The implications of future technological change for Scotland's infrastructure

Report Prepared by Frost and Sullivan

August 2019

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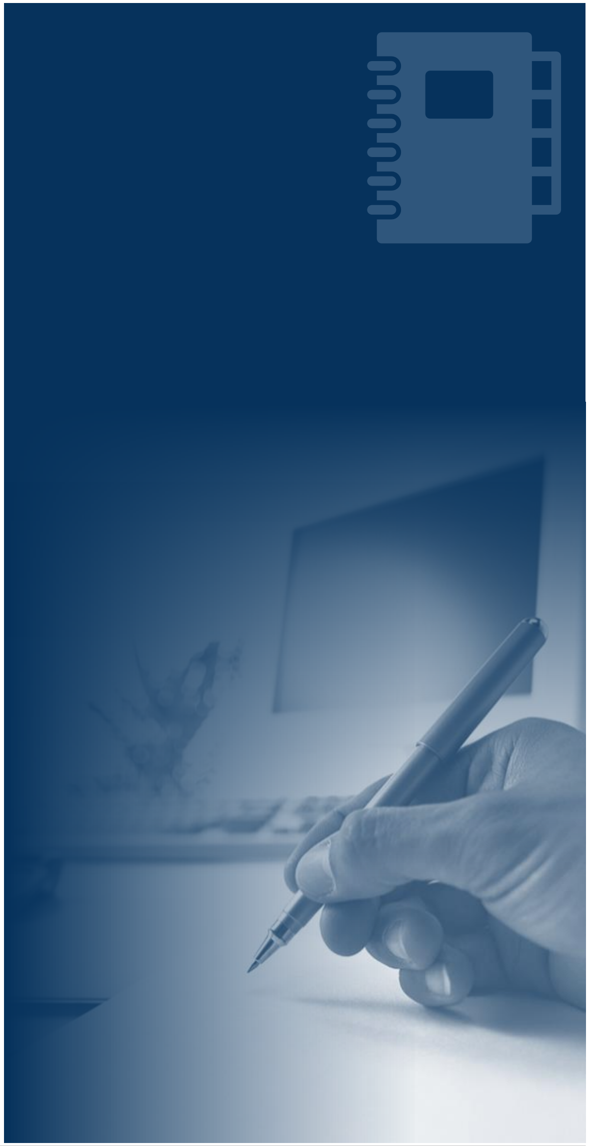


Introduction

This report was prepared by Frost and Sullivan Limited, on behalf of the Scottish Government. It is intended as a submission to the Infrastructure Commission for Scotland, as well as a discussion document for the Scottish Government. It does not necessarily represent the views of Scottish Government Ministers.

The intention of the report is to illuminate the implications for Scotland's infrastructure of technological change and innovation. This is one of the key strategic drivers for the infrastructure vision identified by the Commission. The timeframe applied in the analysis is of 5 years and 30 years, to inform the Scottish Government's Infrastructure Investment Plan for the next five years and the longer term 30-year strategy for infrastructure on which the Commission is advising.

Method

The approach included:

- Identifying a set of key technology trends of potential importance to Scotland in the mid-term future (using the findings of previous research undertaken by Frost and Sullivan), and from this, identifying those most relevant to each infrastructure 'portfolio' or area
- For each area and trend, identifying the likely timescale for impact (5 or 30 years) and the level of certainty over the impact, and identifying illustrative examples of how the trend is playing out or may do so in the future
- Drawing out the implications of these findings for future infrastructure investment in each area

Scope and limitations

The report provides an overview of the range of technology trends potentially impacting on infrastructure in Scotland and provides examples of their uses and implications. It focuses primarily on the potential for deployment of technologies in infrastructure design and delivery. While it draws attention to technologies that may drive wider behavioural changes it does not attempt to estimate the potential direct and indirect impacts of these changes on infrastructure *demand* (e.g. such as changes in work practices or the way we access services resulting in a reduction in demand for transport infrastructure and services).

The report is designed to provide a stimulus for future-focused thinking on Scotland's infrastructure vision and strategy. It does not provide an economic assessment of the impacts of any particular technology deployments in Scotland.

Introduction

Definitions

- Judgements about the timeframe and certainty of impact are qualitative and have been assessed using available secondary sources.
    - The assessment of *uncertainty* is based on a judgement about how unstable or unpredictable the trend is. This includes consideration of both the impact of the trend on infrastructure as well as the development of the technology itself.
    - When considering the *timing* of impact, this was defined as impact that is significant in terms of large scale commercial deployment. This means that even though there may be some active pilot deployments in some areas currently (e.g. carbon capture or hydrogen), large scale commercial deployment may still be judged to be some way off.
- The assessment of timing and certainty for each technology is estimated separately for each area of infrastructure and may vary accordingly. For example, drones could see different rates of commercial adoption in transport (for last-mile-delivery) than in energy (for inspection applications). Further, among each technology category there may be sub-categories with different rates of adoption. For instance, within advanced materials, hydrophobic coatings are ready for wide deployment, whilst self-healing materials that could be applied to concrete are still under development and require a longer timeframe to be adopted at commercial scale.
- Definitions for each technology trend are supplied in the appendix.

Key Findings, Commonalities and Connections

This section highlights the key findings of the research, including the commonalities in themes or issues identified across infrastructure areas, and connections between infrastructure areas.

Digitisation and Automation

Two key overarching trends across infrastructure areas in terms of technology deployment are digitisation and automation.

- **There is a big shift in the pace of digitisation of services, systems and solutions.** The development of smart and intelligent systems is one example of deploying advanced IT technologies on top of existing infrastructure, or as an integral part of it (such as energy generating materials on buildings), that enables more intelligent management of services. Digitisation is also having an impact on how infrastructure is planned for and maintained. For example, the use of Augmented and Virtual Reality solutions in planning, maintenance and operations is increasing. We also witness the use of Digital Twins in various applications. Along with big data, machine learning and analytics, this enables a variety of maintenance issues in infrastructure networks to be solved.
- **There is a clear trend towards automation.** Whether by deploying sophisticated Artificial Intelligence (AI) solutions, or in the use of Robotics and Drones, the trend to augment or replace human involvement in many areas of infrastructure activity is evident.

Harnessing these trends will require digital connectivity infrastructure to be enhanced. In turn, this drives a focus on cyber security; system interoperability and workforce skills development.

1) Cyber Secured Communications

- **All major infrastructure areas require strong and secure communications networks.** Whether communications are delivered over 5G, Broadband or via Satellite Applications, data exchange and communications are a necessary condition for the delivery and sharing of data that can be translated into insight and action. Whether this is for enabling Intelligent Transport Systems, Smart Grids, Intelligent Buildings and Waste Monitoring, or in telehealth applications, all depend on effective communication systems. To ensure that such critical communication systems operate smoothly, cyber security is a critical requirement.
- **With the growth in interconnected systems and networks for transport, energy and healthcare, critical national infrastructure is increasingly becoming a potential target for cyber attacks.** The challenges around cybersecurity will need to have a clear prioritisation as national or business risk issues, which may require a shift in resource allocations and skill sets.
- **5G and the Internet of Things (IoT) will support the rise of smart cities, resulting in significantly more data being created**. This means the need for significantly more capacity to transmit that data reliably and consistently, which may require investment in data centre capacity and better data management strategies.

Key Findings, Commonalities and Connections

2) Systems inter-operability and Common Standards

- **Systems inter-operability and common standards (technical, operational, communication) are a critical enabler for many of the applications reviewed.** Making sure that energy, home or building automation and communication systems are truly inter-operable is a basic building block of smart home and smart energy solutions. This also requires a focus on open systems (i.e. where multiple rather than only one or a few vendors can co-exist). Combining this with common standards is an important component of enabling and speeding up technology deployment.

3) Skills Development

- **Developing smart, intelligent systems for infrastructure could have major benefits to citizens and businesses, but a major issue is the skills available to support deployment and operation of these systems to maximise that benefit.** For example, experiences and skills in recycling technologies are needed to facilitate the wide adoption of the Circular Economy concept; and for the deployment of advanced energy management systems, technology-familiar staff will need stronger skills in areas such as data analysis and AI tool use. While there is uncertainty around the scale of the future impact of automation on jobs and skills, there is the potential for significant disruption. This will require a focus on skilling and re-skilling the workforce, particularly in areas where automation is expected to have a significant impact such as transport and construction.

Decentralised Models of utility and service delivery

Another cross-cutting trend as a result of technology deployment is towards decentralised models of activity, service use and resource generation and consumption. Examples includes remote working, remote service use and distributed energy generation.

- **Increased remote working due to technology solutions will see a rise in new opportunities.** The growth in communications technology infrastructure and cloud based solutions have enabled a growth in remote working. This has opened up opportunities for work at home / work anywhere models, both for employees and for self-employed workers. This has implications for employment regulation and for taxation, as well as for transport and travel.
- **Digital Health is changing models of healthcare delivery via telehealth solutions.** This technology could reshape and improve services, support person-centred care and improve outcomes, by enabling citizens to better manage their health and wellbeing – thus moving to a more preventative focus - and to gain access to services using digital technologies. Such technologies might bring significant health impacts among patients in areas where the physical health infrastructure is limited.
- **There is an increasing localisation of energy supply and demand solutions.** Distributed energy generation and storage, smart buildings that aim for net zero energy status and using advanced material technology to generate energy at the point of use, are all examples of this trend. This supports a range of objectives such as low carbon targets and energy efficiency. It could also enable prosumer-based business models, which could potentially generate revenue streams for rural communities.

Key Findings, Commonalities and Connections

Prevention Rather Than Repair

A third key trend enabled by technology deployment is a shift in focus towards preventative maintenance of infrastructure.

