UK 5G Innovation Network

CGI

Connect to Innovate

The UK Water Sector's opportunities to transform, leveraging emerging technologies and data insights

Foreword

The water sector today faces massive environmental challenges, many driven by regulatory requirements. These range from sustainably ensuring resilience and quality in meeting business and public needs, to de-carbonising the sector in the drive to Net Zero.

Water is heavy, requiring a lot of power to move it to where it is needed. It is a finite resource that needs to be efficiently managed from sources and must meet demands that are sometimes as unpredictable as the weather itself. Much of the infrastructure deployed is aged, Victorian in some instances, and depends on widely remote distributed assets.

Many of these challenges can be better addressed with digitalisation. Real time data is key. Once you have the right data you have the raw material to better to manage operations, generate actionable business insights and innovate. To get the data you need connectivity - and the technical characteristics and deployable reach of 5G make it ideally suited in many future water industry scenarios, especially when the full promise of Ultra Low Latency, Ultra Reliability, and Massive Machine to Machine Communication take effect from around 2023. There is fantastic potential here, where 5G, AI and IoT technologies converge.

We are grateful for CGI's support of the UK5G programme and assistance in the production of 'Connect to Innovate'. CGI's experience and knowledge has allowed us to surface challenges and practical examples (including from the 5G Testbeds & Trials programme) where converged tech can solve real-life water sector problems. The key challenges identified are mitigation of increasingly unpredictable environmental impacts, critical asset management through high volumes of sensor data, and, of course, meeting customer needs. I hope you find 'Connect to Innovate' informative - and inspiring. We are on the cusp of genuine transformation where 5G fuses with IoT and AI.

Bob Driver

Head, UK5G Innovation Network

Bob leads the national 5G Innovation Network, called UK5G. It brings together and markets the UK's 5G eco-system on behalf of the DCMS Testbed & Trials programme along with other business-led 5G initiatives. UK5G is delivered through a consortium of three partner organisations, Including Cambridge Wireless Ltd (CW), the Knowledge Transfer Network (KTN) and TM Forum.

Bob was previously CEO of CW from 2015 to 2018. CW is a not for profit organisation owned by its members, with over 400 member companies drawn from all parts of the digitally connected world, including semiconductor design, securely connected devices, networks, smart phones, software and applications, through to data analytics, artificial intelligence, content delivery, telecommunications and satellites. Prior to working at CW, Bob was Director for Technology at UK Trade & Investment (now part of the Department for International Trade) where he successfully led teams helping UK tech companies to access overseas opportunities as well as attracting technology inward investment into the UK. Prior to this he worked in environmental science instrumentation for a UK SME. He lives in Cambridge UK.

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Executive Summary

This paper sets out the enormous opportunities and challenges for the UK Water Sector using Emerging Technologies. The UK water industry is facing critical challenges it must address if it is to continue to deliver safe, reliable, affordable and sustainable services. Emerging technologies, enabled by 5G communications, will drive change and bring new solutions to help the water industry address these challenges.

We identify the core challenges for the water sector, notably: environmental impacts, effective management and exploitation of critical assets, and the changing nature of customer demands.

Environmental impacts

As Sir James Bevan, Chief Executive of the Environment Agency put it in a now-infamous speech in March 2019, "… we are approaching 'the jaws of death'. At some point, probably in the next 20 to 25 years, we will not have enough water to supply our needs, unless we take action to change things. And this is a UK crisis, caused by a combination of a growing population, increasing demand and warmer and drier climate".[1]

Critical assets

The services delivered by our water companies are essential to us all. The delivery of these services depends on large networks of Critical National Infrastructure. In operating those assets, water companies have only a limited view of their performance and rely heavily on manual activities. With an ageing asset base and an urgent need to decarbonise, the sector must make some big changes in the next few years.

Customer demands

Customers have increasing expectations of their water suppliers. They want modern ways of interacting with them, they expect a service that is always there at the 'turn of a tap', and they need an affordable service. Water companies must find a way of meeting these expectations.

There is the opportunity for the water sector to use 5G and associated enabling technology for its critical operations, and begin to redefine how the sector can lead on key environmental, customer and market-defining issues – placing it at the forefront of core services provision.

The technology story is of convergence.

Looking back to look ahead, we have historically seen high-value, often niche technologies come to market without realising their full potential. The convergence of technologies is set around a number of traditional favourites, namely of data to drive operational insights.

Going forward, what is new and different is the way data is captured, moved, analysed and exploited by a new generation of connected technology. The reach and depth of these insights are greater than ever before, offering a step-change for industries and sectors with an appetite to explore:

- Leveraging customer consumption data through to sentiment analysis on current and future demands
- Effectively managing water networks through asset driven insights drawing on high volumes of sensor data
- Measuring the environmental impact of consumption and generation of water across your local markets

5G can provide data connectivity with associated technologies enabling compute on Edge, predictive analytics and scenario modelling - all converging to support future decision making on a new level–and all available today.

5G will provide high bandwidth, low latency data exchange that aligns to the critical needs of the water sector with its asset-heavy footprint and extensive field force operational reach.

The key to the water sector will be how it chooses to apply the technology, and which areas it wishes to start with to respond to its key challenges. This will unlock value and start to redefine customer and market operations.

[1] Escaping the jaws of death: ensuring enough water in 2050, a Speech by Sir James Bevan, Chief Executive of the Environment Agency Waterwise Conference, 19 March 2019
https://www.gov.uk/government/speeches/escaping-the-jaws-of-death-ensuring-enough-water-in-2050

Challenges Facing the Water Industry

Water and the services the industry provides are essential to us all: as domestic consumers to sustain us in our daily lives; and as business customers to help drive our economy. Yet the UK water industry has some very pressing challenges it must address if it is to continue to deliver safe, reliable and affordable services to us all.

Emerging technologies, enabled by 5G communications, will bring new solutions to help the water industry respond to these challenges and provide the services that are essential to us alll.

Water companies in the environment

Growing populations, risk of droughts through reduced rainfall and competing demands for existing resources, such as through agriculture, all add up to water scarcity issues and supply deficit in some regions, creating a major societal issue.

On the opportunity side, though, there is a changing attitude to the value of water and the need to use it sustainably. Can we capitalise on this consumer sentiment and reduce our per capita consumption?

The changing climate also brings with it an increased risk of extreme weather events such as flooding, generating the need for operational resilience. How can the industry see these events coming and operate in a resilient way to mitigate these risks?

The global need to decarbonise affects our water industry too. Being a highly energy-intensive industry, it must find ways to reduce demand and to make more use of the bio-resources it creates.

Water companies and their assets

Water companies rely massively on ageing infrastructure. Tighter regulatory controls mean there is less money to spend on replacing the older infrastructure. Together, these issues generate the need to monitor more to understand how the systems are performing. By operating assets closer to the limit, more value can be squeezed from them. Maintaining assets based on need and extending their life will avoid new build capital costs.

Another key dimension here is the geographic one. Water assets are distributed over a large region, remotely away from offices, often underground or in locations difficult to access. This presents a visibility and monitoring challenge, but a challenge new technology can help solve.

Water companies employ large remote workforces, and they rely heavily on manual operation of assets. To do their job effectively and safely, those people need to be armed with the right information, knowledge and supported by experts. Ultimately, the future aim must be for more autonomous operation of the assets and processes.

Water companies and their customers

Affordability is a major societal challenge for the industry. Increasing levels of water poverty generate the need to operate water business much more efficiently.

Customers have changing expectations about the way a water company should serve their needs. The leading digital business sets expectations. As well as satisfying the customer experience expectations, a water company must continue to deliver safe and reliable services with high-quality water standards and few service interruptions.

Will water play its part in the smart home of the future? We may well see new technologies being employed to help customers understand and reduce their consumption and to support the needs of vulnerable customers.

Water companies and innovation

The AMP7[2] regulatory period in England and Wales comes with a major challenge from Ofwat for the industry to be more innovative. In Scotland, the Scottish Government has established the Hydro Nation Water Innovation Service to support the commercialisation of innovation. Innovation is a necessity if the industry is to address the challenges laid out above, i.e. to do more for less and to be resilient in the face of the environmental challenges.

Emerging technologies have the power to create new opportunities and drive digital innovation. Water companies, in collaboration with their supply chain, can take advantage of these opportunities to transform the industry.

The good news is these are challenges that can be tackled by the judicious application of smart technologies. 5G and the convergence of emerging technologies can drive a new future for the industry. In this future:

- There will be a massively increased visibility of assets and networks and how these are operating to deliver the essential services. The availability of low-cost sensors and mass Internet of Things (IoT) brings visibility. Advanced Analytics, Artificial Intelligence (AI) and digital twins can turn visibility into actionable insight.
- Expertise will not be tied to an expert at a specific location. Immersive technologies can be used to bring a ‘corporate expertise’ to the worker on-site. High Definition Video techniques and autonomous drones can be used for monitoring of remote assets or underground networks.
- The industry will be moving at pace towards the autonomous operation of the water systems.

[2] https://www.ofwat.gov.uk/wp-content/uploads/2019/12/Time-to-act-now-driving-transformational-innovation-in-the-sector-decision-document.pdf

5G Communications: the transformation enabler

Through the AMP7 regulatory period, Ofwat has challenged the water industry to be more innovative in delivering improved resilient services at a lower cost to consumers and resolve environmental challenges. Meeting these challenges requires the judicious application of emerging technologies such as 5G, the convergence of these technologies can drive the transformation to create the water industry of the future.

