and utilities so consumers can tailor their energy consumption based on individual preference, such as price and/or environmental concerns. They enable more efficient transmission of electricity; quicker restoration of electricity after power disturbances; reduced peak demand; increased integration of large-scale renewable energy systems; better integration of customer-owner power generation systems, including renewable energy systems; and improved security. 4. **Smart fleet management**[29] with GPS, sensors and enhanced 5G connectivity will enable enhanced maintenance and fuel management; driver safety; telematics; geo-fencing and tracking; smart surveillance; vehicle-to-vehicle communications; optimal real-time routing; speed/idling real-time feedback; real-time cargo monitoring; and collision avoidance. Through integrated planning, improved vehicle utilization, and route and speed optimization, oil companies have demonstrated 10% to 30% reductions in overall transportation costs. 5. **Smart contracts stored on blockchain**[30] are self-executing, customizable and tamper-proof in nature, smart contracts are seen as a key technology for enabling the transition to a more efficient, transparent and transactive energy market. The applications of smart contracts include coordination of smart electric vehicle charging, automated demand-side response, peer-to-peer	need for more capable edge computing to support required latencies. 2. **Extremely high bandwidth for data transmission (eMBB),** which will enable the transfer and download of massive data files, high-resolution images, videos and supporting AR/VR. 3. **Massive IoT (mIoT)** - 5G will be able to facilitate a large network of IoT devices and sensors. 4. **Fixed wireless access (FWA)** - ultra-low-cost networks in rural areas. 5. **More deployment flexibility** for sparse and dense options. 6. **Mobility capabilities to ensure a smooth handover** between base stations. 7. **Reliability of device interoperability** and low device cost at scale. 8. **Resilience and high availability** - All deployment scenarios must be able to ensure an elevated level of resilience and availability. To satisfy utilities' requirements, carriers may need to dedicate spectrum, radios, packet core instances and edge computing to utility customers. These dedicated resources can be enabled through the 5G slicing feature set. **9. Location awareness** for navigating, real-time locating, and positioning.

[27] Link to report: https://www.analyticsinsight.net/top-10-applications-of-ai-and-robotics-in-the-energy-sector/#:~:text=%20Top%2010%20Applications%20of%20AI%20And%20Robotics,energy%20companies%20to%20provide%20customers%20with...%20More%20
[28] Link to report: https://www3.weforum.org/docs/WEF_The_Impact_of_5G_Report.pdf
[29] Link to report: https://ihsmarkit.com/research-analysis/upstream-oil-and-gas-meeting-its-challenges-through-innovation.html
[30] Link to report: https://www.sciencedirect.com/science/article/pii/S1364032121012764

energy trading and allocation of the control duties amongst the network operators. 6. **Drone video surveillance, notification and analytics** to manage the security of campuses of oil and gas and electric utility companies and drilling, generation and distribution infrastructure; alerting systems that send notifications directly to mobile devices. 7. **Supervisory control and data acquisition (SCADA) systems that can proactively detect leaks and other issues** provide an abundance of data about the functionality and health of equipment. They can indicate the level of pressure within each pipe, monitor durable valves, measure tank level, track flow monitoring and much more. In addition to alarm notifications, operators can create preventative maintenance alerts so they can be proactive about their equipment. 8. **Digital workforce management** with seamless real-time collaboration; connecting employees across locations and time zones, allowing instant access to document and file sharing, and streamlined communication. Digital workforce management will also enhance remote work support, sustainability and better AI integration. 9. **Electric vehicles** (EVs) – 5G will be critical to guaranteeing safety and reliability via network slicing, which will play an essential role in guaranteeing connectivity. Network slicing will allow the creation of individual network slices with their own SLA-grade requirements for EVs and their charging infrastructure. This will require operators to be better equipped to guarantee the low latency and reliability they need to adapt to changing scenarios. EVs will be able to automatically switch to 5G without disrupting or interrupting communication with charging stations and management systems; they will dynamically switch back to fixed connectivity. **10. Smart meters**[31] that will expose information about end-point energy consumption and generation and the quality of energy that is received from the distributor. When this information is exposed to the latest grid optimization tools, it shows distributors how to reconfigure their grids to reduce losses to heat and vibration and better use available capacity.	
Potential Operational Benefits	**Potential ESG Benefits**