- **Predictive maintenance across infrastructure aims to reduce repair challenges.** With the rise of predictive analytics, advanced materials and sensor technologies, it is possible to better anticipate maintenance needs. Observational technologies such as drones can also be used to monitor infrastructure. The aim is to reduce both the risk and the operational costs of unexpected breakdowns of infrastructure capacity.

Connections between infrastructure types

Converging technology trends across a range of infrastructure areas creates interdependence and connections between infrastructure types.

- **The growth of smart cities creates more interdependent infrastructure systems such as smart transport, wireless systems, water networks and power grids.** Technologies like digital twins could also enable better real-time analysis of assets for greater efficiency across infrastructure areas. This requires collaboration and cooperation across industries, technology firms and public organisations.
- **As systems become increasingly interconnected, one of the challenges is to isolate failures,** which can spread from one infrastructure to another. This requires making critical infrastructure more resilient and reallocating resources toward prevention and recovery.
- **Energy and water systems are closely interconnected**; energy is required to extract, treat and deliver water, while water is used in many stages of energy production and electricity generation. Demand for these is increasing and technologies will need to address and optimise energy-water trade offs, while there will need to be an integrated approach to energy-water planning. The merging of technical and operational managements could potentially drive more business mergers in these sectors.
- **Due to technology developments, all areas of infrastructure have an increasing demand for communications infrastructure**, so having a unified utility infrastructure approach when planning and building new developments will become more appealing.
- **Given the increase in supply and demand for data, driven by the rise of IoT and advanced sensing technologies, and growth in cloud computing, there is a large demand for data centres**. A potential trend occurring is the location of data centres closer to centres of consumption. Given the growth in distributed energy generation, it is also possible to imagine a more distributed model of data centres co-located with distributed and renewable energy sources. For example, Microsoft Corp has deployed an underwater data centre powered by renewables at the European Marine Energy Centre (EMEC) in Orkney. Co-located energy and data utilities could become a future trend, with the implications for infrastructure planning and management becoming clearer over time.

Key Findings, Commonalities and Connections

Climate Change Impact

Finally, an important driver of technology adoption across a range of infrastructure areas is climate change. Technological developments will become increasingly important in both the mitigation of climate change impacts and in adaptation to those impacts.

- **An increase in the frequency and intensity of extreme weather events due to climate change is likely to impact on infrastructure planning and operation.** The UK is set to get warmer and wetter, with some cities being impacted by rising sea levels. Along with changes in temperature, this may have important implications for infrastructure design, operation and maintenance, and could increase the risk of disruptions, damage and failure of systems.
- **Technology adoption will be central to both climate change mitigation and adaptation, with implications for infrastructure**. For example, more stringent regulations on emissions to mitigate climate change may drive a preference for investments in greener modes of travel, such as renewable energy charging stations for electric vehicles, or better walking/cycling infrastructure. Investments in the digitisation of infrastructure could enable better adaptation to the effects of climate change, by enabling smart risk management at regional or country level, which would facilitate the design of infrastructure that is more climate-resilient.

Energy

Technology trends are driving distributed energy, decarbonisation and smart grid management in order to meet the critical requirements of economic viability, sustainability and reliability.

Smart Grids and the increasing importance of digital infrastructure

Smart grids are advanced, digital infrastructures with two-way capabilities for communicating information, controlling equipment and distributing energy capabilities to make energy infrastructure more reliable and stable. The key focus is to enable more efficient use of the network infrastructure. One of the key differentiating factors of a smart system is the data fidelity associated with it. With better sensing and communication capability, the amount of data generated and transferred could be extremely high. The Internet of Things (IoT) and Smart Sensing technologies, as well as other technologies such as Blockchain, enable the Smart Grids concept. Photonics is the key enabling technology for both IoT and advanced sensing.

Big Data and Artificial Intelligence can also significantly improve overall energy infrastructure efficiency by real-time data analysis and new control algorithms. These technologies enable assessment of environmental conditions, such as sun or wind intensity and can help address the unpredictability of renewable energy supply by matching and managing supply, demand and storage.

Through 5G Infrastructure, Scotland's energy sector demand for reliable and secure data exchange will be addressed. One of the major benefits of 5G is its reduction in latency (delay in data transmission) which means it can be used in data critical areas such as autonomous vehicles. It can also support low power, low cost applications such as ubiquitous sensing applications e.g. throughout the distribution grid. Combined with Cyber Security, this can enable faster and safer network connections. This is why there is a convergence of energy, telecommunications and IT supply systems to enable more integrated and secure solutions.

Blockchain is a distributed ledger technology (DLT), where every node in the distributed peer-to-peer computer network maintains its own record of a transaction, eliminating the requirement for a trusted third party. In decentralized energy, this can enable a peer-to-peer energy trading network.

The ACCESS project on Mull – funded through the Low Carbon Infrastructure Transition Programme (LCITP) – aims to lay the foundations for a cost-effective platform for enabling real time matching of local electricity generation with local electricity demand at a distribution network level.

Scottish and Sothern Energy and Scottish Power are working on a Street2Grid project, led by Aston University, aimed at developing an electricity blockchain platform for peer-to-peer energy trading.

Energy

Growing renewable energy generation & storage and the rise of Decentralised Generation

Distributed generation (DG) produces energy by utilising various decentralised conventional and renewable energy sources. It involves energy sources often located closer to the consumer and dispersed geographically, ranging between a few kilowatts and approximately 10 to 50 MW. Decentralised production of energy (either conventional or renewable) can contribute to overall lower energy costs, particularly in areas with little or no spare grid capacity. The Scottish government has provided long-term funding for the development of local energy systems through a number of initiatives, such as the Renewable Energy Investment Fund and the Local Energy Challenge Fund. Up to £20m funding will be allocated in 2018-19 to invest in renewable and low carbon energy solutions.

As **Renewable Energy** generation increases in Scotland, so does the need for **Energy Storage** infrastructure projects to mitigate the problem of unpredictability associated with renewables. Due to this, energy storage will be an integral part of the transition to renewable energy. A 2017 report published by National Grid forecasts that energy storage will increase by up to 30 GW by 2050. Hydrogen fuel cells are also being developed to provide energy network stability. Projects such as Orkney's *Surf 'n' Turf* and *BIG HIT* supported by the Scottish Government, generate hydrogen from renewable energy and make use of it in fuel cells.

According to the National Grid, the adoption of **Electric Vehicles** is likely to accelerate the uptake of renewable energy generation, as the electrification of transport will increase electricity demand and new electricity capacity will increasingly come from renewables. Home charging points that are to be set up could have the option to install solar panels to complement clean transport with a clean source of energy charging.

A low carbon economy based on Carbon Capture, Utilisation and Storage (CCUS)

The aim of Carbon Capture and Storage is to prevent greenhouse gas (GHG) entry into the atmosphere by capturing, compressing and injecting CO_2 into deep underground rock formations. The UK currently has one CCS project in the feasibility stage - Acorn CCS and Hydrogen project, a low-cost, low-risk carbon capture and storage project, situated on the north east coast of Scotland. It aims to use relatively small initial quantities of CO_2 to quickly establish a low-cost opportunity to commission large scale CO_2 transport and storage infrastructure that can support much larger volumes in the future. In June 2018, Acorn CCS became the first carbon capture utilisation and storage (CCUS) project in Europe to have been awarded funding from the European Commission's Connecting Europe Facilities (CEF) fund. The project could be operational by the early 2020s.

Energy

Material and automation advances will help reduce operational costs

Advanced materials such as nanocoatings are key enablers for the development of photovoltaics, smart sensors, efficient carbon capture and storage and energy storage technologies. **Robotics and automation** technologies can also bring significant benefits in reduced maintenance costs and improved worker safety, especially in **energy distribution**, via inspection and monitoring of power lines for condition assessment. Scottish and Southern Electricity Networks (SSEN) in partnership with Williams Advanced Engineering Ltd is developing robots for high-voltage power line inspections.

Heriot Watt University leads a consortium delivering the £36m 'ORCA Hub' project ('Offshore Robotics for Certification of Assets') which will develop robotics and AI technologies for use in extreme and unpredictable environments. Examples of use include for the inspection, repair, maintenance and certification of offshore energy platforms and assets.

Managing energy in an era of climate change and adverse weather

Using **Artificial Intelligence** and predictive analytics, combined with advanced sensors, **IoT, Big Data and Cloud Computing**, allows for analysis of historical data to predict upcoming events. For instance, in energy infrastructure, transmission lines can be designed within the limits of their capability in relation to historical air temperatures analysis. In the construction sector, bridges can be designed to withstand the requisite amount of flow rates. Another example is tunnels and bridges equipped with storm-water systems in cities with significant storm risks.

Smart Grids will become increasingly important since energy infrastructure based on **Distributed Generation and Renewable Energy**, such as photovoltaics and wind energy, is highly dependant on the climate and weather conditions. The smart grid concept (an advanced, digital infrastructure with two-way capabilities for communicating information, controlling equipment and distributing energy) can make energy systems and infrastructure more reliable and stable. The Scottish Government is planning to deploy smart energy infrastructure projects, including smart grids, in remote areas. For instance, the Low Carbon Infrastructure Transition Programme's Fair Isle project includes storage of clean energy sources to provide round-the-clock energy solutions to residents. Moving forwards, using renewable energy and developing a low carbon economy will also support mitigation of climate change by lowering GHG emissions.