Taking a closer look at the topic of digital connectivity, and the evolution of mobile technologies, the journey to 4G LTE was motivated by the need to satisfy requirements identified as unmet in preceding technologies. 5G is the same, looking at its three main characteristics:

- **Higher Data Speeds**: eMBB (enhanced Mobile Broadband)
  Throughput rates of up to one Gbps per connection
- **Higher Responsiveness**: URLLC (Ultra-Reliable and Low Latency Communications) Latency of one ms per connection
- **Greater Connection Capacity**: mMTC (Massive Machine Type Communications)
  Up to 1,000,000 connections per square kilometre

The connectivity, latency and capacity offered by 5G are opening up the potential for new, innovative services for businesses and industry, but making 5G a reality requires a transformation in conceptualisation, planning, and implementation for the operators. It is unknown how the 5G ecosystem will function at scale, and no one has demonstrated a sustainable business model for the operator. However, 5G is an opportunity to do things differently:

- Leading the digital transformation of the network and the business behind it
- Changing of culture in business
- Developing new approaches to connectivity solutions

A major concern for the water industry is the capacity of the system. This directly relates to the reserves of water they hold, leaks or failures in the supply network and how this affects the level of service they can supply to their consumers. Deploying 5G will allow the sector to use 5G's eMBB and URLLC characteristics to provide real-time information from sensors, smart meters and other devices in the water network. Leveraging Massive Machine Type Communications will gather this data from a larger number of devices used in the monitoring and management of infrastructure than today. 5G will provide better support for incident response and emergencies, where time is of the essence and gathering all the relevant insights to make the best risk-based decisions will be essential.

Gathering a large amount of data has other useful benefits for the water companies. They can collate this information into datasets for processing to gain better insight to whom the assets and infrastructure are performing. Algorithms, trend analysis, pattern matching and other Advanced Analytics can be deployed, providing predictive insight into when assets might be required for routine or emergency maintenance, or replacement. These can combine with other internal and external data sources to look at other aspects and trends within the business, such as leaks, floods, droughts. This will lead to operational and procurement efficiencies and improve the resilience of the supply to their consumers. Analytics and their application are discussed in more detail later in this paper.

5G has been described as the ‘network of networks’; it has the potential to integrate with and transform existing networks, is all-IP and supports open standards. For example, 5G could be used as the connectivity aggregator for a series of different local communication protocols used by assets, such as sensors, meters, valves, Bluetooth, WiFi, Zigbee, LoRA, IoT, NB-IoT are a few of these protocols in regular use. The 5G network has the ability to connect other protocols, either directly or via integration gateways, connecting the whole infrastructure with a single connectivity network.

5G standards allow greater interoperability with other types of networks, which will help when looking at remote sites where there is no fibre or fixed telecommunication connectivity. Heterogeneous network deployment models have been developed to allow 5G to reach most locations. Satellite integration with 5G is standardised and already running in trials to support 5G connectivity in remote locations with a satellite backhaul, including resilience for fibre backhaul paths. 5G can be used as a backhaul itself, connecting up a remote location to the nearest main network connection, to provide ubiquitous access coverage.

The ability to connect remote sites is important, providing remote monitoring and management of assets, and removing the need for people to travel to site for certain activities. However, if people are required to go to the site, then 5G eMBB and URLLC characteristics mean remotely working staff can connect directly to the operations centre in real-time. They can use high bandwidth applications such as 4K video, Augmented Reality (AR) or Virtual Reality (VR) to perform complex maintenance tasks with full support from the operations centre, as well as interactive health and safety support. eMBB and URRLC support the ability to take CCTV streams and process them in real-time with advanced video analytics applications to analyse assets, conditions, check for intruders. The video data is usable in the same way as sensor data.

5G was designed to support virtualisation, enabling the whole 5G network to be virtualised apart from the antennas. This reduces the need and costs of bespoke hardware as all the intelligence is in the software. It means some core components of a 5G network can be placed at the network Edge access location making it possible to process and act on data without having to send it back to a central site. This improves responsiveness to incidents and reduces backhaul costs and operational overheads. A 'Smart Water' supply network similar to energy 'smart grids' could be created using Edge computing, virtualisation and advanced analytics. Over time, automation and machine learning will support the move from reactive, through predictive and even into cognitive operational processes.

As well as virtualisation, 5G brings the concept of network 'slices' into the market as a fully-formed concept. The network can be 'sliced' virtually into a series of concurrently running but separate networks, allowing greater flexibility in how the network is used. Each 'slice' can have separate service and connectivity characteristics, so different services have their dedicated connectivity, command and control paths. In the water case, sensor data could be on a different 'slice' to command and control traffic.

Along with a 'Smart Water' supply network, all data gathered can be combined with asset inventory data, network topology, Geographic Information System (GIS) data, Building Information Management (BIM) data and mapping software. This enables the creation of 2-D and 3-D 'digital twins' of the water supply network, as explored in a later section.

Recent innovations in 5G technology and changes to the Ofcom licencing of spectrum has opened up mobile networks to new deployment models and new supply chains. The water industry and other utility sectors are areas of potential innovation to explore the benefits of procuring and deploying smaller, dedicated 'private' networks. This would place the water company in full control of the infrastructure and services used to support its business aims and operational requirements, as discussed later.

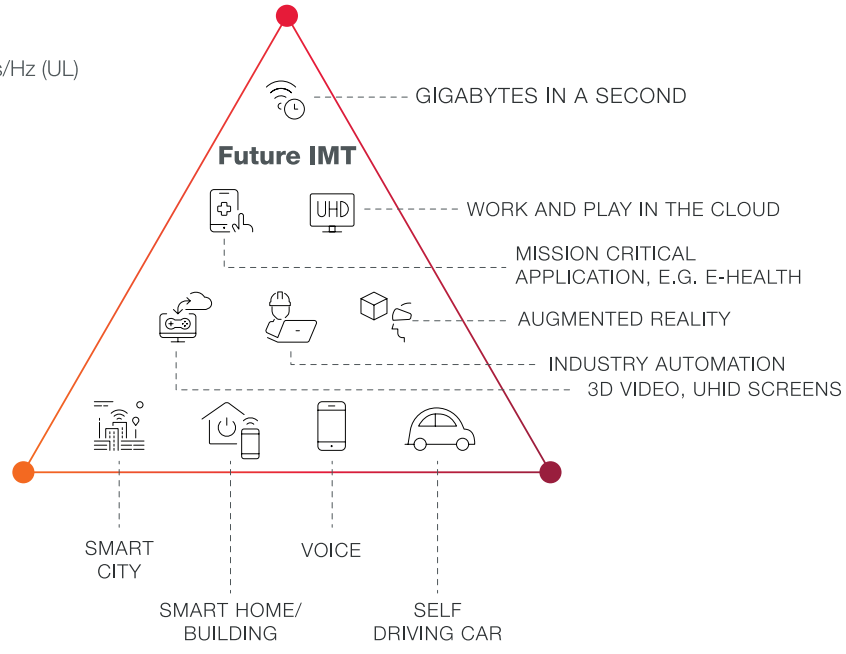
5G Use Cases and Requirements

Key challenge for 5G design: support for different services having diverging requirements

Enhanced Mobile Broadband (eMBB)
- Peak data rates: 20 Gbps (DL) and 10 Gbps (UL)
- Peak spectral efficiency: 30 bps/Hz (DL) and 15 bps/Hz (UL)
- 4 ms user plane latency
- Indoor/hotspot and enhanced wide area coverage

Massive Machine Type Communications (mMTC)
- Low data rates (1 to 100 kbps)
- High device density (up to 1,000,000 /km2)
- Latency: Seconds to hours
- Low power: Up to 15 years battery life

Ultra-Reliable and Low Latency Communications (URLLC)
- Low to medium data rates (50 kbps to 10 Mbps)
- 0.5 ms user plane latency
- 99.999% reliability and availability within 1 ms
- High mobility



Linking the Physical and Digital worlds: Mass IoT and Digital Twins

IoT and digital twins are changing the link between the physical and digital worlds. IoT provides connection and access to intelligence in the physical world. The advancement of mass IoT to manage significant volumes of data has the potential to unlock further value through digital twins, which are digital models that virtually represent their physical counterparts.

Smart meters

How they are used today

Across the energy sector, the idea of smart meters is not a new one. Today smart meters are giving consumers near real-time information on energy use to manage their energy better, save money and reduce emissions. Smart meters, as an example of Mass IoT, will bring an end to estimated billing, meaning consumers will be billed only for the energy they actually use, helping them to budget better and improve competition.

The national rollout of energy sector smart meters in Great Britain will facilitate an increasingly competitive market place. Empowering the consumer, and enabling them to make informed decisions about their consumption and their choice of supplier.

Additionally, smart meters open up new sources of flexibility and new ways consumers can engage with the market; driving innovation and new business models that seek to take advantage of the opportunities that arise.

CGI is the Data Communication Company (DCC) Data Service Provider (DSP) responsible for building and operating the DCC data systems required for communicating with Britain's 53 million smart meters at full roll-out.[3]

How the technology and business use may develop

The energy sector is investing well in the UK implementation of smart meters, supported by the government. The UK water sector is seeking to learn from this experience and shape its industry approach.

We are starting to see water companies exploring the use of smart meters and extending to create smart water networks. Trials are expected to grow with the use of more reliable and frequent data, capturing key elements of water management across the physical network, including consumption patterns and ultimately the generation of new related water and energy services.