[31] Link to report: https://www.telit.com/blog/how-5g-enables-advanced-metering-infrastructure-smarter-utilities/

1. **Optimized and automated drilling** with advanced analytics should increase drilling operations productivity by improving drilling speed by 25% or more.[32] Remote or semi-automatic drilling should also reduce the number of people required on the rig, driving down cost per well. With increased automation, an offshore rig would require 10 to 15 full-time employees, compared with approximately 100 employees at present. Onshore rigs currently staffed with 10 to 15 full-time workers could get by with a staff of five to 10 full-time workers.[33] Productive drilling time would increase to 94% from the current 90%. Together, drilling optimization and automation should drive a combined 5% to 10% reduction in cost per barrel of oil equivalent.[34] 2. **Reduced unplanned downtime -** Oil and gas producers experience on average 32 hours of unplanned downtime each month, costing a single facility $220,000 an hour and $84 million annually. In refineries alone, losses to Fortune Global 500 (FG500) constituents are estimated to total US $47 billion from 213,000 downtime hours. 82% of oil and gas respondents say predictive maintenance is a strategic objective, the most of any sector surveyed.[35] Today, 70% of companies lack awareness of when assets are due for maintenance. Applying real-time asset condition monitoring and identification of anomalies to pumps and compressors should reduce maintenance sessions by 25%, as well as unplanned downtime by 32%. It should extend the life of equipment by 25%.[36,] It should reduce maintenance costs by 20% to 40% and increase production by 3% to 5%.[37]	1. **Optimized and automated drilling** would reduce emissions tied to drilling and associated activities by approximately 10%.[39] [U.N. SDG - 9 and 13] 2. **Optimized production -** Enhanced SCADA technologies will enable timely data collection across production systems substantially improving the performance of the plant, reducing the risk of leaks, and increasing public health safety. They should also create value by increasing throughput and reducing the energy consumed and emissions produced.[40] [U.N. SDG - 9 and 13] 3. **Reduced health and safety incidents** - Mobile device-accessible schematics and plans combined with features like push-to-video will make workers more efficient both on and offsite. A digitally enabled workforce is 8.5% more productive and reduces loss from health and safety incidents by 48%.[41] [U.N. SDG - 3 and 8] 4. **Reduced carbon dioxide emissions** by up to 12% with the Smart Grid.[42] [U.N. SDG - 12] 5. **Shift of skills** and access to better professional jobs; in-field AR support for e-learning and expert advice in remote areas. In the 22nd Annual Global CEO Survey, 76% of respondents from the energy, utilities and resources space expressed concern about the availability of skills, particularly digital skills, in the marketplace. It has becoming increasingly difficult for energy operators to find—and retain and engage—talent with key skill sets, including digital business strategy and data analytics.[43] [U.N. SDG - 8]

[32] Link to report: https://www.mckinsey.com/industries/oil-and-gas/our-insights/how-tapping-connectivity-in-oil-and-gas-can-fuel-higher-performance
[33] Link to report: https://www.mckinsey.com/industries/oil-and-gas/our-insights/how-tapping-connectivity-in-oil-and-gas-can-fuel-higher-performance
[34] Link to report: https://www.mckinsey.com/industries/oil-and-gas/our-insights/how-tapping-connectivity-in-oil-and-gas-can-fuel-higher-performance
[35] Link to report: https://pressreleases.responsesource.com/news/101458/world-s-largest-manufacturers-lose-almost-trillion-a-year-to/
[36] Link to report: https://www.ericsson.com/en/industries/offshore-and-processing
[37] Link to report: https://www.bcg.com/publications/2019/digital-value-oil-gas
[39] Lin to report: https://www.mckinsey.com/industries/oil-and-gas/our-insights/how-tapping-connectivity-in-oil-and-gas-can-fuel-higher-performance
[40] Link to report: https://www.mckinsey.com/industries/oil-and-gas/our-insights/how-tapping-connectivity-in-oil-and-gas-can-fuel-higher-performance
[41] Link to report: https://www.ericsson.com/en/industries/offshore-and-processing
[42] Link to report: https://www.frontiersin.org/articles/10.3389/fenrg.2021.681244/full#:~:text=The%20use%20of%20a%20smart,of%204608.28%20Mt%20in%202017.
[43] Link to report: https://www.pwc.com/ca/en/industries/energy/energy-visions-2020/new-world-new-skills-preparing-your-workforce-for-the-energy-transition.html