Energy

Implications for energy infrastructure investment

- With the increased integration of renewable energy into the grid system, there is an increased use of inter-connectors and changes to the design of the grid system.
- The move towards a smart grid opens the system up to cyber security risks. As energy systems become more interconnected, the need for investment in enhanced physical and cyber security will grow.
- Interoperability and common standards are key to Smart Grids. Making sure that energy systems are truly interoperable is a basic building block of smart energy solutions. A focus on open systems (open to all or many vendor solutions) as opposed to closed systems (only open to one or a few vendor solutions) is important.
- Since renewable energy sources fluctuate, co-operation and management of a wide range of power generating assets is required.
- New residential developments could incorporate distributed energy storage and system capabilities; and include the provision of electric vehicle charging infrastructure.
- All new buildings (residential, commercial, industrial) could be designed as Zero Energy Buildings, where energy generation and storage capacity are an integral part of the overall smart energy solution to achieve carbon reduction.
- There will be a need for the right skills investments for energy management systems (including in AI, data analytics and technology capability). There will be demand for Hydrogen pipe system maintenance, as well as Fuel Cell technology management skills.

Energy

Key 5-year perspectives

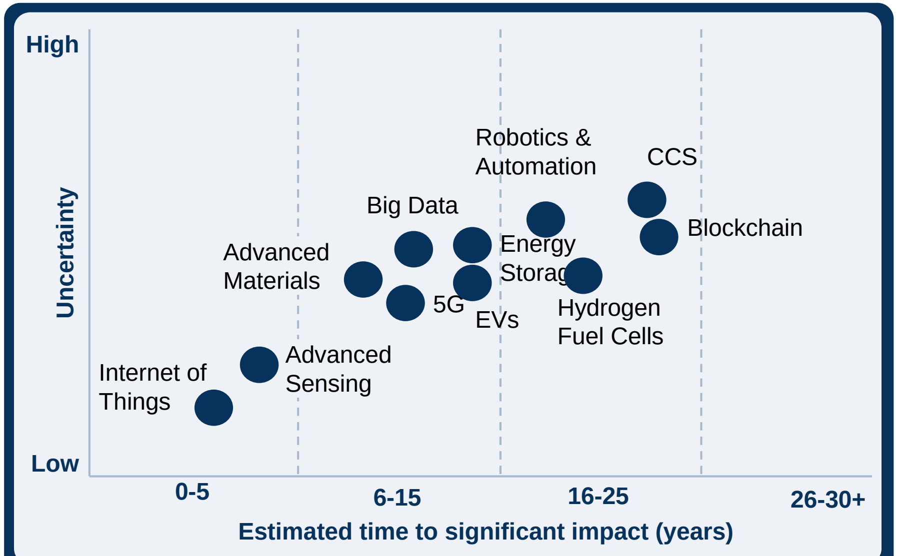
- The Internet of Things (IoT) together with smart sensors are already being incorporated by utilities, for example Scottish energy supplier SSEN implements these technologies for remote control and outage prevention on the Isle of Skye.
- 4G enables connectivity, but the 5G network will be a key enabler for fast and reliable data exchange and remote decisions. Satellite communication will be used to fill in any gaps in connectivity.
- Skills in big data, cyber security and communications are required.
- Self-healing materials can be applied to prevent pipe and cable damage.

Implications for inclusive growth and the transition to a low carbon economy

- Deploying renewable energy will help to meet carbon emissions reduction targets, meet energy demands and help to keep consumer costs low - playing a role in reducing levels of fuel poverty.
- Renewable and distributed energy adoption will generate prosumer-based business models. This could enable lower cost/no cost energy generation for residential and commercial consumers.
- Rural communities could create an energy surplus, due to land/sea access for renewable energy generation, which could generate new revenue streams, using blockchain technology for secure transactions.
- Use of renewable energy for charging electric vehicles supports sustainable, low carbon transport.

Key 30-year perspectives

- Significant changes will be seen in the implementation of distributed energy concepts. For example, more locally produced energy from renewable sources, both onshore and offshore, will be seen; energy storage solutions will be increasingly widespread; and hydrogen fuel cells will be implemented as an alternative energy storage.
- Robots and automation technologies, combined with AI, can be incorporated for predictive maintenance and repair applications, for example in pipe maintenance.
- Blockchain could experience mainstream adoption across Europe for continental peer-to-peer energy trading by 2050.
- Efficient renewable energy storage technologies will be deployed.
- Carbon Capture and Storage are currently at a very early pilot stage of activity. Larger-scale commercial deployment will take place over the thirty year period.



Transport

New technologies can have an impact on mobility and transport systems within and between cities, and between rural areas and cities. Better connectivity and more efficient solutions can bring positive environmental, social and economic impacts.

Intelligent Transport Systems can drive better connectivity and realise economic impacts

Intelligent Transport System (ITS) refers to a set of technologies and communications used to improve efficiency and safety for transport users. It includes monitoring equipment such as CCTV and traffic detection sensors; speed control and queue management via gantry signals; and informing travellers using Variable Message Signs (VMS), web services, smartphone apps, news feeds, social media and radio broadcasts. It also encompasses the growing field of connected and **autonomous vehicles** which are expected to have significant benefits for road safety and in transforming how real-time traffic monitoring and analysis can be carried out. ITS contributes to enhanced transport resilience, smoother journeys, quicker reaction to incidents and environmental and economic improvements via more efficient management.

5G technology will enable the digital transformation of Scotland's transport infrastructure. Its ultra low latency network capability (allowing faster, more reliable connectivity and the ability to handle greater amounts of data) will allow for driverless cars, monitoring and potentially reducing taffic congestion, platooning (grouping autonomous vehicles as a method of increasing road capacity) and other applications enabling improved connectivity via roads and public transport. The Wireless Infrastructure Group (WIG) in Scotland is already working with 5G network operators and public bodies to enable superfast connectivity for various uses, including transport. **Advanced Sensing** will also have a significant impact on transport infrastructure and commuter safety. For example, the £10m Smart Cities Scotland programme is expected to encompass projects such as intelligent street lighting to reduce CO_2 emissions and enhance transport management, analysing data collected using sensors to reduce congestion

Blockchain technology can enable automatic and real-time payments in Mobility-as-a-Service concepts, for instance in public transport or parking fees.

The Traffic Scotland Information Service (TSIS) already provides real-time and planned, future information about the Scottish road network including monitoring, controlling and informing users about Scotland's trunk roads by levering CCTV cameras, bluetooth detectors, and weigh in motion sites.

Edinburgh-based enterprise Wallet.Services, with support from the Scottish Government, is working on a blockchain platform for public transactions, which could be used for transport infrastucture applications.

Transport

Electrification of transport to drive low carbon emissions

Electric Vehicles (EV) can have an important impact on the transport infrastructure as part of a wider decarbonisation agenda. The Scottish Government is already carrying out strategies, with the ambition to facilitate the use of electric vehicles and phase out the need for petrol and diesel cars and vans by 2032. This includes the installation of publicly available EV charge points on the ChargePlace Scotland network and developing an 'Electric A9', the country's longest road, with EV charge points installed along the route. The Scottish Government's most recent assessment of EV uptake in cars and light vans forecasts considerable acceleration of EV sales from around 2022-23, reaching 100% of new vehicle sales by 2032.

Drones and 'last mile delivery'

Drones are unmanned aircraft controlled by a ground-based remote pilot, with a communications system linking the two. This is collectively referred to as an unmanned aircraft system (UAS). A drone is also sometimes referred to as a remotely piloted aircraft system (RPAS). However, as technology progresses, drones are becoming increasingly automated, and may one day become fully autonomous without the need for a remote pilot. Global retail and delivery providers such as Amazon and DHL are already investing substantial sums of money into researching and developing solutions using drones for the delivery of goods to purchasers. Regulatory developments will drive progress in this area. This could change how we understand courier deliveries and emergency medical supplies delivery. Over the longer term, autonomous passenger drones could also be used to transport people between UK cities. Trials of autonomous electric drones have already taken place in Dubai, China and the US.

NHS Highland is working with Highlands and Islands Enterprise and the University of the Highlands and Islands on a project looking at the potential of using drones to deliver medical supplies to GP surgeries, hospitals and care homes in the Highlands.

Hydrogen

Recent developments in the UK and elsewhere also point to the use of **hydrogen** as an alternative low carbon fuel source. For example Alstom recently announced the introduction of the first hydrogen passenger train in Germany. The emergence of Hybrid Fuel Cells could have a significant impact on Scotland's decarbonisation plans. Transport Scotland are appraising hydrogen and other self-powered low-carbon alternatives to diesel for some of Scotland's non-electrified railway routes. In 2013, Scottish Ministers contributed £3.3m funding to a project in Aberdeen deploying a fleet of 10 hydrogen buses with on-site green hydrogen production and a storage system. Aberdeen now also has a second hydrogen station (with a third planned) serving a fleet of vehicles used by the council, NHS and SEPA. Hydrogen fuel cells are also being explored for marine applications. For example, Innovate UK recently provided funding to design a hydrogen-diesel dual fuel injection system on a ferry that travels between Kirkwall and Shapinsay island.

Transport

Search and rescue will be transformed by drones and autonomous technologies

Emergency services are increasingly turning to drone technology to help them with their tasks. Remotely piloted aircraft systems (RPAS) are now being used operationally by Police Scotland in Aberdeen and Inverness, following a successful pilot, with a particular use in missing persons cases. The deployments allows for faster searches of large areas. British start-up, Unmanned Life, has developed software to send out multiple autonomous **drones** at the same time to gather information during a crisis, such as when a building is on fire. One drone hovers in the air providing 4G coverage, while another flies around the building providing live video. A third, equipped with heat sensors, creates a heat map of the building, while a fourth uses sonar to map structural damage. The Lochaber Mountain Rescue Team has deployed drones in searches of peaks in its area, one of an increasing number using the technology to support rescue activities. There is also a developing concept of implementing drones into ambulance fleets. This would mean that medical kit could be flown directly to accident locations, which can be a substantial advantage in congested cities.