[3] https://www.cgi-group.co.uk/en-gb/utilities/smart-metering

The areas explored in a trial by South East Water[4] have identified the following potential benefits:

- The ability to locate and fix leaks more quickly
- Reducing the volume of water lost to leaks
- Improved customer engagement on reducing water consumption
- The potential to offer new customer services such as innovative tariffs or water use reduction planning

Among the potential benefits above is testing the 'enabling technology'. We see supplier consortia being formed bringing together a range of technologies. We will discuss this later in this paper.

The evolution of monitoring millions of smart meter devices, driving operational as well as consumer-driven insights from the data generated, takes us towards a need for improved data connectivity and timely processing. This starts to open the debate for exploiting emerging technologies such as 5G, mass IoT and use of digital twins.

Potential implications for the water sector

The key implications for the water sector on the use and adoption of smart meter technologies are set around:

- **Operational Efficiency:** the degree to which operating costs can be improved, through more effective supply-side management, i.e. reducing leakage and improving water quality.
- **Consumption Patterns:** the degree to which customers change their usage levels in absolute terms and across an average day, week, month or seasonal basis, where awareness of use becomes more event.
- **Consumer Pricing Level:** the degree to which new business models evolve as smart meter data provides new opportunities to charge and reward their customers for consumption, based on factors beyond simple volume consumed.

Southern Water[5] has begun the world's first mass rollout of an innovative IoT leak detection system in Southampton. 700 NB-IoT acoustic logging devices will be fitted around the city to increase the utility's ability to detect leaks before they become bursts.

Southern Water said the devices are a crucial tool to support both long and short-term challenges. Water use has soared by as much as 20% in lockdown. Hot weather is further driving demand, making it a challenge for water to be treated and pumped enough to maintain pressure. The water company has committed to reducing leaks from its network by 15% over the next five years.

The new devices negate the need for manual or 'Drive-By' collections, therefore, reducing Southern Water's carbon footprint. The acoustic loggers 'listen' at night to the sound of water in the network. Acoustic signatures wirelessly transmit to a cloud-based service before the files are analysed searching for the traces of water being forced through a split or hole in the pipe. Every morning a detailed report is sent to Southern Water's team of Leak Technicians who collate the data and prioritise teams to make repairs.

[4] https://www.southeastwater.co.uk/digitalmeters

[5] https://www.waterbriefing.org/home/technology-focus/item/17361-southern-water-in-world-first-mass-roll-out-of-new-iot-leak-detection-technology

Physical Network and Digital Twins

How they are used today

The physical network and associated plant, employed to manage and operate core water services, are asset-heavy, geographically dispersed and not well supported by modern technology.

How technology and business use may develop

Applying simulation models can provide powerful insights to aid the operational running and performance of large complex physical networks, treatment works or other related assets.

Simulation can be used to test scenarios for resilience, operational readiness, emergency planning, as well as critical operator training scenarios.

The evolution of scenario planning across a physical network takes us towards the creation of more advanced technologies, including digital twin solutions. This is where digital twins can create the opportunity to drive optimisation of large networks. Given the depth, frequency and volume of data associated with creating, tracking and driving operational alerts and interventions from digital twin solutions, this offers high business value opportunities but requires emerging technologies, such as 5G to enable it.

As 5G embraces concepts such as virtualisation, and support for mass IoT deployments through Massive Machine Type Communications mMTC functionality, the use of digital twins is an essential element to consider when planning 5G networks. When considering the planned geographical ubiquity of 5G, the ability to monitor and control network infrastructure assets in remote or hostile locations in real-time is an important requirement. 5G supports the pairing of physical and virtual digital worlds, either as physical or software sensors, integrated as ‘smart components’ in the components or assets.

Infrastructure, services and processes can be created virtually during the planning phase and real-time data is fed back during operational monitoring to support the analysis and ‘tuning’ of the network, services and processes in the digital twin before deploying in the real world. Every physical asset will have a virtual copy that will become richer as more operational data is fed into it. This allows the entire lifecycle of the ecosystem and its assets or processes to be closely linked to business imperatives, as lessons are learned, and opportunities are uncovered within the virtual environment of the digital twin that can apply to the physical world.

In addition to digital twin technologies, the use of mass sensor-based IoT solutions is worthy of note. When looking at the range of solutions that sensor-based technologies can unlock through use of an IoT connected platform, they are significant.

The following examples are seen in the water sector today. We predict their use is becoming key to driving business outcomes:

- Monitoring to predict network events before they impact customers
- Sensing flooding and predicting and mitigating the impact on communities
- Monitoring assets so they can be operated closer to the limits
- Monitoring assets for predictive maintenance
- Providing digital twins with high impact operational data
- Enhancing situational awareness

Potential implications for the water sector

The key implications for the water sector on the use and adoption of the physical network and digital twin technologies are set around:

- **Data Exploitation:** knowing which data is critical to driving business outcomes will be increasingly important. Having technology solutions able to capture and analyse high-value data that create operational insights
- **Skills Development:** supporting the workforce in adapting ways of working to harness the data-driven insights and being able to act on them effectively
- **Business Planning and Performance:** as improved insights are generated, this will enable steps changes in operational performance, which will re-set traditional business planning ambitions and open new opportunities for monetisation of data/water-related services.

Anglian Water[6] has created a water utility digital twin based around the Newmarket area as a proving ground for innovations. This will include the creation of digital visualisation of the region's water treatment and distribution infrastructure and the embedding of Hybrid Adaptive Real-Time Virtual Intelligence (HARVI), an AI system into the digital twin, to support predictive analytical capabilities and intuitive decision support and intervention.

A water utility digital twin offers the prospect of helping enhance customer experience, without increasing bills to fund improvements, by optimising the performance of existing assets and increasing the operational and maintenance efficiency. The twin supports this by facilitating systems thinking and combining multiple internal and external data sources across the asset base with predictive analytical techniques served through multiple functional views. This enables improved insights to support better decisions, leading to better outcomes in the physical world.

[6] https://www.bv.com/news/anglian-water-commissions-black-veatch-create-one-worlds-first-water-utility-digital-twins

Water use efficiency

How efficiently is water used today?

Freshwater resources across the globe are coming under increasing pressure from population growth, rising per capita water use, urbanisation and increased industrial activity. These pressures, and the risks the lack of adequate water of a suitable quality poses for people, industry and ecosystems, are highlighted in a growing number of reports.

Today, the water industry in the UK collects, treats and supplies more than 17 billion litres per day of water to domestic and commercial customers; and then collects and treats more than 16 billion litres of the resulting wastewaters, returning it safely to the environment.

Key operational focus areas across the water sector to unlock efficiency gains, continue to focus on water pumps, filtration, demineralisation, treatment, pipeline and leakage delivery, and reuse. These associated costs comprise of long-term, short-term, fixed, and variable costs and impact the bottom line business performance as well as the communities they serve.

Wider environmental factors, which impact efficiency include:

- Weather-related events, such as flooding, storm surges and drought
- Varying water temperatures and flows from season to season
- Turbidity related to runoff from the landscape
- Algal blooms from upstream activities that enrich surface water with nutrients

All of these factors affect the quantity, quality of water available and its timing. They all require monitoring to optimise water efficiency.

How water use efficiency may develop

The water sector has long developed cost models that seek to take historical information to predict future demands across a range of operational factors.

Typically, this analysis is founded within specific operational areas and is not connected across the water network.

Today, with more data being produced, the creation of digital twin models, combined with increasingly powerful advanced analytical tools means there is a real opportunity to develop high-value insights that translate into step-changes in water efficiency.

Key areas for consideration include:

- Creating more complete ‘end-to-end’ water models from operations to customer
- Supporting predictive maintenance and servicing through asset and plant focused data-driven insights
- Using geospatial insights drawing on historical data to connect in environment shifts
- Exploiting sensor-based data across the water network
- Translating this analysis in easier to consume forms through digital twins

Potential implications for the water sector

The key implications for the water sector on the use and adoption of the physical network and digital twin technologies are set around:

- **Societal Demands and Consumption Patterns:** the demand side of water efficiency challenge cannot be ignored. Managing volume and period of use will have a significant impact on absolute costs associated with the water sector and direct implications for how efficient those demands can be serviced.
- **Adoption of data-driven new technologies:** the extent to which the water sector is able to harness the use of IoT sensor-based technologies, powered by 5G connectivity across the network, will determine the rate of insights and improvement opportunities to exploit.
- **Environmental changes:** the extent to which climate change impacts the aquatic landscape, water scarcity and its management, remains an open question. Leveraging 5G enabled geospatial technologies may provide some helpful predictive insights into meteorological outcomes.

South East Water[7] is taking part in a digital water meter trial that could significantly improve the way the water industry detects and prevents leaks. The water company, which supplies 2.2 million customers in parts of Kent, Sussex, Surrey, Hampshire and Berkshire, is the first utility in England to have a full Narrowband Internet of Things (NB-IoT) commercial agreement in place with Vodafone UK.

It will use the partnership to transmit data for analysis from digital water meters at 2,000 homes in the trial area, as well as information from other network sensors. This is the first time data from both pressure and water quality monitors have been combined into one data set for analysis. This analysis is aimed at creating new methods of looking for and preventing leaks in the future, reducing interruptions to supply, reducing the water taken from the environment and increasing the resilience of the service provided to customers.

The trial aims to alert on the smallest of leaks on both the utility's and their customers' pipes, as soon as they occur; with the target of predicting and preventing pipe failures before they happen. Data is received at regular intervals from the digital meters and sensors within the trial area. It is hoped this will introduce a step-change in the efficiency of providing the digital information as it does not require the prohibitive costs of installing new apparatus such as radio masts to transmit local data back to a central processing platform.