3. **Enhanced field operations and reduced operations costs driven by connected workers -** Digital twins, mobile device-accessible schematics and plans combined with features like push-to-video and smart integrated modeling will make workers more efficient both on and offsite. Overall, companies are expected to experience an 8% reduction in operational spending due to the increased effectiveness of a digitally enhanced worker.[38] 4. **Streamlined end-to-end supply and logistics** with improved demand management, transparent materials tracking and more efficient logistics operations. 5. **Reduced electricity theft, losses from transmission, distribution, etc.** from the development of smart grids. Smart grids can also reduce electricity costs, meter reading costs, operations and maintenance costs, and equipment failures by using automatic operation based on varying load conditions. The demand response of smart grids should decrease the stress on smart grid systems during peak conditions, which will reduce the probability of failure. Smart grids are also capable of meeting increased consumer demand without adding infrastructure. 6. **Digitization and standardization of regulatory compliance** processes should allow energy operators to support new business models and meet regulatory requirements while remaining competitive in the marketplace. It should also improve operating efficiencies and reduce the time for administrative regulatory tasks, thereby enabling legal and compliance functions to redirect their efforts to strategic initiatives and managing regulatory risk.	
Estimated Economic Benefits	**Example Metrics Potentially Impacted by 5G[44,45]**
1. 5G applications in smart utilities could add US$330 billion to global GDP and US$83 billion to US GDP by 2030.[46]	1. Access to the 5G network 2. Number of 5G-enabled digital solutions implemented 3. Estimated total value realized from 5G enabled digital solutions that are implemented 4. Decrease in GHG emissions 5. Decrease in number/size of oil and/or gas leaks 6. Decrease in waste and fresh water used

[38] Link to report: https://www.ericsson.com/en/industries/offshore-and-processing
[44] Link to report: https://reader.elsevier.com/reader/sd/pii/S2351978917303785?token=D25F402D35B6D6745093B449B53CDFD965C2A798E449BA76E555B043D9657B59955AC398E8753E8A0B04AF6B06F74AC5&originRegion=us-east-1&originCreation=20220428154529
[45] Link to report: https://www.spiderstrategies.com/kpi/industry/utilities/
[46] Link to report: https://www.pwc.com/gx/en/industries/technology/publications/economic-impact-5g.html#explorer

	7. Decrease in health and safety incidents 8. Decrease in physical and cyber attacks 9. Increase in workforce training and development 10. Increase in compliance with regulatory standards and reporting 11. Decrease in cost per megawatt produced 12. Decrease in maintenance cost per mile of pipe/line/cable 13. Decrease in average number of labor hours to complete a maintenance task 14. Decrease in average response time to fix breaks 15. Increase in crew productivity 16. Decrease in equipment failure or unavailability 17. Decrease in mean time to repair 18. Decrease in number of complaints received 19. Decrease in number of power failures per year 20. Decrease in number of staff per 1,000 customer connections 21. Decrease in outage time per event 22. Increase in billing accuracy and timeliness

Select case studies:

VR Training for Oil & Gas Operators[47]	
Background	▪ Saudi Aramco has converted a remodelled wing of its Dhahran premises into a Fourth Industrial Revolution centre, where technological and digital solutions are being developed to transform the way in which the company runs its operations. ▪ The "VR Zone" is used to develop, prototype and train for AR/VR applications. This hub can be used to visualize plant assets and get a live sense of the plant experience from a simulation booth. ▪ The "3D Operator System Training Centre" provides real-world incident training in a safe and engaging VR-simulated environment. The system uses VR headsets and standard controls that allow operators to virtually walk through a generic gas-oil separation plant, a gas and condensate processing plant, and a water injection plant. During these training scenarios, operators encounter several process disruptions.
Improvement areas	▪ 5G-enabled immersive VR training for the workforce ensures accuracy and effectiveness in routine operations. ▪ VR training is highly scalable and can thus reduce time and resources spent on training overall. ▪ VR training programs reduce the need to travel to receive training. ▪ Innovative learning through VR helps to uphold job satisfaction and retention.
Economic and societal impacts	▪ Reduction in training budgets and operational downtime, leading to increased profitability ▪ Increased skill capacity and job satisfaction of the workforce