Improving transport safety

Intelligent Transport Systems (ITS) can potentially have significant benefits for road safety. This is because transport systems will be more efficiently monitored and managed, enabling quicker responses to accidents. With the emergence of autonomous vehicles, there is also a view that road accidents caused by human error can be substantially reduced. The whole system will be underpinned by **Advanced Sensors, Internet of Things (IoT)** and advanced video technologies.

Smarter, stronger and greener materials

Advanced Materials could have a major impact in achieving the goals of zero carbon emissions and increasing energy efficiency in transport. Self-healing concrete could impact on road maintenance, for example, by reducing road damage, while materials like graphene could support completely new structures. Lightweighting transport is another application, where the focus is on reducing weight by using advanced composite and other advanced materials in the body and components of a vehicle without losing strength or durability. This in turn reduces energy consumption and damage to roads. The Lightweight Manufacturing Centre at Strathclyde University is focused on ‘off highway’ transport solutions for vehicles like tractors, four-wheel drive solutions and specialist machinery.

Implications for transport infrastructure investment

- The delivery of Intelligent Transport Systems (ITS) could make transport infrastructure more efficient. It implies that, rather than a focus on new infrastructure (e.g. expanding highways or building new rail capacity), making existing infrastructure more intelligent will be a key focus for passenger and freight transport investments in the future.
- ITS also enables greater co-ordination between transport modes, enabling more seamless mobility solutions. This includes enabling transport modes to communicate with each other and the wider environment, as well as smarter ticketing solutions. ITS can therefore encourage public transport use through better information and reliability, and can also encourage uptake of more active modes of travel. This could shift some investment towards public transport as well as better walking and cycling infrastructure.
- To achieve the required penetration rates of Electric Vehicles, suitable charging infrastructure will be a key enabler of market development. All new and existing public buildings, and all new commercial and residential buildings, could incorporate charging infrastructure points.
- One of the major implications of connected and autonomous vehicles is that the data they gather can be used for other purposes. For example, connected cars could generate and share data on pothole locations or local weather conditions. Transport authorities will therefore need to become much better at collecting and analysing data and at communication system management.
- Autonomous vehicles can also ‘platoon’ (drive more closely together at the same speed, like a train) which generates some energy efficiency gains but, more critically, also helps reduce congestion. That means that less new infrastructure may be required and roads could be made narrower, allowing more space for bike lanes or green infrastructure.
- There are potential consequences for road signage and markings for autonomous vehicles. For example, new signage may need to be introduced to support autonomous vehicles to better navigate the environment, particularly in urban areas. In initial roll-outs of controlled, low-speed autonomous driving in urban environments, it may also be necessary to have defined kerbs or barriers to separate the cars from pedestrians and cyclists.
- At a regional or city level, ‘last mile’ drone deliveries will require a clear understanding of the availability of airways and where drone delivery centres or hubs should be optimally placed. Public buildings and infrastructure may need to design in drone ports for take-off and arrival. There will also need to be skills development on how to operate drones safely for medical, fire or rescue purposes.
- In the longer term, cities may need to build skyports for passenger drones. Some cities (e.g. Dubai) and companies (e.g. Uber) are already shifting their attention to the design of skyports to accommodate vertical take-off and landing capabilities.
- Hydrogen fuel-filling station locations may need to be planned to provide maximum coverage, particularly in rural areas.

Transport

Key 5-year perspectives

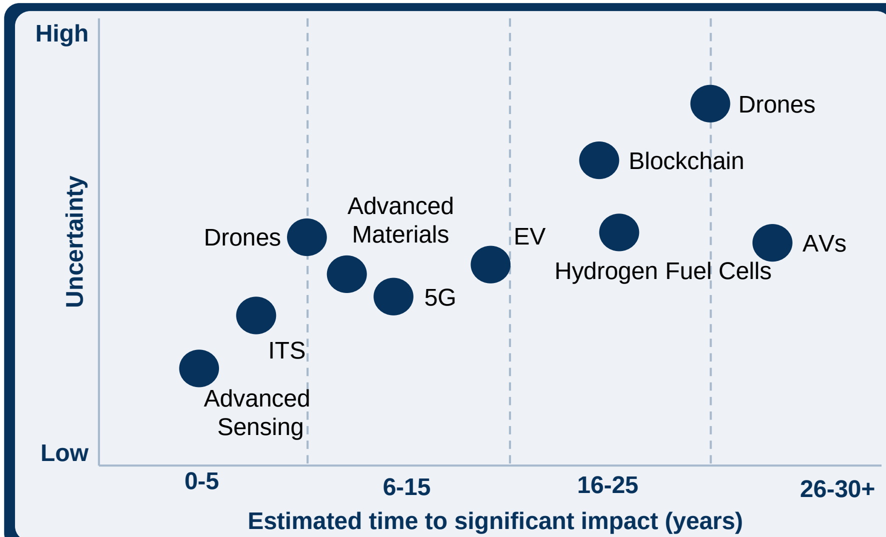
- Components of Intelligent Transport Systems (ITS) such as advanced sensing, intelligent street lighting, intelligent controls, travel planning tools and mobility-as-a-service, will see further adoption.
- A 5G network will be a key enabler for fast and reliable data exchange, impacting on the evolution of ITS.
- Drones will be used to deliver first aid kits or, equipped with 3D cameras, used in missing people searches, in accidents and in mountain rescues.

Key 30-year perspectives

- Higher adoption of EVs will generate an increased need for electricity, especially from renewable sources.
- Blockchain is being strongly investigated in Scotland for many applications. It can potentially be used for reliable automatic and authentication transactions for public transport fees, driving license applications, proof of registration or vehicle insurance, and potentially for low emission zone management.
- Drones could be adopted in Scotland for cargo transportation or for short-distance ('last mile') delivery in city centres and low emission zones to decrease road congestion. By 2035, autonomous passenger drones could be in service in some areas.
- Autonomous Vehicle (AVs) could see commercial deployment, particularly in logistics.
- Hybridized Hydrogen fuel and Electric vehicles (EVs) could be used where they provide range extension capabilities compared to pure EVs.

Implications for inclusive growth and the transition to a low carbon economy

- Progressive adoption of EVs in Scotland can lead to a substantial reduction of greenhouse gases helping to meet emissions targets.
- The target for no new diesel or petrol cars by 2032 should generate a significant number of business and job opportunities in the area of engineering. Skills development related to EV infrastructure and car maintenance will also be required.
- ITS and smart connections will support fast and reliable transport across Scotland. This can potentially impact on commuting to work, thus supporting social inclusion (though other factors such as public transport pricing are also important). ITS can also enhance tourism, thus supporting sustainable economic development in rural communities.



Digital Connectivity and Communications

It is vital to provide excellent telecommunication and digital infrastructure to support economic growth and inclusion objectives.

The rise of the as-a-service data economy

Cloud Computing (on-demand availability of computer system resources, without direct active management by the user) is an important technology that leverages **Big Data** and Advanced Analytics to provide access to data and analysis from anywhere. This Data-as-a-Service (DaaS) model allows organisations to access real-time data streams and removes the constraints of internal data sources. Implementation of cloud computing is part of the Scottish Government's strategy for the delivery of ICT services in the public sector in Scotland.

IoT and **Advanced Sensing** technologies are essential enablers for digital operations. They allow for data collection and exchange across connected smart devices. **Photonics** provides the underpinning technology for fast and efficient capturing, storing and transferring of data capabilities in communications infrastructure, and is therefore a crucial enabler of the efficient adoption of digital technologies such as **Big Data**, **cyber security**, **artificial intelligence**, **IoT** and **cloud computing**. Photonics is a key innovation sector in Scotland. **Quantum** technologies, enabled by photonics, will enable more accurate measurements and quicker communications.

In 2018 the Scottish Government announced an advanced Internet of Things (IoT) network as part of a £6m project to invest in new wireless sensor networks. This will enable organisations to monitor the efficiency and productivity of their assets and equipment and scheduled maintenance, thus improving production.

Digital Connectivity and Communications

The demand for improved and secure data and communications connectivity

The delivery of **5G** networks will be commercially driven, but public sector support for the development of 5G use and testing of networks is already underway, including the Dundee Waterfront Wi-Fi/5G project and the UK Government-funded 5G trials in rural Scotland (Orkney), led by Cisco and the University of Strathclyde. 5G will have a major impact on a variety of aspects of people's daily lives, as it radically changes the speed of data transmission and reduces the 'latency' (time between data being sent and received), enabling data rich connectivity to take place seamlessly. Everything from connected and smart home applications, including telehealth and smart energy, connected and autonomous cars and intelligent transport systems, are all enabled by radically improving the speed of connectivity.

As individuals and governments begin to rely more and more on smart and connected systems, Cyber Security also becomes critical to safety, privacy and wellbeing. A total of £3.5m has been allocated for the year 2018-2019 by the Scottish and UK Governments to help support implementation of the Scottish Government's cyber security action plans, aiming to ensure that citizens are equipped with the skills needed to operate safely online, and that the country is training the cyber security specialists needed to support industry and government. Blockchain technology allows for credible and transparent transactions and has been identified by Scottish Government as a tool that can address key issues in digital public services to make them safer. Wallet.Services is collaborating with the Scottish Government to establish a blockchain strategy.

Satellite communications

Satellite Technology is becoming an important element in the 5G ecosystem, complementing and building on fixed, wireless terrestrial communication infrastructure. Due to their difference in capabilities, satellites will not compete directly with terrestrial technologies, such as cellular and fibre optics, but will, instead, likely be used as a complementary technology to fill communication gaps. This technology can be leveraged by the Scottish Government in its plan to provide internet access across the whole of Scotland, especially in remote or difficult-to-reach locations.