[7] https://wwtonline.co.uk/news/south-east-water-in-smart-metering-deal

Environmental management

How effective is environmental management today

The effective management of water and the aquatic environment is an important area of focus. Identifying, responding and resolving issues centred around harmful pathogens and assuring water quality remains a key area of concern.

Traditional means of water quality monitoring and control, have lacked automation, and typically centred on a relatively small number of monitoring points from which sample readings are taken infrequently. The result is often unreliable data provided post the optimal detection time to resolve the issues effectively.

How environmental management may develop

We see activity in the use of 5G technology to provide connectivity across differing settings. 5G-based smart water control and monitoring have been successfully piloted in Baiyangdian Lake of Xiong'an in China:

- High bandwidth and low latency of the 5G network has enabled crewless aerial vehicle (UAV) to carry out visual inspection of the water surface and any solid matter removed as needed.
- Data from connected water quality sensors are aggregated, and intelligent processing allows pollution prediction. This provides a scientific basis for preventive and proactive water management.

In the Orkney Islands in Scotland, a group of 70 islands, of which 20 are permanently inhabited have developed use cases that seek to improve connectivity in remote areas[8] and apply the following:

- **Legionella Conditions Monitoring:** monitoring water systems for compliance can be challenging in remote, unconnected areas. The Orkney based use case employs IoT sensors to enable remote monitoring of water temperatures as a cost-effective way of ensuring the required health and safety standards are maintained.
- **Aquaculture Health Monitoring:** farmed salmon is the UK's largest food export and a major contributor to the nation's economy. Measuring (pH/dissolved oxygen/salinity/temperature) inside and outside the salmon cages is vital as exceeded parameters can pose a serious risk of death to fish stocks. Despite this being a tech-heavy industry, limited connectivity seriously constrains deployment today.

Potential implications for the water sector

The key implications for the water sector on the topic of environmental monitoring are set around:

- **Harnessing 5G geographic coverage:** the advent of 5G at its fuller coverage of non-urban areas typified by the likes of 4G can provide the basis to support the extensive water network across the UK. This will allow for increased data volumes supporting mass sensors for monitoring of environmental conditions across the water estate.
- **Exploiting 5G data exchange:** with the advantages or data volumes and low latency, this can provide high-value environmental insights such as 4K video, 5G Immersive to enable a step-change in visual monitoring of water resources. This allows for greater regulatory compliance and proactive monitoring and control.
- **Harness Advanced Analytics:** with Big Data and AI powering the creation of scenario-based water models, three-dimensional monitoring with alert and predictive based analysis takes smart water control and environmental protection to a new level.

During Northumbrian Water Group's Innovation Festival in 2019, CGI led a design sprint called 'Enabling the Rural Revolution – how can we enhance rural communities and the environment using emerging technologies?'[9]. The result was Dragonfly[10], an innovative solution providing real-time monitoring of the aquatic environment using current and emerging technologies to monitor a range of determinands, including dissolved oxygen, turbidity, phosphates/nitrates, pH, temperature, as well as the flow and depth of watercourses.

The aim is to use large numbers of 5G technology sensors in a mesh, distributed over a watercourse or a larger river catchment area to connect wirelessly as a mass IoT solution. This solution will provide a real-time view allowing continuous monitoring of quality conditions in that river or catchment. It will identify trends – where quality is improving or deteriorating – and allow the linkage of those trends to events or other factors, such as weather or changes in usage. With large numbers of devices in a mesh, quality issues will be spotted that affect a small part of the watercourse while identifying their cause. Continuous monitoring using predictive analytics will identify issues and mitigating actions before they cause environmental damage.

Different stakeholders for the aquatic environment will use the information provided by Dragonfly to decide how and when they interact with it. For example, a water company can use water quality information to inform its water abstraction processes. Recreational users can use it to judge when conditions are best for their particular activity.

Dragonfly has the potential to transform the quality of the aquatic environment by changing the way different stakeholders engage with that environment and act as a positive force for improvement.

[8] https://www.5gruralfirst.org/project/community-and-infrastructure/

[9] https://www.cgi-group.co.uk/en-gb/video/utilities/dragonfly-much-more-just-water-monitoring-system

[10] https://www.nwg.co.uk/news-and-media/news-releases/organisations-looking-for-inventors-to-help-dragonfly-idea-take-flight/

Combining 5G, Edge and AI drives insight

How are they used today

A wide consensus is that 5G is essentially a data challenge. Enabled by 5G, sensors and devices will produce data at a volume and velocity never seen before; combining variety to the challenge, where there is a complicated problem to deal with, especially when most organisations can barely manage their data assets today.

Sensors produce lots of data, and much of it is not useful. One principle is not to transfer huge volumes of data over the network for storage in enterprise cloud platforms, unless clear business outcomes are associated with the data. Storing large volumes of data in enterprise platforms without any value associations is a cost with data governance penalties and risk. This is where Edge comes in: compute power deployed closer to the Edge in proximity to physical assets. The core idea being that data is captured at the Edge, processed as needed and with a smaller subset transferred over the network to enterprise cloud platforms to drive enhanced employee, consumer or citizen experience.

Professor John McCarthy[11] introduced the concept of Artificial Intelligence (AI) at a conference in Dartmouth University in the mid-1950s. It is defined as 'making a machine behave in ways that would be called intelligent, if a human were so behaving'. The real-life discipline for realising this concept is machine learning, which is making a machine learn from data and develop abilities to predict or answer future questions, as humans would do for numerous tasks. Machine learning is maturing, with various production deployments across various sectors, while an additional benefit of AI is the ability to identify patterns in data at scale.

How the technology and business use may develop

We see enormous amounts of sensors being deployed across industries, including the water sector. 5G will only accelerate their growth and open up the feasibility of new use cases by providing much-desired low levels of latency.

Edge computing and 5G are mutually dependent and will co-evolve as 5G cannot realise its true value without joining forces with other emerging technologies such as Edge and AI. Many of the high-value use cases in the water industry, e.g. assessing water quality, detecting water leakage could be addressed by leveraging sensors and associated data, Edge and AI-enabled by strong data management architecture.

Machine learning algorithms fed with poor quality data result in weaker accuracy and performance. We recommend water companies apply strong data management discipline and invest in developing their data assets, for example through sensors. The main benefits of AI include the ability to identify patterns in data and to learn from these patterns, which will address key use cases.

Embedding security by design very early in the lifecycle is also a key consideration. Physical assets and Edge compute infrastructure require necessary security guardrails to protect devices and the integrity of associated data.

To successfully deliver value across water industry use cases, we need a convergence of various technologies like IoT, Edge, Advanced Analytics, Cloud and AI. The water industry needs to resist the temptation of looking at capabilities as silos as it is key to develop capabilities as an ecosystem internally and alongside trusted partners. This will allow organisations to deliver value with agility, quality at a lower level of required investments.

[11] https://en.wikipedia.org/wiki/John_McCarthy_(computer_scientist)

[12] https://enterpriseiotinsights.com/20200715/channels/news/bt-switches-on-nb-iot-in-uk-to-underpin-largest-smart-water-pilot

Potential implications for the water sector

The key implications for the water sector on the topic of Edge, Analytics and AI are set around:

- **Technology is an enabler for transformation:** Edge, Analytics and AI together could be great enablers for water industry companies to drive digital transformation. This will provide the opportunity for the 'WaterTech' sector to develop and create new opportunities as a rebound and reinvent phase of the pandemic. It is about improving the way services are provided in line with the expectations of today's consumers.
- **Intelligent water solutions will drive efficiencies:** Edge and AI have the potential to transform the water industry by enabling intelligent water solutions. For example, detection of inefficient meters and optimising maintenance scheduling. Embedded AI in their sensor network to reduce sewer overflows will save precious water resources.
- **Environmental benefits:** There could be huge benefits to the environment by deploying Edge and AI capabilities to perform flood management and forecasting, enhanced information sharing and local intelligence of natural assets, water quality measurement and pathogen detection.

Yorkshire Water[12] is completing a pilot with BT to connect 4,000 acoustics, flow, pressure and water quality meters to manage leaks and interruptions in the water network in the north of England through the deployment of a digital twin and AI. BT has deployed NB-IoT to support the pilot as the significant improvements in data quality and battery life, compared to other technologies, will support the identification and prevention of leaks and network incidents more accurately for many years to come.

The pilot will integrate data from new and existing sources, presenting it in a single management dashboard and include a digital twin of the water network in the region. The platform will use AI to cluster data sets, removing false positives, to inform asset and operational decision making accurately.

Immersive Technologies improve Site Management

The following section examines how 5G will affect the use of emerging immersive technologies in the management and support of the activities conducted by field workforces. It looks at how the current activities can be improved and expanded on and how 5G will act as the enabler for the technology of the future.

How they are used today

Field workforces in the water sector are using immersive technologies today. By operating over existing 4G networks, the use cases, location, coverage and general effectiveness are constrained. A good example of this is Welsh Water, who needed to provide its field workforce with information on how to operate and maintain their assets. They developed 'The Interactive Work Operations Manual' (IWOM) a smart, tablet-based electronic manual worn or held by users, delivering complex technological information in a simple to use, intuitive device. The IWOM uses near field communication (NFC) and QR codes to identify equipment and presents users with information about the equipment. The IWOM is intrinsically safe so is used in hazardous, outdoors, wet and dusty environments. It overlays an augmented reality layer to show process information and instructions.