[47] Link to report: https://www3.weforum.org/docs/WEF_The_Impact_of_5G.pdf.

VR Training for Oil & Gas Operators[47]	
	[U.N. SDG 8] ▪ Mitigation of risk and safety concerns [U.N. SDG 3] ▪ Reduced carbon emissions due to reduced travel requirements for training programmes.
5G capabilities used	▪ eMBB ▪ URLLC
CapEx requirements	▪ VR headsets, motion control devices, knowledge management platforms and digital infrastructure
Maturity timeline	▪ Current state: 4K streaming that ensures faster delivery of training programmes ▪ Short-term: gamification that leads to more immersive training programmes ▪ Long-term: volumetric video that further augments the immersion and effectiveness of VR training programmes

5G Smart Grids[48]	
Background	▪ China South Power Grid Co., Ltd. (CSG) operates power grids in five Chinese provinces, including Guangdong, Guangxi, Yunnan, Guizhou, and Hainan, and has connections with national or regional power grids in Vietnam, Thailand, Myanmar and Laos. CSG has a total service area spanning 1 million square kilometres and serves more than 254 million people. ▪ CSG partnered with China Mobile and Huawei to jointly pursue the innovative application of 5G smart grid technologies and they have achieved breakthroughs in technologies and services.
Improvement areas	▪ 5G networks enable drones to inspect power transmission lines and make the process up to 80 times more efficient. ▪ 5G technology allows power transformation substations to operate nearly three times more efficiently and enables accurate remote monitoring of equipment status. ▪ 5G technology minimizes fault detection and isolation times from minutes to milliseconds. ▪ Unlike 4G, 5G is capable of handling power consumption data collection from tens of millions of users and opens new avenues to create value for customers. ▪ 5G enables security isolation of power grids with end-to-end network slicing and chip encryption technology.
Economic and societal impacts	▪ Duration of power failures can be shortened, power supply efficiency can be improved, and the cost of electricity consumption can be reduced, which minimizes losses to society and saves operating costs.

[48] Link to report: https://www.gsma.com/greater-china/wp-content/uploads/2021/02/5G-Use-Cases-for-Vertical-China-2021-EN.pdf.

5G Smart Grids[48]	
	[U.N. SDG 7] ▪ Rollout of these 5G-enabled smart grid innovations to the five provinces served by CSG is expected to generate economic and societal benefits of at least RMB 5 billion.
5G capabilities used	▪ eMBB ▪ URLLC
CapEx requirements	▪ Unmanned drones, data analytics applications and digital infrastructure.
Maturity timeline	▪ Current state: grid infrastructure monitoring via unmanned drones and remote technology ▪ Short-term: integration of decentralized power grids and smart meters that provide additional information to end-users ▪ Long-term: predictive analytics that anticipate demand fluctuations and service outages and react accordingly in real-time