Scotland now has its own regional downstream applications centre, the Scottish Centre of Excellence in Satellite Applications, supported by the Satellite Applications Catapult in Harwell. Glasgow is a centre for building satellites due to the city's existing expertise in space technology. There are plans for Scotland to become a hub for commercial satellite launches which could see spaceports open in northern Scotland from the early 2020s.

Digital Connectivity and Communications

Implications for digital infrastructure investment

- Cloud Computing is an important component of the physical infrastructure for smart cities (including smart water systems, smart energy and utility grids, intelligent transport systems) which relies on sensor networks, as it enables greater sharing of resources and assets to help manage a complex system. Enabling cloud computing for smart cities includes investment in sensors, low-cost communication, real-time analysis and control and the horizontal integration of pre-existing services.
- Wireless (or wired) sensors and IoT networks form part of the smart city infrastructure e.g. sensors on street lights that enable environmental and traffic monitoring. As a result, the skills and capability to harvest, analyse and make actionable insights from generated data will become increasingly important. These skill sets within government agencies will have to be supported. The data can have value for consumers and intermediary companies, which means that the public sector may need to become more consumer centric, and/or better at identifying opportunities for joint partnering with private sector providers. Being aware of data privacy and ownership issues will also be ongoing.
- With the growth in interconnected systems and networks for transport, energy and healthcare, critical national infrastructure is increasingly a potential target for cyber attacks. The challenges around cybersecurity will need to shift from being perceived as IT issues to national or business risk issues. This will potentially require a shift in resource allocations and skill sets. Any emergency & resilience infrastructure will need to have a high degree of co-ordination and data sharing capability.
- The rise of smart cities will result in significantly more data being created. This means a need for significantly more capacity to transmit that data reliably and consistently. This may require investment in data centre capacity and better data management strategies. Service providers will provide seamless connectivity between terrestrial 5G and satellite communications. Technical standards should be designed for both terrestrial and satellite systems.
- For satellite based applications, investments are already proposed for Spaceports (e.g. Sutherland in Scotland). An operational spaceport would provide the UK with a key piece of infrastructure for the aerospace industry.

Digital Connectivity and Communications

Key 5-year perspectives

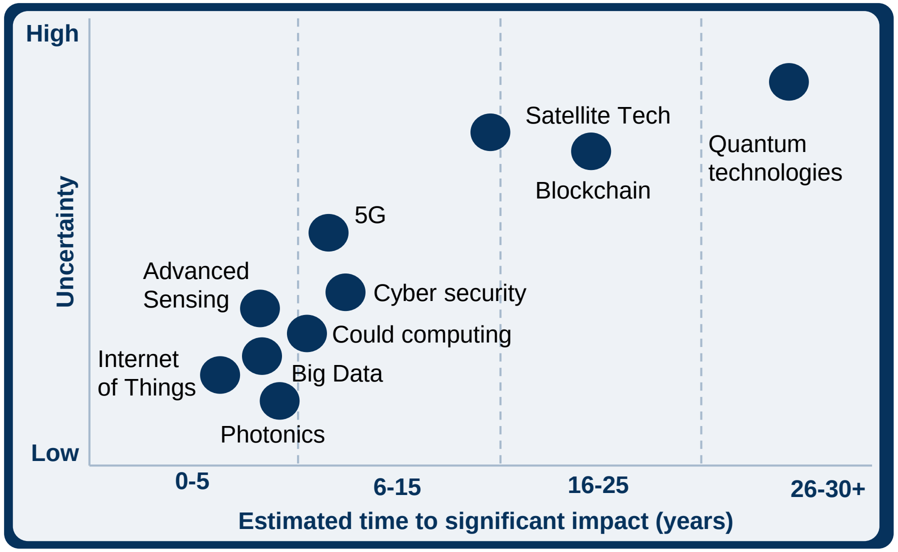
- A 5G network will be a key enabler for fast and reliable data exchange to boost the potential of IoT and Big Data Analytics.
- IoT, smart sensors and photonics are already being implemented in Scotland and 5G can support the development of these technologies across other applications, such as wireless vehicle communications, by offering fast and reliable data exchange.
- Due to potential threats from cyber attacks, with the progressive adoption of digital technologies, we expect to see high implications for cyber security development, which is essential to ensure safety across public and private sectors.

Implications for inclusive growth and the transition to a low carbon economy

- High-speed data transfer, including streaming of live events through 5G can make a significant contribution to employment opportunities and education and skills delivery.
- The development of digital technologies in Scotland is reflected in an increasing number of technology-related job positions, which are higher in average salary than the overall average for Scotland.
- The Digital Participation Charter of the Scottish Council for Voluntary Organisations aims for more organisations to train their staff in basic digital skills to support inclusion by building more digital capability.
- Digital infrastructure can enable remote working, but there are downsides with new forms of employment putting pressure on wages and mobile technology making it difficult for workers to "switch off“.

Key 30-year perspectives

- Quantum technologies are currently in very early stage research. Commercialisation of these technologies could contribute to unprecedented speed in data access and exchange, advancing ultra-fast sensing and communication technologies.
- Blockchain could be adopted for cash-free, reliable and transparent transactions in the public sector. It also holds strong potential for adoption in businesses (in procurement and value-chain tracking) in Scotland and worldwide.
- Scotland is well positioned as a potential location for space ports for satellite launches.



Environmental Management and Resilience

Using technologies in environmental management and resilience can help in reducing waste and moving to a circular economy, anticipating climate change impacts and improving resource and organisational efficiency.

Water risks mitigation

Using **Advanced Sensing**, in combination with the **Internet of Things (IoT)** and **Big Data** analytics, allows for the identification of river, coastal and surface water flooding across Scotland. This requires implementing smart sensors across Scottish infrastructure, such as bridges, seashores or river banks to measure and analyse the current level of water and correlate this with weather conditions. Advanced sensors can also be applied in drainage systems to allow better understanding of the capabilities of the system and to manage flood risk effectively. As a result of measurements, some areas deemed high risk might need significant infrastructure modification, for instance by installing new pumping capacity or raising roads.

Rivertrack is a website that gives people in flood risk areas a local flood alerting tool. The system uses low-cost sensors to send accurate time sensitive information to individuals about water levels in their local watercourse. In 2018, Scottish Flood Forum and SEPA supported community trials of this innovative tool.

Augmented and Virtual Reality (AR & VR) technologies can also help in mitigating water risks. The use of AR can help visualise a development and implement changes needed. This technology can be used for planning buildings and infrastructure development with relevance to mitigating flooding risk. It could be used, for example, to visualise flood mitigation infrastructure, such as sunken parks, designed to flood and mitigate water runoff, which could lead to reduced flood risk in those areas. An increasing focus in the management of storm water and excess run off is using green infrastructure (fields, meadows, etc.) and existing networks (e.g. canals) to better deal with high water levels. The use of **sensors** and **predictive analytics** is also important in this. The North Glasgow Integrated Water Management System has a project to create a so-called 'sponge city‘, to passively absorb, clean and use rainfall intelligently.

Water Purification Technologies, including water desalination, enable generation of drinking water from seawater and can thus help facilitate Circular Economy principles. Although generally considered a wet country, Scotland can be vulnerable to periods of dry weather (in the summer of 2018, for example) which can result in significant pressure on water supply. Additionally, climate change might impact on areas with no previous water scarcity issues. SEPA has launched The National Water Scarcity Plan to manage water resources during low rainfall periods. Installation of additional water purification and desalination points (based on a highly accessible raw material – seawater) could be an additional protection in the face of such events. Also, advanced predictive technologies can help in enabling simulations of water demand and supply levels across Scotland.

Environmental Management and Resilience

Designing infrastructure resilient to climate change

An increase in the frequency and intensity of extreme weather events due to climate change is likely to impact on infrastructure systems such as transport. The UK is set to get warmer and wetter, and some cities will be impacted by rising sea levels. Along with changes in temperature, this may have important implications for infrastructure design, operation and maintenance, and could increase the risk of disruptions, damage and failure of systems.

In terms of climate change mitigation, more stringent regulations on emissions may drive a preference for investments in greener modes of travel, such as renewable energy charging stations for electric vehicles, or better walking/cycling infrastructure.

In terms of adaptation, investments in the digitisation of climate-resilient infrastructure could lead to more centralised infrastructure design, allowing for smart risk management at a regional or country level.

Incorporation of Advanced Materials, such as advanced concrete, protective (water or sun resistant) nano coatings or self-healing materials affects the durability of infrastructure components, and could be used in creating roads resistant to temperature rise or flooding. For example, Water Energy Scotland has conducted research on the development of new advanced concrete, which is highly water resistant.

Using Artificial Intelligence and predictive analytics, combined with advanced sensors, IoT, Big Data and Cloud Computing, allows for the analysis of historical data to predict upcoming events. For instance, in energy infrastructure, transmission lines can be designed within the limits of their capability in relation to historical air temperatures analysis. In the construction sector, bridges can be designed to withstand the requisite amount of flow rates. Another example is tunnels and bridges equipped with storm-water systems in cities with significant storm risks.

Environmental Management and Resilience

Waste Management

In 2013 the Scottish Government introduced a target to reduce Scotland's waste by 15% by 2025, which is a key plank of the circular economy approach. Many of the innovations in this space are reliant not just on technology developments, but are also driven by and drive new business models and ways of working.

Intelligent Waste Monitoring is a trend in achieving waste reduction targets. Smart and connected bins, equipped with Advanced Sensors to indicate fill levels, can be installed in public infrastructure to facilitate intelligent waste collection scheduling and for waste recycling assessment. The efficiency gains from this technology will be dependent on its interaction with current service profiles.