How the technology and business use may develop

5G will enable a more trusted and consistent experience, allowing more dynamic input and automation, leading to a better user and customer experience. It will enable improved utilisation of specialist resources, having them guide less experienced colleagues on complex operations remotely. Virtual tours and training will ensure the field workforce is more prepared before arriving on-site, reducing accidents. Data accessed via gesture control and voice interactions can provide hands-free assistance.

5G will deliver high-capacity connectivity for collaboration and business operations, enabling improved immersive tech to enhance customer experiences. As 5G enables up to 20 times faster download speeds than 4G, high bandwidth activities are quicker and more efficient. The increased speed with which inspections and reporting will process into actions will enable use in time-sensitive situations, such as repairs related to flooding. 5G will develop more precision in immersive technologies. The accuracy of the location and orientation of water infrastructure (down to a few centimetres) will increase the type of use cases in scope. The first time fix ratio will increase, return visits will reduce and repair timings will decrease, as 5G brings consistency to the immersive tech.

Potential implications for the water sector

The key implications for the water sector on the topic of field workforce are set around how 5G technology is reinventing connectivity:

Innovations will provide water companies with the capability to differentiate themselves and improve services to customers. Water companies will take advantage of the 5G rollout to implement immersive technology where they develop effective strategies, allocate capital and collaborate with experienced partners.

As manufacturers refine the immersive kit, this will win the 'hearts and minds' of the field workforce as it becomes more mobile and easier to carry into the field. Immersive technologies over 5G could provide the following benefits for companies in the water sector:

- **Reduced costs:** easy access to more accurate, up-to-date information reducing the possibility of errors and allowing the field workforce to operate more efficiently, increasing workloads and lowering costs.
- **Improved use of resources:** expert staff can assist field technicians more efficiently using high definition point-of-view cameras with AR maps and illustrations.
- **Better services to customers:** improved working conditions and smarter tools mean problems are resolved faster and better services delivered.
- **New technologies made possible:** 5G can enable real-time access to large GIS databases with high definition AR information available as required.

Northumbrian Water is partnering on 5G trials to increase productivity, efficiency and safety for field workforces[13]. The 5G network provides faster speeds, lower latency, greater network coverage, uninterrupted access and capacity, enabling Northumbrian Water to explore new opportunities using 5G-enabled Augmented Reality (AR) technology

- **Remote Expert:** allowing experienced technicians to guide on-the-ground teams through complex tasks.
- **AR Mapping:** providing a 3D representation of buried assets for technicians. The AR headsets will allow technicians to 'see' the network of assets beneath their feet.
- **GIS Management:** allowing field technicians to quickly access and upload crucial data from NWG's central GIS database without requiring a WiFi or cable connection. The database is 24GB in size, making it impossible to transmit over the 4G network.
- **Home Water Maintenance App:** this is an app for consumers to monitor their home's water supply and flow, identifying any unusual patterns flagging potential issues. The IoT sensor is known as 'Barnacle'[14] and provides valuable insights to make decisions fast and take proactive action.

The technology of the future will need the connectivity 5G brings.

The next wave of innovation will see VR Training in the field and drones used for richer media footage of inspections.

[13] Interview with Martin Jackson, Head of Strategy and Enterprise Architecture, Northumbrian Water on 8th July 2020

[14] https://www.cgi-group.co.uk/en-gb/article/project-barnacle-how-smart-technology-can-improve-people-lives-and-help-the-environment

The Importance of Private 5G Networks

How are they used today

Before the Internet, networks did not have to consider the levels of security and protection. Business or enterprise networks were considered ‘private networks’, where the company owned the connecting telecommunication equipment, machines and software at either end. The only external elements might be a private circuit purchased from BT or another fixed network operator. There was no sharing of the connection with another enterprise, and sensitive lines were usually encrypted using physical scrambling equipment at either end. Even where physical access to the point-to-point link was possible, it was encrypted and could not be read.

Nowadays, infrastructure sharing and outsourcing of infrastructure and communications have increased. The use of public open-access Internet increased along with technological concepts, such as cloud-based data centres and ‘as a Service’ model for procurement and use of software/ platforms/infrastructure.

The need for private networks has not gone away; in fact, their use is increasing, as businesses and enterprises realise that private networks will give back control over service flexibility, capacity growth, service availability, service reliability and security. These are becoming more prevalent business imperatives, as the Internet struggles to keep up with traffic demands, keeping hackers out and network operators juggle rollout plans with commercial investment and payback models.

Recent innovations in 5G technology and changes in the Ofcom licence spectrum have opened up the telecommunications market to new deployment models. The aim of the water company would be to reduce costs by buying a smaller, dedicated network, or by generating revenues through leveraging its locations and infrastructure. It is possible to connect up the water supply infrastructure in several ways:

- Using existing operators to supply equipment, spectrum and services
- Deploying a private 5G network
- Deploying a neutral host

The existing operators’ path is the least innovative, as the water company will still be reliant on the operator for everything, including the timeline to be connected up to the 5G service and the operator’s service plans.

A private network can be owned and operated by the water company or outsourced to a third party, with the necessary expertise. This private network would use ‘shared spectrum’, which Ofcom has released for £80 per 10MHz band per year. This spectrum is geo-locked, meaning it only has a narrow area of operation, but it would be ideal for a water treatment plant deployment. Virtualisation means that minimal equipment is deployed at the location and it is a fully functional 5G network, so features such as slicing and Edge computing are still available.

In a neutral host deployment, the infrastructure is deployed, and outsider spectrum providers or operators are invited to connect their core networks up, supplying services to the water company as part of the deal to ‘rent’ space on their network. This is more complex than the private network model, due to the need to create a neutral host operating company to manage the infrastructure and access to it.

Network ‘slicing’ is available on mobile networks, due to the ability to virtualise network functions in software, which began in 4G but has been fully realised in 5G. This allows both private and public operator mobile networks, providing they are running the right software, to support the concept of the network as a series of concurrent but virtually-separated network slices. As slices are created, managed and monitored by the same infrastructure, Operations and Management software, it is possible to introduce and remove slices without any operational and maintenance overheads. The network can be sliced as many times as the physical capacity, and management software will allow it.

How technology and business use may develop

As the private network market has started to grow again, water companies could buy several different types of private network:

- Purchase their private network and run it themselves
- Purchase their private network and outsource its running
- Purchase a private network where the Core is run in the cloud as a service

Because slices can exist on a private or a public mobile operator network, the open standards mandated will allow these slices to interact, meaning a private network slice can be maintained over a public network with no degradation of service or integrity. This uses a technique known as Software Defined Networking (SDN) 'orchestration' to configure a path with a defined set of performance and service characteristics across the fixed infrastructure joining two or more mobile networks.

It is possible to create end-to-end network slices over a mix of private and public mobile networks, by using orchestrated fixed network links that match the slice characteristics. These build national and international private networks composed of a series of distinct network slices designed for specific purposes.

Potential implications for the water sector

The key implications for the water sector on the topic of Private 5G Networks and slice are:

- **Private Networks & Network Slices:** the use of private networks and network slices can deliver the network services a water company might want but struggles to procure from one of the commercial operators. This could be due to a lack of connectivity in a certain area, a lack of capacity in that area, or network services that do not support the stated requirements.
- **Advanced connectivity:** can be provided to a remote location through a single backhaul link that does not have to be part of a larger network rollout. The link could be physical, mobile (5G as backhaul) or satellite as the range of non-terrestrial connectivity options increases.
- **Private mobile network core:** can be situated in one or more remote locations, and virtualisation will allow the deployment of the necessary control, processing and access functions to each of them.
- **Slicing** will support the aggregation of data from disparate monitoring and control systems, as well as supporting greater flexibility in terms of the services that can run over the communications network. This means that the control or video monitoring traffic can run under lower-latency network characteristics due to their real-time criticality. In contrast, datalog retrieval can run on a separate slice tuned for batch processing.

Northumbrian Water requires a range of technical skills and competencies to manage the logistical challenge of maintaining water and sewerage services across the North East region. The deployment of uninterrupted network access and 5G connectivity aims to support almost 2.7 million customers.[15]

Ericsson and O2 will create a Private Network for Northumbrian Water to guarantee uninterrupted network access and capacity, as well as lower latency, higher speeds and greater network coverage. This will support trials in three key areas:

- AR Mapping to provide a 3D representation of buried assets for technicians, as well as supporting remote technical support
- GIS Management to allow field technicians and engineers to quickly access and upload crucial data from a central database without the need for WiFi or wired connections
- Nome Water Maintenance application for customers to monitor their home's water supply and flow, which can highlight unusual patterns to flag potential issues ahead of time

[15] https://www.ericsson.com/en/news/3/2020/ericsson-and-o2-partner-with-northumbrian-water-to-harness-the-power-of-5g

Video Monitoring for Assets and Workforce Safety

How it is used today

CCTV cameras have come a long way since their inception as analogue surveillance cameras. Today's video monitoring is a series of intelligent sensors, used to track assets and people in a way that still protects privacy.

Traditionally, CCTV is widely used over wired connections and existing networks. As more cameras are connected, and the adoption of higher definition cameras continues to rise, 4G networks are struggling to keep up with demand. Monitoring has traditionally been performed 'offline' or via a control room operated by security or operational personnel.

The high bandwidth, low latency and reliability of 5G network allows for growth in numbers of cameras and supports real-time uploading, and streaming of high-quality video feeds in real-time. Combined with AI, these advanced video analytics solutions deliver a step-change in the way water companies use video monitoring.