A. Glossary of Key Terms

Terms	Definitions
3GPP	The focal point of development for 5G specifications and standards is the Third Generation Partnership Project (3GPP), a consortium made up of seven of the regional telecommunications standards development bodies. 3GPP has hundreds of technical specifications under development for mobile wireless communications, including the air interface/radio access (5G New Radio), the 5G core, and the IoT, among others. 3GPP is also developing standards for networks to interconnect and collaborate with one another. For example, 3GPP's non-public network support is intended to allow private networks optimized for a specific purpose (e.g., an automated manufacturing facility) to co-exist with public carrier networks.
Area traffic capacity	Total traffic throughput served per geographic area, measured as data rate per unit area. Area traffic capacity increases will enable better network performance in densely populated areas. *Category - Massive Internet of Things (Massive IoT).*
Artificial Intelligence	The ability of a computer or a robot controlled by a computer to do tasks that are usually done by humans because they require human intelligence and discernment.
Augmented Reality (AR)	An enhanced version of the real physical world that is achieved through the use of digital visual elements, sound, or other sensory stimuli delivered via technology.
Automation	Describes a wide range of technologies that reduce human intervention in processes. Human intervention is reduced by predetermining decision criteria, sub process relationships, and related actions — and embodying those predeterminations in machines. Automation includes the use of various equipment and control systems such as machinery, processes in factories, boilers, and heat-treating ovens, switching on telephone networks, steering, and stabilization of ships, aircraft, and other applications and vehicles with reduced human intervention. Automation has been achieved by various means including mechanical, hydraulic, pneumatic, electrical, electronic devices, and computers, usually in combination. Complicated systems, such as modern factories, airplanes, and ships typically use all these combined techniques. The benefit of automation includes labor savings, reducing waste, savings in electricity costs, savings in material costs, and improvements to quality, accuracy, and precision.
Backhaul	The portion of the network that comprises the intermediate links between the core network and the small subnetworks at the edge of the network. In the context of a mobile network, the backhaul connects a cell site toward the core network. The two main methods of mobile backhaul implementations are fibre-based backhaul and wireless point-to-point backhaul.
Bandwidth	Is the maximum aggregated system bandwidth. The bandwidth may be supported by single or multiple radio frequency (RF) carriers. The requirement for bandwidth is at least 100 MHz. *Category - Enhanced Mobile Broadband (eMBB), Mission Critical Control (MCC) and Massive Internet of Things (Massive IoT).*
Big Data Analytics	The use of advanced analytic techniques against very large, diverse data sets that include structured, semi-structured and unstructured data, from different sources, and in different sizes from terabytes to zettabytes.
Connection density	Total number of connected and/or accessible devices that can be accommodated, measured in devices per unit area. Increased connection density will support customer use where there are a tremendous number of devices, such as in stadiums and warehouses. *Category - Massive Internet of Things (Massive IoT).*
Control plane latency	Control-plane latency refers to the transition time from a most "battery efficient" state (e.g., Idle state) to the start of continuous data transfer (e.g., Active state). The target for control plane latency should be 10ms. *Category - Enhanced Mobile Broadband (eMBB).*
Coverage	Is the uplink and downlink between device and Base Station site (antenna connector(s)) for a data rate of 160bps, where the data rate is observed at the egress/ingress point of the radio protocol stack in uplink and downlink. The target for coverage should be 164dB (decibel). Link budget and/or link level analysis are used as the evaluation methodology. *Category - Massive Internet of Things (Massive IoT).*
Cyber-physical system (CPS)	A computer system in which a mechanism is controlled or monitored by computer-based algorithms. In cyber-physical systems, physical and software components are deeply intertwined and are able to operate on different spatial and temporal scales, exhibit multiple and distinct behavioral modalities, and interact with each other in ways that change with context. CPS involves transdisciplinary approaches, merging theory of cybernetics, mechatronics, design and process science. CPS is also similar to the Internet of Things (IoT), sharing the same basic architecture; nevertheless, CPS presents a higher combination and coordination between physical and computational elements. Examples of CPS include smart grid, autonomous