Scotland aims to recycle 70% of all waste and to send no more than 5% of all waste to landfill by 2025, but contamination is currently a barrier to high quality recycling. Even low levels of contamination can render materials unsuitable for reprocessing, thus losing value. The Scottish Statutory Code of Practice for Materials Recovery Facilities has introduced a sampling procedure to improve the transparency of waste and the quality of materials arriving for sorting. There is an increasing use of optical sorting (sometimes called digital sorting), which automates the process of sorting solid products using cameras and/or lasers. Electronic tracking methods are also being used, through technologies such as radio frequency identification (RFID) and global positioning systems (GPS).

In future, the development and deployment of advanced monitoring, testing and sampling of materials will increasingly use **Advanced Sensors** and the **Internet of Things (IoT),** and could start to benefit from **Automation** and **Robotic** solutions. All of this could be aided by **Artificial Intelligence** and **Big Data** in automating the analysis.

In parallel with the drive to reduce food waste, developments are happening in anaerobic digestion solutions and plants. Where thermal treatment plants are required, the Scottish Government supports high quality combined heat and power schemes.

The Scottish Government participates in DEFRA's project to drive advancements in electronic waste tracking. Five companies working across the UK have recently been awarded up to £80,000 to develop innovative digital solutions to tackle the challenge of tracking waste from its source through its treatment and final disposal.

The projects include research into tracking waste through electronic chips and sensors, the use of blockchain, looking at common reporting platforms and new data analytics.

Environmental Management and Resilience

Continuous Water and Waste Monitoring Systems drives Water Safety

There are three key trends impacting on water and waste infrastructure: a) the drive to a more sustainable and circular economy to reduce resource use and waste; b) improving resilience: protecting and better managing assets as well as supply chains (e.g. for chemicals used in treatment plants); and c) digital transformation: the deployment of advanced IT services and solutions that will drive greater efficiency, safety and resource management.

Technologies including **Advanced Sensors**, the **Internet of Things (IoT), Drones, Robotics** and **Blockchain** will allow for continuous monitoring of water quality (pH, temperature, dissolved particles, chemicals) without the need for human intervention. The infrastructure for this will require implementation of water robots and drones equipped with a set of water sensors for autonomous measurements and an internet connection for data exchange between the drone and an IoT platform.

Advanced Materials, including nanomaterials, polymers, and composites are core components for the development of advanced membranes for water purification systems. Next-generation membranes based on polymer nanocomposites can be implemented at various levels: in homes for final purification or in water treatment plants to provide clean water. Pumping stations may also incorporate advanced materials for water cleaning purposes. Additionally, advanced coatings such as nanocoatings can be applied on connections and pipe structures to prevent corrosion and water pollution.

Advanced Sensing, combined with **IoT,** allows for the monitoring of the entire process of water management from sourcing (water pumping systems), water supply systems to the end user (private or public). Real-time water management, together with **Artificial Intelligence (AI)**, can make automated decisions about whether the water can be consumed or needs purification. It might also enable the selection of specific membranes in the purification system with regards to the contaminations detected. The maintenance of water quality can also be enhanced with AI and Machine Learning (ML) algorithms for environmental prediction and pollution control. These predictive technologies require the implementation of additional hardware devices, such as sensors, as well as computers allowing for data storage and analysis.

Environmental monitoring **Robots** can be used for data capture, remote sensing and mapping areas where pollution is detected, allowing action to be taken to counter negative effects. Robots can also be deployed down water pipes to detect leaks and issues.

Waste management techniques can help in wastewater and water treatment, specifically to treat micro pollutants which could otherwise enter the ocean and harm aquatic biodiversity. Both **nanotechnology** and information technology could provide more sensitive detection systems for air and water quality monitoring too, allowing the simultaneous measurement of multiple parameters to prevent pollution. Although leak detection may have reached its maximum economic benefit, there may still be a value in using **Satellite** observations to support leak detection in more remote locations where other solutions may be uneconomic.

Environmental Management and Resilience

Decentralised solutions for local communities and getting energy from waste

As part of the Hydro Nation Strategy, the Scottish Government via Scottish Water has been researching new technology solutions to support the development and deployment of local, small scale solutions for drinking water and waste water. These solutions will be designed to run in a fully automated fashion using AI and IoT. One of the most interesting developments is how waste treatment facilities are able to generate increased (renewable) energy from their treatment processes, as heat is generated from the sludge generated. As a result, Scottish Water is now facilitating the generation of renewable energy amounting to more than twice the level of energy consumed by the organisation annually.

Driving sustainable use of water, reducing consumer impacts

The Scottish Government has installed Water Top Up Points across public buildings in over 30 cities and towns to encourage people to reduce plastic waste. Integration of sensors to show the quality of water in real-time would be helpful to convince people about the low risk of contamination. Use of connected devices, such as smartphones, tablets and wearable devices can help people know the quality of water in real time, which enables them to take necessary action, for example installing water filters in their homes if they feel it is necessary. The increasing adoption of **smart meters** in water utility companies, which is anticipated across Europe between now and 2030, is part of a drive to support changing consumer behaviour and ultimately demand, to help with resource management.

Design and simulation of water and wastewater infrastructure

Augmented and Virtual Reality (AR&VR) technologies may enable the visualisation and design of water and wastewater infrastructure automatically. Scottish Water has trialled the Dynamic Objects™ system of Atkins for drafting and estimating water and wastewater assets. The digital twin concept - a digital model or replica of a physical asset, product, process or system - would also allow utility bodies to simulate and test potential plans for improvements in water quality before physically implementing them.

Implications for environmental management infrastructure investment

Water:

- Smart technologies for system-wide operation and control could increase the efficiency of water infrastructure. Smart sensors and robots could deliver information about water quality to provide better data, as well as deliver repair techniques which are less disruptive to supply and more cost effective.
- Investments in water management infrastructure (green and conventional) in urban landscapes may significantly reduce the risk of flooding. Moves towards smart, green, sustainable excess rainfall management in urban areas will drive changes in infrastructure planning and design, which could be tested virtually using AR/VR or digital twins, before being deployed physically.
- All new buildings (residential, commercial, industrial) could incorporate water purification systems, including intelligent wastewater systems, enabling a circular economy across production.
- Advanced materials for pipes and connectors in the public water supply system could prevent corrosion, reducing maintenance costs.
- New skills in the water sector could be required. For example, local, automated wastewater treatment centres will require skilled operators for remote monitoring, with experience of technologies such as AI/ML and data analytics.

Waste:

- Waste material monitoring, analysis and sampling will become increasingly automated, using advanced sensing and measurement technologies, as well as data analytics and AI. Investments in these areas and in new skills could be required to support this shift.
- To deliver the Circular Economy, current and planned waste and resource recovery infrastructure would require a number of interventions as there is both a lack of data and of investment. Data will need to be more compatible and there could be a requirement for a new approach to regulation. If successful, Scotland could export the model and the technology for a circular economy globally.
- Regulatory and legislative requirements, such as the Waste Framework Directive, require separate collections for recyclable materials. This will drive investment in collection and storage technology and infrastructure as well as more capacity to process these materials.
- The increasing amount of waste is leading to a growing demand for waste treatment infrastructure, including energy-from-waste (EfW) power plants. Investments in these plants, and in technologies such as anaerobic digestion, can support this growing demand.

Environmental Management and Resilience

Key 5-year perspectives

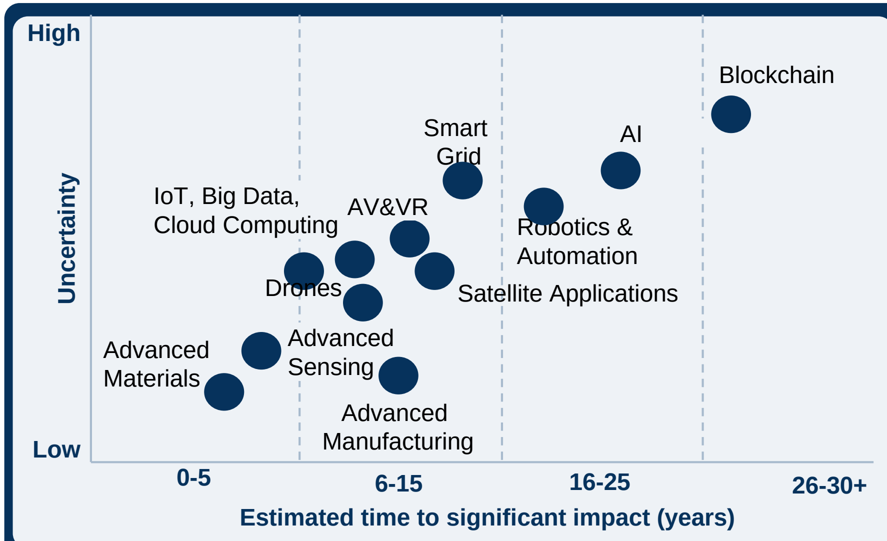
- Advanced materials (self-healing materials or protective nanocoatings), will be used for infrastructure components to withstand extreme weather and corrosion conditions, resulting in lower maintenance costs.
- Advanced sensors plus predictive technologies can be used to predict the nature of risk of weather-dependent events, e.g. water scarcity or flooding, and can be used to provide real-time assessment of contaminations in water.
- The Internet of Things (IoT) together with smart sensors will be incorporated by water supply companies to deliver information about water quality.
- New skills will be required in remanufacture, sustainable resource management, energy efficiency, repair and refurbishment.

Key 30-year perspectives

- On-demand 3D printing, connected with AI, can be used to autonomously deliver and produce the spare parts and elements of infrastructure such as pipes and connectors.
- Robots and automation technologies combined with AI will be used for water purification systems to enable autonomous processes.
- Augmented and Virtual Reality and digital twins can be used by public organisations for the visualisation and design of new water and wastewater infrastructure which will consider how to better support flood prevention in land use from a design perspective.