Within the water sector, video monitoring is commonly used for asset monitoring and inspection and physical site security. 5G will provide a number of benefits to these use cases:

- **Asset and environmental monitoring:** we see the water sector use video monitoring to view and track the condition of assets on a routine schedule. These routine surveys are carried out using fixed, piped, or crawler camera surveys in clean and waste pipeline and enclosed structures. The video output has traditionally been downloaded into proprietary systems for operator review, although more recently, machine learning and AI has allowed for more automated analysis. Remedial actions plans can then be developed.
- **Site and workforce security:** video monitoring provides a view of operations that has benefits for physical asset security. For water companies, this is particularly important due to the threats of supply contamination and disruption and the safety of the workforce in remote locations. Physically safeguarding water supply and associated equipment is of critical importance to water companies. The areas at the most immediate risk are control rooms and water treatment plants, which are potential targets for criminals.
- **Avoiding supply disruption:** other areas of risk include storage facilities and offices used to house high-value assets, dangerous chemicals (such as chlorine gas), or confidential information. Theft or damage has the potential to cause huge disruption to supply and services[16].

Given the remote location of some facilities and the ability to monitor in real-time using video monitoring, security staff, or emergency services may only be able to respond on-site after a detected breach. The police may use the images captured or to reactively improve security in the area.

[16] http://securiclad.co.uk/safeguarding-water-utilities-infrastructure/

How technology and business use may develop

A 2019 Gartner '5G Opportunities for IoT devices' report predicted CCTV cameras offer the greatest opportunities for 5G over the next three years. The report suggests 70% or 2.5 million of worldwide 5G IoT endpoints will be outdoor CCTV cameras in 2020[17].

5G's ultra-low latency, coupled with wider coverage and capacity is ideal for video monitoring. More cameras and real-time streaming of higher quality images used with Edge compute and AI will drive real-time insight for proactive decision making on asset monitoring and security.

Severn Trent is planning a trial of fibre optic cables[18] to 'listen' for leaks across its network. In the future, this will incorporate video monitoring which, if a 5G network is utilised, could provide a real-time high definition view across the network of underground pipes.

Potential implications for the water sector

The key implications for the water sector on the use and adoption of video monitoring technologies supported by 5G connectivity are:

- **Exploiting Advanced Analytics:** mass video monitoring sensors with footage sent directly to the cloud will give water companies much more flexibility when it comes to storing, accessing and managing their surveillance footage. Combined with compute on Edge and AI will lead to proactive alerts for effective monitoring and control. Ultimately, this will reduce the cost of maintenance and leaks, leading to improved customer experience.
- **Enhanced security of workforce, public and assets:** for a regulated industry such as water, the health and safety of its workforce are of paramount importance. High definition videos streamed in real-time with AI techniques could identify where individuals have accidentally or criminally accessed secure areas or are not observing distancing measures required. Appropriate interventions could be mobilised in real-time, increasing the safety of individuals and water company assets.
- **Data and Privacy:** real-time video combined with video analytics at the Edge means individuals can be 'masked' and anonymised. These anonymised images processed at the Edge without a central store means water companies can generate real-time awareness and insight, without breaching the right to privacy.

TELIA COMPANY[19] and Nokia are running a trial on the use of remote surveillance using 5G to provide monitoring and real-time insight into environmental conditions in the Baltics Sea. The blue-green algae situation was monitored with a drone and computer vision analytics, the camera and sensor-equipped drone was flown over the Baltic Sea, and the high resolution video was transmitted over 5g for real-time analysis. The trial revealed that computer vision detected blue-green algae with a 90+% accuracy, leading to the ability to make quick decisions to prevent environmental hazards.

[17] https://www.gartner.com/en/newsroom/press-releases/2019-10-17-gartner-predicts-outdoor-surveillance-cameras-will-be

[18] https://www.waterbriefing.org/home/technology-focus/item/16977-severn-trent-launch-uk-first-fibre-optic-trial-for-leak-detection

[19] https://www.teliacompany.com/en/news/news-articles/2019/5g-used-for-monitoring-blue-green-algae-in-the-baltic-sea/

Drones for Remote Observation

How they are used today

An un-crewed aerial vehicle or drone is an aerial device that can fly with remote human monitoring. Many sectors use the technology for inspection services and aerial surveying of assets[20].

Drones can cost-effectively gather data in locations where physical access is difficult or dangerous, reducing time and risk for a workforce. The high resolution aerial and close up imagery captured can be used for detailed analysis of immediate problems and deterioration over time, enabling data-driven proactive engineering decisions.

We have seen an increase in water companies using technology across other operational areas:

- Asset mapping and monitoring is a compelling use case for water companies' ageing and geographically disperse infrastructure
- Monitoring of reservoir levels to ensure their optimum operation
- Providing a detailed view of potential areas suffering from vegetation encroachment, with regular inspections providing a view of degradation over time.

Drones have historically relied on human interaction to download data once landed. More recent drones now have Edge computing onboard allowing for some machine learning to be applied while in the air. This enables the drone to perform, for example, object detection and alert such as an individual in a restricted area and alert an operator.

How technology and business use may develop

Drone technology is advancing, and many now can contain additional sensors, which can help across industries:

- LiDAR (light detection and ranging) for even greater accuracy of measurements and generation of 3D models
- Thermal for heat detection, with potential to spot underground leaks by monitoring changes in soil temperature
- Optical gas imaging for emissions monitoring of potentially hazardous gases
- Multi and hyperspectral for greater understanding of an area and its composition. Scientists in Korea are developing a hyperspectral sensor to monitor and classify the severity of algae break-outs in a body of water[21]

As 5G connectivity becomes more ubiquitous, data collected by drones will be transferred straight to the cloud for storage and processing. In the future, remote operators, potentially through augmented and virtual reality, may perform real-time operation of a fleet of drones for real-time interaction with drones and interrogation of their data. This will drive even greater situational awareness and insight.

Drones provide a compelling business case for the water sector. Enabling a real-time view of geographically diverse assets results in true insight to optimise operations, drive down costs and improve quality.

[20] https://wwtonline.co.uk/features/the-power-of-drones-for-the-water-sector

[21] https://www.aquatechtrade.com/news/water-treatment/south-korean-institute-tracks-algae-with-drones/


PHANTOM

Potential implications for the water sector

The key implications for the water sector on the topic of drones are:

- **Harnessing 5G geographic coverage:** the advent of 5G at its fuller coverage of non-urban areas can support the rollout of a fleet of drones managed remotely for cost-effective monitoring of geographically diverse assets.
- **Exploiting Advanced Analytics:** Big Data and AI, combined with images and data from drones, can power greater insight for predictive modelling and maintenance across the water network.
- **Workforce optimisation:** drones will free staff time from labour-intensive monitoring operations. Skills may need updating to effectively operate, monitor and operationalise the insight-driven by drone technology.
- **Extending coverage:** drones have been deployed to operate as flying mobile base stations[22] in experiments aimed at extending 5G coverage into remote areas, where the use of static ground base stations and aerial balloon stations is not possible[23].

Further afield than the UK, in **Baiyangdian Lake of Xiong'an**, China, a 5G Smart Water Control and Monitoring solution has been successfully piloted. A 5G network and cloud infrastructure were built to support the deployment of drones for inspection, unmanned ship patrol and the support of real-time video feedback. This allowed the 3D monitoring of water source site in combination with data from connected water quality sensors.[24]

The high bandwidth and low latency support in 5G made it possible for drones to carry out visual inspection of the water surface, including the identification of foreign objects such as solid waste. This video inspection is combined with data from the water quality sensors to predict pollution build-up and proactive and preventive water management.

The three major innovations compared with traditional water management that 5G introduces were:

- 4K Video support in the UAV due to the high bandwidth and low latency characteristics of 5G, supporting accurate visual monitoring
- 5G Augmented/VR (5G AR/VR) support for remote control of the drones, using AR for remote control and VR for 3D visualisation
- Data Analytics, using AI and Big Data technology to establish a water quality model; this can also be used over time to optimise operations as well as develop a water quality prediction model

[22] DroneCells: Improving 5G Spectral Efficiency using Drone-mounted Flying Base Stations, Azade Fotouhi, Ming Ding, and Mahbub Hassan https://arxiv.org/pdf/1707.02041.pdf

[23] https://www.researchgate.net/publication/319661913_Drone-Aided_Communication_as_a_Key_Enabler_for_5G_and_Resilient_Public_Safety_Networks

[24] https://www.rcrwireless.com/20190122/5g/5g-enables-iot-industry-application

Moving towards Net Zero

Water companies have committed to challenging industry-wide carbon zero targets by 2030, with individual organisations setting individual goals that are even more stringent[25]. The sector is uniquely positioned to feel the impact of climate change, and with effective use of its assets, to make a difference in terms of carbon emission reduction.[26]

This section of the paper explores potential steps water companies can explore to meet net zero targets by reducing the carbon emissions of its organisation, and maximising the use of its assets for energy generation.

> "Climate change is the defining issue of our time, and we are at a defining moment. From shifting weather patterns that threaten food production to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale." United Nations[27]

Where we are today

As the fourth most energy-intensive industry in the UK, the water sector is a major national contributor to emissions, responsible for around five million tonnes each year. Electricity use makes up around half of these emissions[28]. The water sector has committed[29] to achieving net zero carbon emissions by 2030, a challenging goal which will require a step-change in operations to meet.