Terms	Definitions
	automobile systems, medical monitoring, industrial control systems, robotics systems, and automatic pilot avionics.
Digital Twin	A virtual representation that serves as the real-time digital counterpart of a physical object or process. Data collected from sensors connected to a physical device can be used to update the digital twin copy to reflect any changes to the device's current state.
Digitalization	The use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business.
Digitization	the process of converting information into a digital (i.e., computer-readable) format. The result is the representation of an object, image, sound, document, or signal (usually an analog signal) obtained by generating a series of numbers that describe a discrete set of points or samples. The result is called digital representation or, more specifically, a digital image, for the object, and digital form, for the signal. Digitization is of crucial importance to data processing, storage, and transmission, because it "allows information of all kinds in all formats to be carried with the same efficiency and also intermingled".
Energy efficiency	On the device side, the number of bits transmitted or received per unit of energy consumption. On the network side, energy efficiency refers to the quantity of information bits transmitted to or received from users, per unit of energy consumption of the radio access network (RAN), measured in bits per joule. Energy efficiency improvements are critical due to the expected massive increase in data use over time. Category - Massive Internet of Things (Massive IoT).
GSMA	Global System for Mobile Communications, originally Groupe Spécial Mobile, is an industry association representing the interests of mobile operators worldwide, including more than 750 operators and almost 400 companies in the broader mobile ecosystem. GSMA has published hundreds of security guidelines, recommendations, and requirements over the years regarding best practices in mobile security that support real world deployments related to security of devices, networks, interconnect protocols, and services. GSMA's Fraud and Security Group is particularly active, working on 5G security in the context of other interdependent topics such as IoT and roaming.
IEC	International Electrotechnical Commission is an international standards organization that prepares and publishes international standards for all electrical, electronic, and related technologies – collectively known as "electrotechnology". IEC standards cover a vast range of technologies from power generation, transmission and distribution to home appliances and office equipment, semiconductors, fibre optics, batteries, solar energy, nanotechnology, and marine energy as well as many others. The IEC also manages four global conformity assessment systems that certify whether equipment, systems, or components conform to its international standards. All electro-technologies are covered by IEC Standards, including energy production and distribution, electronics, magnetics and electromagnetics, electroacoustics, multimedia, telecommunication, and medical technology, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility, measurement and performance, dependability, design and development, safety, and the environment.
IEEE	Institute for Electrical and Electronics Engineers is involved in the creation of many standards, including WiFi and WiMAX standards, as well as other machine communications standards that will change with 5G.
IETF	Internet Engineering Task Force covers specifications related to 5G non-radio network segments.

Terms	Definitions
Industry 4.0	The Fourth Industrial Revolution, 4IR, or Industry 4.0, conceptualizes the current rapid change to technology, industries, and societal patterns and processes due to increasing interconnectivity and smart automation. The term has been used widely in scientific literature, and was popularized by Klaus Schwab in 2015, the World Economic Forum Founder and Executive Chairman. Schwab asserts that the changes seen are more than just improvements to efficiency, but express a significant shift in industrial capitalism. A part of this phase of industrial change is the joining of technologies like artificial intelligence, gene editing, to advanced robotics that blur the lines between the physical, digital, and biological worlds. Throughout this, fundamental shifts are taking place in how the global production and supply network operates through ongoing automation of traditional manufacturing and industrial practices, using modern smart technology, large-scale machine-to-machine communication (M2M), and the internet of things (IoT). This integration results in increasing automation, improving communication and self-monitoring, and the use of smart machines that can analyze and diagnose issues without the need for human intervention. It also represents a social, political, and economic shift from the digital age of the late 1990s and early 2000s to an era of embedded connectivity distinguished by the omni-use and commonness of technological use throughout society (e.g., a metaverse) that changes the ways we experience and know the world around us. It posits that we have created and are entering an augmented social reality compared to just the natural senses and industrial ability of humans alone.
Internet of Everything (IoE)	The networked connection of people, process, data, and things. The benefit of IoE is derived from the compound impact of connecting people, process, data, and things, and the value this increased connectedness creates as “everything” comes online.
ISO	International Standards Organization is an international non-governmental organization made up of national standards bodies that develops and publishes a wide range of proprietary, industrial, and commercial standards. In addition to producing standards, ISO also publishes technical reports, technical specifications, publicly available specifications, technical corrigenda, and guides. The ISO plays an important role in facilitating world trade by providing common standards among different countries. ISO standards cover all fields, from healthcare to technology to manufacturing to security to the environment.
ITU	The International Telecommunications Union is in the process of developing ITU-R Recommendations for the terrestrial components of the IMT-2020 radio interface(s) based upon specifications from external, industry-led standards development organizations.
Latency	Time it takes from when the source sends a packet of data to when the destination receives it, usually measured in milliseconds. More precisely, latency for 5G is the contribution by the radio network to this time. Low latency is especially important for applications, such as industrial automation or remote medicine, where delays in data transfers could be disastrous. *Category - Mission Critical Control (MCC).*
Machine Learning	The use and development of computer systems that are able to learn and adapt without following explicit instructions, by using algorithms and statistical models to analyze and draw inferences from patterns in data.
Mobility	Maximum speed a device can be traveling and still experience a defined quality of service. Mobility is important for applications that require reliable connection when moving, such as in transportation safety. The target for mobility should be 500km/h. *Category - Enhanced Mobile Broadband (eMBB).*
Mobility interruption	Mobility interruption time means the shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions. The target for mobility interruption time should be 0ms. This KPI is for both intra-frequency and inter-frequency mobility for intra-New Radio (NR) mobility. *Category - Mission Critical Control (MCC).*
Network energy efficiency	The capability is to minimize the RAN energy consumption while providing a much better area traffic capacity. Both qualitative and quantitative KPIs are proposed. Network energy efficiency shall be considered as a basic principle in the New Radio (NR) design. The target is a design with: (1) the ability to efficiently deliver data; (2) the ability to provide sufficiently granular network discontinuous transmission when there is no data to transmit and network availability is maintained; (3) the ability to provide operator flexibility to adapt sleep durations of base stations depending on load, services, and area. *Category - Enhanced Mobile Broadband (eMBB), Mission Critical Control (MCC) and Massive Internet of Things (Massive IoT).*
Operational lifetime	Operation time per stored energy capacity, which is particularly important for Internet of Things (IoT) devices requiring a very long battery life whose regular maintenance is difficult for physical or economic reasons. *Category - Enhanced Mobile Broadband (eMBB), Mission Critical Control (MCC) and Massive Internet of Things (Massive IoT).*