Implications for inclusive growth and the transition to a low carbon economy

- Predictive technologies allow for flood event detection at an early stage, better enabling its prevention, thus keeping people safe and preventing significant economic losses. These technologies might also support Scotland in preparing for water scarcity in low rain areas.
- New skills required in areas such as repair and refurbishment, if supported, can support economic restructuring.
- Circular economy principles and utilization of wastewater can contribute to fighting global water scarcity issues and reduce emissions.
- Implementation of continuous water purification and monitoring systems can help prevent tap water contamination.



Housing

Transformations in building materials and construction techniques could lead to improvements in controlling and reducing environmental impact and construction costs

Building of homes supported by advanced manufacturing and automation solutions

Advanced Manufacturing, including additive manufacturing techniques, can change how houses are built. Mobile 3D construction printers, capable of printing whole buildings completely on site, are being used to build houses more quickly and cheaply. Advanced manufacturing techniques will also enable more modular and off-site building processes that may improve productivity and decrease costs. More prefabricated and standardised components will also further enable robotic construction. As a highly labour-intensive industry, construction could benefit from robotic deployments, although uptake will be driven by wider economic drivers - labour availability being a key one. Combined with artificial intelligence and **3D printing,** robots could improve the speed of construction work. In the longer-term, swarm robots could be used to build entire houses, piece by piece. Drones and autonomous vehicles will have implications in the nearer term for security, surveillance and inspection, as well as for deliveries. Increased automation could also mitigate any potential skills shortages. The Construction Scotland Innovation Centre is enabling opportunities for collaboration and experimentation for automation and other technology solutions relevant to construction.

Advanced Materials such as encapsulated ceramics, self-healing cement, super-hydrophobic coatings, anti-corrosion paints and interlocking blocks of recycled materials can all potentially support improvements in material longevity and a reduction in maintenance costs.

Virtual and Augmented Reality solutions (VR & AR) can help investors, buyers and councils visualise a property and recommend changes to the plans. Virtual reality (VR) immerses users in a fully artificial digital environment whereas augmented reality (AR) overlays virtual objects on the real-world environment. Building information modelling (BIM), a process using various tools and technologies to generate and manage digital representations of physical and functional characteristics of places, is also increasingly being used as an advanced standard of operation in the construction industry, to drive up standards and productivity.

A consortium including the University of Strathclyde’s Advanced Forming Research Centre has secured £1m of funding from Innovate UK to develop the use of virtual and augmented reality in the construction industry. This will create an Augmented Worker System, to help companies with intelligent design, construction, maintenance and the whole-life value of buildings.

Housing

Making homes smart, connected and energy efficient

The **Internet of Things** and **Advanced Sensing** technologies are enabling the development of the connected or smart home concept. The **Internet of Things** (IoT) connects multiple smart devices and objects to a single network over the Internet. It allows data exchange in a secure manner, providing opportunities for developing energy efficiency solutions, or enabling telehealth and care solutions, for example. The Scottish Government is piloting innovative intergenerational and co-housing housing solutions for older people, which could also drive technology solutions.

Renewable Energy technology advances will also enable improved energy management in homes and buildings. Low carbon heating, electrification of heat with heat pumps and renewable energy through **Distributed Generation** will provide the opportunity to attain net zero energy buildings. **Energy Storage** will also be increasingly important, particularly with Electric Vehicle adoption.

CleverCogs, a digital care and support system developed by Just Economics, Blackwood Housing and the Scottish Government, provides specialised care services in homes for people with disabilities. It provides simplified access to various assets such as internet connection or video cameras, enabling increased use of Technology Enabled Care in service delivery and access to online health information and social media. The aim is to increase digital participation amongst people currently excluded.

Implications for housing infrastructure investment

- Investments in advanced manufacturing techniques and off-site prefabrication technologies could enable time savings in construction, reduce material waste and make construction sites less demanding in terms of transport needs (by reducing the number of delivery trips). This will also impact on planning processes around vehicle access to building sites.
- New technologies could allow a greater focus on driving the circular economy in the construction industry, as housing could be designed for disassembly and components could be more easily re-used, re-manufactured or re-cycled. This would require planning for new centres for handling, storing and re-purposing materials retrieved from deconstructed houses.
- Deploying more automated and robotic solutions is likely to have an impact on skills and jobs in the construction industry, potentially changing the type of work people will undertake and requiring reskilling or upskilling of the workforce.
- Using advanced materials such as hydrophobic coatings or self-healing concrete will result in improved material and infrastructure longevity, reducing the investment required for maintenance. Advanced materials (such as graphene) could also enable new types of structures to be built that are stronger, lighter and greener which could have positive environmental impacts. Maintenance planning protocols would need to be reviewed.
- Augmented and Virtual Reality solutions could have a positive impact on cost reduction both for new-build social housing and public buildings, as well as for their maintenance. This is enabled by enhanced productivity per worker and by making maintenance functions more efficient.
- Smart Homes can enable greater energy efficiency by using intelligent systems to better manage energy usage based on occupation and activity. Deployment of smart solutions in social housing and public buildings could enable substantial savings, as well as provide remote health and care solutions for the elderly.
- The move towards renewable energy and energy self-sufficiency could see more investment in passive heating and cooling design, natural ventilation and local energy generation in homes. Homes could also include charging stations for electric vehicles as a default setting in new-build environments.

Housing

Key 5-year perspectives

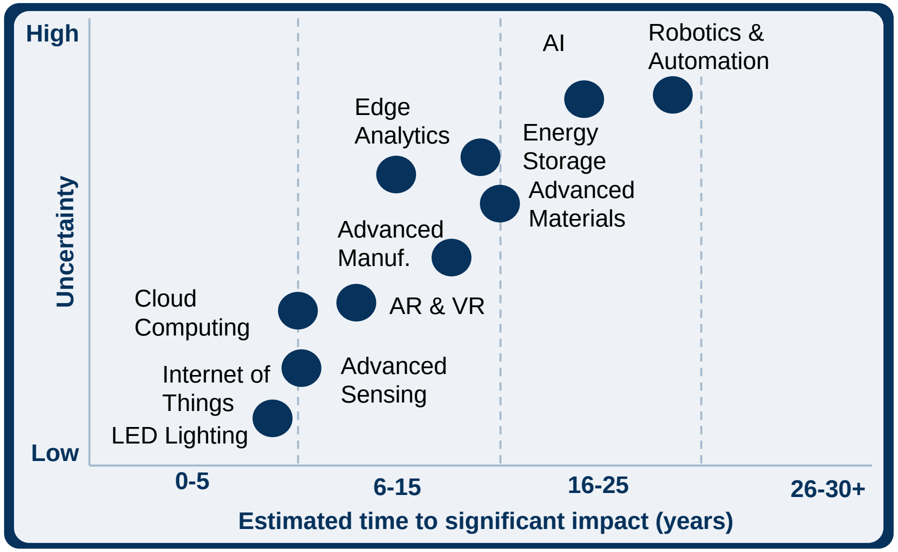
- Given limited adoption of automation in the construction industry so far, we expect robots to have a small impact on construction in the short term. However, there are already instances of use for 3D printers, drones and unmanned machinery on building sites. Automation could increase if skills shortages worsen.
- The Internet of Things (IoT) will have implications for controlling our homes and organising our lives (e.g. Nest and Amazon Alexa), which could improve the resource efficiency and security of homes
- Smart homes will begin to deliver benefits such as energy efficiency and proactive healthcare management in the 5-year time frame, but these impacts will be greater over a 10-15 year timeframe.

Implications for inclusive growth and the transition to a low carbon economy

- Bio-based materials, with enhanced performance, could enable more sustainable buildings
- Better connectivity could meet the increasing requirement for remote working. House design could accommodate 'remote working' function rooms and housing developments could be in more varied locations.
- Smart homes will help reduce carbon emissions.
- Advanced building techniques could create more affordable housing solutions. Areas such as social housing could conceivably benefit from better supply capability.
- Smart, connected homes can enable more independent living for disabled and elderly residents.

Key 30-year perspectives

- With advances in AI and robotics, construction techniques could be significantly automated by 2050.
- Advanced manufacturing techniques and 3D printing will be mainstream in this timeframe. New materials that are lighter, smarter, stronger and greener will be available by 2030 and they could support completely new structures.
- Advanced materials, such as self-healing materials, could lead to lower maintenance requirements and decrease the need for repairs on construction components, such as concrete.
- With increased automation and the use of prefabricated building components, house construction costs could be more effectively managed, enabling quicker supply (although this depends on other factors too).



Public Infrastructure and Public Services

Advancement in technologies such as IoT , Advanced Sensing and AI is leading to increasing digitization of operations across public organizations, improving the operational efficiency of organisations and the energy efficiency of buildings.

The rise of smart buildings drives resource and energy efficiency

Smart buildings make use of intelligence, control and the built environment, both internal and external, to deliver energy efficiency, sustainability and occupant comfort, as some of the key objectives. Smart buildings have high adaptability to changes in the environment and to the occupants' needs. This concept may be translated into public infrastructure in order to deliver improved energy efficiency to public buildings that are significant users of energy, for example hospitals with high energy use due to medical equipment. Research conducted by Centrica, one of the largest suppliers of electricity in the UK, suggests that adoption of **Grid Parity Renewables & Storagee (GP&RS) technologies**, as part of **Distributed Generation (DG)** technologies such as **solar,** combined with **battery storage systems,** could bring about reductions in carbon emissions.

Developments such as flexible solar, solar tiles, building integrated PV (BIPV), transparent and bifacial solar have the potential to influence building design and construction considerably. For example, in order to reach net zero energy buildings, BIPV can be used more widely. The Scottish Institute for Solar Energy Research (SISER) at Heriot-Watt University is focused on researching technologies suited to Building Integrated or Building Applied Photovoltaic generation systems. Other technologies include **hydrogen fuell cells**, which can also be used as an alternative energy storage solution, and the deployment of **district heating solutions** in which a network of buildings in a development are served by a single energy source, such as a Combined Heat and Power (CHP) unit. The network functions at a lower temperature than standard systems which reduces heat wastage and minimises heat loss, ensuring long-term energy savings for building occupants.