Initiatives currently underway by water companies to achieve this include:

- **Energy use and generation:** developing greener energy by utilising the land and resources it has available, for example, through solar farms and using sludge to generate renewable energy. Severn Trent has publicly committed to targeting 100% renewably sourced electricity by 2030.[30]
- **Updating vehicle fleets:** with a significant automotive footprint, water companies are looking to reduce associated emissions by updating their fleets. Northumbrian Water has publicly stated it aims to make all new vehicle purchases for its thousand-strong fleet zero emissions from 2024. Challenges around the supporting battery and charging infrastructure for electric vehicles is driving innovation in other fuel sources such as biomass.
- **Wastewater treatment:** organisations are actively working to reduce the emissions from water treatment, and reusing associated methane as a potential energy source.

[25] https://wwtonline.co.uk/features/reaching-net-carbon-zero

[26] https://wwtonline.co.uk/features/how-the-water-sector-is-moving-to-be-net-zero

[27] https://www.un.org/en/sections/issues-depth/climate-change/

[28] https://wwtonline.co.uk/features/how-the-water-sector-is-moving-to-be-net-zero

[29] hhttps://www.water.org.uk/news-item/water-industry-plans-to-reach-net-zero-carbon-by-2030/

[30] https://www.stwater.co.uk/about-us/climate-responsibility/climate-change/reducing-our-greenhouse-gas-emissions/

How technology will help in the future

The use of technology, mass sensor deployment and associated data will allow for a step-change in the monitoring, forecasting and reduction of energy use.

Mass IoT devices underpinned by a platform to drive insight, will allow for a better understanding of energy use across assets. One example being an understanding of building occupancy, allowing for dynamic heating and lighting control and even closing off unoccupied sections to further reduce energy use.

Sensors will allow for proactive maintenance and diagnostics of assets and equipment, enabling fa real-time view to optimise operations. Through proactive monitoring and maintenance, this will help to reduce leaks across the network.

5G's connectivity allows for the integration of all these devices for accurate monitoring and forecasting of energy needs. For water companies, managing energy demand and planning the renewable infrastructure required will be much easier and more efficient. Leveraging 5G-enabled geospatial technologies may provide some helpful predictive insights into meteorological outcomes.

Looking ahead, the use of digital twins, pilots of large-scale battery storage and the production of hydrogen in hydropower sites that cannot connect to the grid demonstrates the progress and leadership the sector is taking in this area[31].

Potential implications for the water sector

The key implications for the water sector on energy management and net zero initiatives and technologies are:

- **Harnessing 5G geographic coverage:** increased remote monitoring in the form of video monitoring, drones, and associated real-time data transfer enabled by 5G will reduce the need for travel and for workers to be physically located on-site. This will reduce the demands on fleets of vehicles and associated emissions, allowing water companies to deploy on-site presence only when required. Mass deployment of IoT devices for monitoring energy use across assets such as buildings will also allow targeted energy reduction.
- **Exploiting Big Data and Advanced Analytics:** the Advanced Analytics enabled by remote monitoring and real-time connectivity means physically diverse assets can be maintained on a proactive basis, reducing the need for the maintenance workforce to travel. Immersive technologies will provide maintenance staff with a real-time, remote view of operations and trend analysis using geospatial and video monitoring will detect changes over time, allowing for deployment of resources as required; resulting in reduced energy and travel use and associated carbon emissions.
- **Environmental impact:** proactive maintenance schedules enabled by ubiquitous connectivity reduces the risk of environmental incidents such as sewer discharge, which may damage the environment and require significant energy to treat. As water companies move to renewable energy, recovering energy and heat from its sources, this will also reduce associated emissions. Enhanced land management monitoring using drones and video monitoring will help to reduce contamination and improve environmental outcomes.

[31] https://www.nwg.co.uk/our-purpose/public-interest-commitment/net-zero-by-2027--taking-on-the-challenge-of-carbon-emissions/

[32] https://www.ispreview.co.uk/index.php/2020/03/o2-seeking-to-become-uks-first-net-zero-mobile-network.html

Looking beyond the water industry, the use of 5G networks is now part of the mobile networks operators' plans to reduce their carbon footprints. Mobile operator O2 aims to become the UK's first Net Zero mobile network[32]. As part of their plan, they have pledged to remove carbon emissions from their entire business and network by 2025, whilst working with their supply chain to cut emissions by 30%.

O2 will switch third-party landlords that support the O2 network over to renewable energy, while creating technical and energy transition solutions across its entire business where required; O2 has been using 100% renewable energy since 2008 in areas where it controls the energy bill.

O2 already does a number of other things to reduce their environmental impact. For example, their network saves energy by dropping capacity when demand is low and they have long worked to recycle both mobile phones from customers (over 3 million devices have gone through their recycle process, saving 450 tonnes of waste from landfill) and they do the same for old retail uniforms. O2 also claims to have been the first to introduce an Eco rating scheme for new phones. Progress against these commitments will be reported annually as well as being independently assessed and audited.

Energy Generation in the Water Industry

Where we are today

Water is essential for key phases of energy generation, from fossil fuels to biofuels and power generation. Energy is also vital for a range of water processes, including water distribution, wastewater treatment and desalination.[33]

The topic of energy generation can be seen through two lenses, water use in:

- Non-renewable energy generation and water processing
- Creating renewable energy

Energy utility companies have long focused on driving improvements in non-renewable energy generation and water processing[34]. Coal, natural gas and nuclear power produce provide a significant amount of the world's energy but in doing so draws on a huge amount of fresh and saline water per year. In addition, energy costs often make up a significant proportion of an organisation's costs.

The topic of water's role in creating renewable energy continues to gather pace across the globe. Like the wind, water can be used to drive turbines directly. There are several ways to use water, including waves, tides and falling water in hydroelectric power schemes.

How technology will help in the future

When taking a closer look at the use of technology to support future opportunities in the non-renewable energy and water processing area we see the following examples:

- Creation of more complete 'end-to-end' water models from operations to customer
- Asset and plant focused data-driven insights support predictive maintenance and servicing
- Use of geospatial insights drawing on historic data to connect in environment shifts
- Exploitation of sensor-based data across the water network
- Translation of this analysis in easier to consume forms through digital twins

Turning to the topic of renewable generation[35], we see the use of hydropower as a key area of interest. It is recognised that new plant development often comes with large upfront capital investments. The following examples show where technology and associated engineering advancements may be able to:

- Development of modular hydropower[36] using common components to reduce installation costs
- Powering non-powered dams adding turbines to create hydropower to the grid
- Further exploiting pumped-storage hydropower to turn turbines and meet energy demand
- Exploitation of tidal energy making further use of tidal turbines together with other energy sources to operate as a more integrated system

While technologies are advancing across a range of water-related operations, wave energy advances remain limited. The potential to harness this immense natural energy source is yet to be safely, reliably and cost-effectively converted into usable electricity.

[33] https://wwtonline.co.uk/news/water-firms-explore-new-relationship-with-energy

[34] https://www.epa.gov/sustainable-water-infrastructure/energy-efficiency-water-utilities

[35] https://www.ucsusa.org/resources/environmental-impacts-renewable-energy-technologies

[36] http://blog.parker.com/hydropowers-future-relies-on-next-generation-water-power-technologies

[37] https://www.smart-energy.com/partners/edp-surpassing-the-competition-in-digitalizing-for-the-future/

Potential implications for the water sector

The key implications for the water sector on energy generation increasingly focused on renewable energy are:

- **Societal demands:** the water sector will need to further support green energy production and play a visible role in doing so from a market and consumer perspective
- **Exploiting biological resources:** using new innovative techniques and resources, such as sludge, combustion and digestion to extract energy
- **Demand-driven energy:** further supporting the energy sector, potentially by flexing energy production to times of peaks in demand across the network

EDPR has wind farms across Portugal and Spain with an ambitious expansion plan stretching across several continents. Control and efficiency were at the forefront of EDPR's mind[37].

From the beginning, EDPR understood the benefits of having a real-time single view of the whole portfolio, as well as the business control they would have if they were independent of turbine vendors.

The solution was a single, easy-to-use system that could scale up at short notice across the different geographical locations, with different manufacturers and models of wind turbines. At any given moment, each turbine provided 200 to 300 signals. The system could retrieve data and control all 6,000 turbines in real-time.

Added to this historical data representation made reporting and analysis simpler achieving operational excellence. The result was the real-time control of hundreds of wind farms remotely, enabling maximisation of energy injected into the grid by improving asset availability, increasing energy revenues while reducing operational costs.

The Smart Water Grid

Where we are today

One definition of the term smart grid is 'an electricity supply network using digital communications technology to detect and react to local changes in usage.' This definition jumps to an electricity network as the 'grid'. The definition also picks out digital communications technology as a key part of a smart grid. It implies a level of autonomous reaction to changing events and usage. The definition also implies, as one of the 'reactions', demand side management measures.

Does the definition apply to our water networks and their operation today? UK water companies are installing an increasing number of smart meters. These offer a clearer view of consumption patterns but do not offer direct control of consumption. However, the information can be used to encourage customers to change consumption behaviours. There is an increasing level of monitoring applied to water networks through sensors and loggers. This sensing is being added to the well-established SCADA and telemetry sensing already in place. There are also some automated local control schemes used, for example, to pressure manage DMAs or to automate the on-site processes.

How technology will help in the future

In coming years, the introduction of low-cost sensors communicating over 5G, and mass IoT solutions will give water companies a clearer view of how the network is behaving. This view will be on a much more granular level than it is now, down to individual consumption points and assets. It will also be available in near real-time. This increased visibility will allow more specific and timely actions to improve operations.