Terms	Definitions
O-RAN Alliance	Is working to build specifications and standards for 5G networks, focused on open and interoperable interfaces for radio access networks.
Peak data rate	Peak data rate is the highest theoretical data rate, which is the received data bits assuming error-free conditions, assignable to a single mobile station when all assignable radio resources for the corresponding link direction are utilised (i.e., excluding radio resources that are used for physical layer synchronisation, reference signals or pilots, guard bands and guard times). The target for peak data rate should be 20Gbps for downlink (DL) and 10Gbps for uplink (UL). *Category - Enhanced Mobile Broadband (eMBB).*
Peak spectral efficiency	Maximum achievable data rate under ideal conditions, usually measured in gigabits per second (Gbps), that can be transmitted over a given bandwidth in a specific communication system. It is a measure of how efficiently a limited frequency spectrum is utilized by the physical layer protocol, and sometimes by the medium access control (the channel access protocol). The target for peak spectral efficiency should be 30bps/Hz for downlink (DL) and 15bps/Hz for uplink (UL). Higher frequency bands could have higher bandwidth, but lower spectral efficiency and lower frequency bands could have lower bandwidth but higher spectral efficiency. Thus, peak data rate cannot be directly derived from peak spectral efficiency and bandwidth multiplication. *Category - Enhanced Mobile Broadband (eMBB).*
Price per MHz per unit population	A commonly used metric for expressing prices paid for spectrum during government auctions. Price per MHz per unit population first takes the total price paid by a network provider for a range of spectrum and divides it by the number of MHz purchased. This price per MHz is then divided again by the provider's number of people covered to obtain the final price per MHz per unit population. This metric allows for more accurate comparisons of spectrum prices across different auctions to be made since it accounts for market size.
Reliability	Capability to provide a given service with a very high level of availability. Reliability is compromised if too much data is lost, late, or has errors. Improving the reliability of the network is critical for time-sensitive, mission-critical applications like automation and healthcare. Category - Mission Critical Control (MCC).
Resilience	Ability of the network to continue operating correctly during and after a natural or man-made disturbance, such as the loss of power. Category - Enhanced Mobile Broadband (eMBB), Mission Critical Control (MCC) and Massive Internet of Things (Massive IoT).
Robotics	An interdisciplinary branch of computer science and engineering. Robotics involves design, construction, operation, and use of robots. The goal of robotics is to design machines that can help and assist humans. Robotics integrates fields of mechanical engineering, electrical engineering, information engineering, mechatronics, electronics, bioengineering, computer engineering, control engineering, software engineering, mathematics, etc. Robotics develops machines that can substitute for humans and replicate human actions. Robots can be used in many situations for many purposes, but today many are used in dangerous environments (including inspection of radioactive materials, bomb detection and deactivation), manufacturing processes, or where humans cannot survive (e.g., in space, underwater, in high heat, and clean up and containment of hazardous materials and radiation).
Security and privacy	Ability to encrypt and protect user data and signaling, and enhance network security against cyberattacks, such as unauthorized user tracking, hacking, fraud, sabotaging, and denial of service, which can be detrimental to national security and the safeguarding and privacy of users' data. *Category - Enhanced Mobile Broadband (eMBB), Mission Critical Control (MCC) and Massive Internet of Things (Massive IoT).*
Sensor	A device that produces an output signal for the purpose of sensing of a physical phenomenon. In the broadest definition, a sensor is a device, module, machine, or subsystem that detects events or changes in its environment and sends the information to other electronics, frequently a computer processor. Sensors are always used with other electronics. Sensors are used in everyday objects such as touch-sensitive elevator buttons (tactile sensor) and lamps which dim or brighten by touching the base, and in innumerable applications of which most people are never aware. With advances in micromachinery and easy-to-use microcontroller platforms, the uses of sensors have expanded beyond the traditional fields of temperature, pressure, and flow measurement, for example into MARG sensors. Analog sensors such as potentiometers and force-sensing resistors are still widely used. Their applications include manufacturing and machinery, airplanes and aerospace, cars, medicine, robotics, and many other aspects of our day-to-day life. There is a wide range of other sensors that measure chemical and physical properties of materials, including optical sensors for refractive index measurement, vibrational sensors for fluid viscosity measurement, and electro-chemical sensors for monitoring pH of fluids.

Terms	Definitions
Spectrum	The ranges of frequencies (or airwaves) on the electromagnetic spectrum that are allocated to the mobile industry and other sectors for wireless communication. Spectrum is a sovereign asset, which implies that the use of such airwaves is overseen by the government or national regulator, who manages and issues licenses to permit usage.
Spectrum and bandwidth flexibility	Flexibility of the network design to handle 5G Wireless different scenarios, such as the capability to operate at different frequency ranges. *Category - Enhanced Mobile Broadband (eMBB), Mission Critical Control (MCC) and Massive Internet of Things (Massive IoT).*
UE energy efficiency	Is the capability of a UE to sustain much better mobile broadband data rate while minimizing the UE modem energy consumption. *Category - Massive Internet of Things (Massive IoT).*
User Equipment (UE) battery life	Is the battery life of the UE without recharge. For mMTC, UE battery life in extreme coverage shall be based on the activity of mobile originated data transfer consisting of 200bytes UL per day followed by 20bytes DL from MaxCL of 164dB, assuming a stored energy capacity of 5Wh. *Category - Massive Internet of Things (Massive IoT).*
User plane latency	Is also known as the radio segment latency. It is the one-way latency for successful reception of a packet and includes the time for one or more retransmissions if packet reception fails. The target for user plane latency should be 0.5ms for upload (UL), and 0.5ms for download (DL). Furthermore, if possible, the latency should also be low enough to support the use of the next generation access technologies as a wireless transport technology that can be used within the next generation access architecture. For eMBB, the target for user plane latency should be 4ms for UL, and 4ms for DL. *Category - Enhanced Mobile Broadband (eMBB).*
User-experienced data rate	User experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e., the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time. The target values for the user experienced data rate are as follows in the Dense Urban – eMBB test environment: (1) Downlink user experienced data rate is 100 Mbit/s; (2) Uplink user experienced data rate is 50 Mbit/s. *Category - Enhanced Mobile Broadband (eMBB)*
Virtual Reality	The use of computer technology to create a simulated environment which can be explored in 360 degrees. Unlike traditional interfaces, VR places the user inside the virtual environment to give an immersive experience.