Advanced Analytics and AI techniques can be applied to the new information to allow water companies to predict events before they occur and to apply proactive responses. Driving this new data through digital twin models will create a more holistic view, allowing the water company's operation to be assessed as a system of systems.

Over the longer-term, water assets will become more controllable, allowing increasing levels of autonomous operation. The technological developments here are driving the water industry along a journey from remote monitoring to autonomous operation.

Potential implications for the water sector

The key implications for the water sector on smart grids will help address some of the pressing, customer service, resilience and sustainability challenges:

- **Asset Management:** allowing asset maintenance to be more predictive or self-alerting as well as extending the life of the assets
- **Event Prediction:** predicting network events as they are developing in time to allow a proactive response, reducing the potential service interruptions that may impact customers.
- **Consumption Behaviour:** providing cues and incentives to customers to encourage them to change consumption patterns where necessary.
- **Pressure Management Optimisation:** bringing the capability for an optimised pressure managed network, that responds dynamically and autonomously to changing demand patterns. This will have the dual benefit of reducing pumping energy and leakage levels.

Potential implications for the water sector

The key implications for the water sector on energy generation increasingly focused on renewable energy are:

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In China's **Southern Power Grid**[38] (CSG) 5G power slicing project, slicing was used for the first time to define power slicing KPIs covering 35 categories and almost 60 parameters including Area of Service, Delay Tolerance, Downlink Throughput Per Network Slice and Downlink Throughput Per UE.

In the project, power service scenarios are classified into Production and Control, and Management and Information. Production and Control scenarios include intelligent distributed power distribution automation, precise load control, and distributed power control.

These scenarios aim to address power distribution network requirements, including ultra-low latency (15 ms), ultra-reliable communication (99.999% reliability), and high security isolation. Management & Information scenarios include low-voltage power consumption information collection and smart grid video applications. The network must meet 100 ms latency, 99.9999% reliability, and 4–100 Mbit/s bandwidth requirements, as well as thousands of connections per square kilometer.

To verify security isolation for 5G E2E slicing, CSG constructed three types of network slices: low-latency for power control, high-bandwidth, massive-connection for information collection, and common for public services. CSG concluded that when the common slice overloaded, the other two types of slices were still normal in network performance and latency.

Based on the project, suggestions for optimisation were proposed for parameters across a series of slicing templates such as slice isolation, slice KPI monitoring frequency, slice security, and session and service continuity. The project is a successful use case, and has confirmed the feasibility of slicing templates, such as the GSMA Generic Slicing Template (GST) on which this project was based. Furthermore, it provides a reference for other industries, such as water utilities, to define parameters based on GST and implement network slicing.

[38] https://inform.tmforum.org/casestudy/china-revamps-om-to-target-verticals-with-5g/

Key Considerations

This paper explores some of the critical challenges facing the UK water sector that must addressed, if it is to continue to deliver safe, reliable, affordable and sustainable services.

The paper also identifies emerging technologies, enabled by 5G communications, that will drive change and bring new solutions to help the water industry address these challenges.

The following key considerations and next steps have been explored:

- **Prioritisation of critical business challenge:** all too often, technology has been the starting point looking for a problem to solve. Being clear on the business and operational challenge, and the associated benefits remains the first key consideration.
- **Exploring the art of the possible with technology:** knowing what technologies can achieve and being able to create Minimum Viable Products (MVPs), which directly align to a business problem and can scale if successful.
- **Engaging the right ecosystem of partners:** recognising that meaningful innovation will be generated across a spectrum of professional disciplines, drawing in equal measure on the business domain as well as technical expertise.

Considerations at enterprise and organisational level point to:

- **Business Planning and Performance:** as improved insights are generated, they will enable step changes in operational performance and re-set traditional business planning ambitions, as well as open new opportunities for monetisation of data/water-related services.
- **Societal Demands and Consumption Patterns:** the demand side of this water efficiency challenge cannot be ignored. Managing volume and period of use will have a significant impact on absolute costs associated with the water sector and direct implications for how efficiently those demands can be serviced. This is a key sustainability consideration too. Reducing demand will reduce carbon, and will help the industry ensure it can continue to supply enough water to meet demand sustainably.
- **Operational Efficiency:** the degree to which operating costs can be improved through more effective use of resources; increased levels of operational automation; a reduction in costly network failures; more cost-effective asset maintenance; and reduced asset capital expenditure.
- **Consumer Pricing:** the degree to which new business models evolve as data provides new opportunities to charge and reward their customers for consumption based on factors beyond simple volume consumed.
- **Skills Development:** Supporting the workforce in adapting ways of working to harness the data-driven insights and being able to act on them effectively.
- **Environmental Challenges:** the extent to which climate change impacts the environmental landscape and water scarcity, and its management remains an open question. Leveraging 5G. enabled geospatial technologies may provide some helpful predictive insights into meteorological outcomes.

Considerations at technology level point to:

- **Harness Advanced Analytics:** with Big Data and AI powering the creation of scenario-based water models, three-dimensional monitoring with alert and predictive based analysis taking customer as well as smart water control and environmental protection to a new level.
- **Data Exploitation:** knowing which data is critical to driving business outcomes will be increasingly important and having technology solutions that can capture and analyse high-value data that create operational insights.
- **Data Exchange:** with the advantages of data volumes and low latency, this can provide high-value environmental insights, such as 4K video, 5G Immersive to enable a step-change in visual monitoring of water resources.
- **Data Coverage:** the advent of 5G at its fuller coverage of non-urban areas typified by the likes of 4G can provide the basis to support the extensive water network across the UK.
- **Harnessing 5G geographic coverage:** The advent of 5G at its fuller coverage of non-urban areas typified by the likes of 4G can provide the basis to support the extensive water network across the UK.
- **Data Governance, Security and Privacy:** The identification, capture and use of information at new scales not seen before, will drive value and the need to explore from data governance, security and privacy perspective; ensuring data use is appropriate for societal needs.

[39] https://www.cgi-group.co.uk/en-gb/white-paper/water/grasping-opportunity-ofwat-innovation-fund-water-sector

Next Steps

Today, what is new and different is the way data is captured, moved, analysed and exploited: a new generation of connected technology is changing the rules of the game. The reach and depth of these new insights are greater than ever before as they offer a step-change for those industries and sectors with an appetite to explore.

The timing is right for the water sector to make the most of new connected technologies, especially at a time when the industry regulator, Ofwat[39] is demanding more innovation from the industry. The creation of a new £200m innovation fund provides an opportunity for water companies to come together with technologists to develop a sector-wide innovation strategy to drive transformational change.

It's now up to the water industry to decide how it chooses to apply the technology and which areas it wishes to start with, to not only respond to its key challenges but to unlock value to redefine customer and market operations.

Call to Action

UK5G and CGI in collaboration with the water sector are embarking on a programme of work to enable the next generation of water market services and operations through connected technologies. This ambition is formed through the creation of high impact consortia organisations to work collaboratively towards a common goal.

If you and your organisation share our ambition, please contact us and join us in a series of business-driven, technology-enabled incubator sessions to unlock the true value of the water market.

Find out more, email: enquiry.UK@CGI.com

Quote: Connect to Innovate

[39] https://www.cgi-group.co.uk/en-gb/white-paper/water/grasping-opportunity-ofwat-innovation-fund-water-sector

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Graham has over 20 years' experience working in the utility sector, helping utility companies respond to their most complex market challenges and drive more value from their asset base. He is an expert in optimising business processes and designing innovative and transformational solutions, having worked with many of the UK's leading water sector and utility companies.

Graham was at the head of the CGI's programme, which successfully created the Central Market Systems that support the operation of the new water retail market in England. In an innovation capacity, Graham has also created the Barnacle and Dragonfly solutions with Northumbrian Water. These innovations use smart technology to improve the lives of water customers and the rural community.

Graham is one of CGI's leading water sector subject matter experts and has co-authored two editions of 'GB Water Industry for Dummies', as part of the CGI For Dummies series.

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Andrew has more than 30 years of experience in IT, Telecoms and TV and Media, having worked in various roles for IBM, AT&T, Ericsson, Motorola and Arris. Andrew is an expert in developing and delivering complex SI and Services solutions that meet the business and technology needs of the communications sector.

Since joining CGI, Andrew's expertise has focused on emerging and maturing technologies, such as 5G, Connected Places and Smart Cities, Private and Neutral Host Networks, and the IoT. Andrew is engaged in determining the business imperatives, use cases and business models that drive adoption of these new technologies across business sectors, as well as investigating the business relationships, consortia and ecosystems required to deliver them.

Andrew is one of CGI's leading communications sector subject matter experts and has co-authored 'UK Telecoms For Dummies', as part of the CGI For Dummies series. A blogger and a regular contributor to media commentary, like in the recent 2020 5G Campaign in The Guardian, he frequently speaks at conferences. He is a member of Cambridge Wireless Virtual Networks Special Interest Group (SIG), Digital Policy Alliance's Smart Society Working Group, techUK Spectrum Policy Forum and the Local Public Services Committee (LPSC).

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About UK5G

UK5G is the national innovation network dedicated to the promotion of research, collaboration and the industrial application of 5G in the UK. Its mission is to ensure that the UK is at the forefront of global 5G development.

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About CGI

Founded in 1976, CGI is among the largest IT and business consulting services firms in the world. Operating in hundreds of locations across the globe, CGI delivers an end-to-end portfolio of capabilities, from strategic IT and business consulting to systems integration, managed IT and business process services and intellectual property solutions. CGI works with clients through a local relationship model complemented by a global delivery network to help clients achieve their goals, including becoming customer-centric digital enterprises.

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