Advanced Materials can also impact on the thermal or acoustic insulation across public buildings, hence delivering buildings with better soundproofing capabilities and thermal stability, and thus with reduced need for heating, ventilation and air conditioning (HVAC) systems. Additionally, advanced materials such as **Quantum** dots (**nanomaterial**-based probes used for optical sensing/biosensing) are being developed for smart sensors that efficiently detect various stimuli relevant to environmental or biological factors. **Smart sensors,** with the **Internet of Things (IoT),** enables data collection about the infrastructure and its exploitation to enable efficient maintenance using predictive technologies.

Public Infrastructure and Public Services

Data and Security

An increasing number of businesses and organisations are using **Cloud Computing** and ‘as-a-service’ business support tools and processes. This means that workers can increasingly work effectively on a remote basis. One of the critical success factors in business continuity, whether for private or public sector organisations, will be continued access to effective communications systems. The full availability of **5G, broadband** and **satellite communications** options will be critical to avoid substantive impacts on business viability in emergencies. To support this, cyber security has to be very effectively managed and priority accorded to it to support the requirement for secure communications.

There will therefore be a need to improve security polices and approaches, covering identity management, radio network security, flexible and scalable security architecture and cloud security for the 5G network. Security companies and governments are focused on **Big Data** analytics tools that have the capability to integrate and process data in real time for actionable security insights.

The digitization efforts of governments are likely to be heavily impacted by **Artificial Intelligence (AI)** adoption. However, proliferation of digitization will also put a lot of citizen data at the disposal of public authorities, so efficient mechanisms for the management and maintenance of this data will have to be put in place to safeguard it. Data and insight can be used in various ways, such as predicting where repair or new infrastructure will be needed, or to understand the requirements for parking in public buildings.

Public organisations in Scotland could benefit from the use of **Blockchain** in data security and credential applications, for example in prescription management or diploma certification in schools. Such digital operations could decrease the administrative costs by over 90%. Increasing safety with blockchain is also expected to protect digital infrastructure from cyber attacks (such as the massive hacker attack in 2017 on England’s and Scotland’s hospitals). Implementation of blockchain in public and private organisations also enables asset management across organisations and the credibility of transactions in procurement. As these digital technologies begin to emerge for public infrastructure and individuals and governments rely more and more on smart and connected systems, **cyber security** becomes critical to safety, privacy and wellbeing.

The gathering and processing of large amounts of data could have a significant impact on service delivery and e-governance, by enabling new service models and collaboration with a reduction in cost. The Scottish and UK governments have adopted a cloud-first approach to support and encourage the use of cloud computing infrastructure (hosting services) in public services. This may mean less investment in on-site data storage facilities and more in cyber security. It also may result in a small reduction in fixed operating costs but an increase in flexible operating costs.

Public Infrastructure and Public Services

Digital health enables remote patient monitoring and telehealth benefits

The rise in the number of smart watches, smartphones, **wearables** and other sensor-based devices in an **IoT** environment is enabling the utilisation of various **connected** living services. These devices are becoming the ‘remote controls’ of our lives, acting as hubs for sensor-based health monitoring products and fitness apps, as well as controlling our homes and assisting with work tasks. Scotland’s Digital Health and Care Strategy describes how technology could reshape and improve services, support person-centred care and improve outcomes. The initiative aims to help citizens to better manage their health and wellbeing and gain access to services using digital technologies.

From early 2019, a shared care healthcare project by NHS boards across the North of Scotland will be set up to share information across primary, secondary and social care systems via an online platform developed by Orion Health. The project will allow healthcare providers across Northern Scotland to view data on patients throughout the region and would be able to provide better care to people living in remote areas. Such technology might bring significant health impacts among patients in areas where the infrastructure is limited.

Connected living is enabled by fast and reliable communication technology, potentially **5G.** The development of **advanced materials, photonics** and **advanced sensing technologies** will also enable sophisticated monitoring of various vital parameters, as well as remote detection of viruses.

Virtual planning of public infrastructure

Augmented and Virtual Reality (AR & VR) technologies can help in planning property for public infrastucture. The use of AR can help designers and investors visualize a property and implement changes to the plan as per their need. Digital Twins technology can also help in simulation and planning of buildings and public infrastructure.

Public Infrastructure and Public Services

Implications for public infrastructure investment

- To further the goals of energy efficiency, and with the right investments, all new public buildings could be designed to meet net-zero buildings standards. According to a WWF Scotland study, Scotland could progress to be net-zero by 2040. Further development of Distributed Energy and Grid Parity Renewables & Storage technologies could lead to more low carbon energy impacts across public buildings.
- To enable the circular economy, investments in skills for recycling and disassembly technologies will be required. Combined with Intelligent Waste Monitoring, smart sensors and logistics systems, these technologies could generate new business models and revenue streams.
- Further development and adoption of smart materials in insulation, or with protective or self-healing coatings, is expected to positively affect the maintenance of public buildings, reducing costs.
- The adoption of Electric Vehicles will drive, and be driven by, the installation of charging stations in parking areas of public buildings for visitors and employees. Through ChargePlace Scotland, the electric vehicle charging offer in Scotland could be expanded to meet such requirements.
- Remote learning and healthcare systems that provide service access to students or patients within their homes could enable increased provision of education and healthcare without the requirement for additional public infrastructure. Investment in platforms and systems would be required to enable large-scale adoption.

Public Infrastructure and Public Services

Key 5-year perspectives

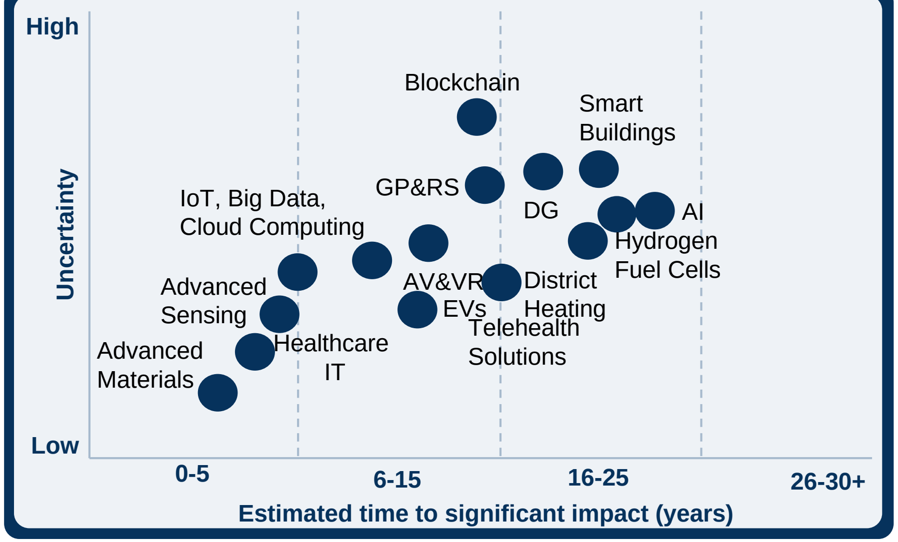
- Public infrastructure already uses smart sensors and IoT to provide data such as air quality, water levels or footfall analysis and to provide additional analytics for social care and health services.
- Advanced materials such as self-healing materials, including smart concrete and advanced coatings such as hydrophonic coatings, can be adopted for reduced maintenance of public buildings.
- Major investments are being made in healthcare IT systems to enable improved operational efficiency of health systems.
- Remote patient monitoring will start to gain traction.
- Distributed generation including photovoltaics will be installed on public buildings in order to reduce carbon impacts.

Implications for inclusive growth and the transition to a low carbon economy

- Renewable and distributed energy adoption will enable generation of clean energy, at the same time significantly reducing the price public organisations pay for energy.
- Digital access to data from anywhere reduces the need for travel, thus lowering greenhouse gas (GHG) emissions and reducing operational costs.
- Telemedicine can help people from rural areas gain improved access to healthcare, potentially reducing health inequalities.
- Cyber-secured cloud services and communications will enable a greater number of people to work remotely, including in the case of emergencies. This can support productivity.

Key 30-year perspectives

- Energy storage facilities will be become increasingly standard for public buildings.
- Digital visualisation and simulation technologies might contribute to greater efficiency in planning and design processes for public buildings and infrastructure.
- AI will be used increasingly in clinical applications, such as assisting in diagnosis analysis.
- Telehealth (remote care solutions delivered to the home) will be increasingly deployed.



Technology Definitions

3D Printing	The term 3D printing covers a variety of processes in which material is joined or solidified under computer control to create a three-dimensional object. When used at an industrial scale, the term additive manufacturing may be used synonomously. One of the key advantages of 3D printing is the ability to produce very complex shapes or geometries.
5 G	A 5G network is a next-generation mobile technology, with a software-defined flexible system of both micro and macro cells, and is expected to handle more data with billions of connected devices, providing global businesses and economies with unprecedented insights and abilities to drive radical change .
Advanced Manufacturing	Advanced Manufacturing is a combination of information technologies (IoT, Big Data, Analytics, AI,) integrated with high-performance and automated (Robotics and AI) production systems capable of furnishing a mix of products in small or large volumes with both the efficiency of mass production and the flexibility of custom manufacturing in order to respond quickly to customer demands.
Advanced Materials	Advanced materials include high strength lightweight metals, alloys, polymers, nanomaterials, ceramics, and composites. Lightweight metals such as titanium, aluminium, and beryllium with superior properties offer energy efficient solutions thereby reducing carbon emissions. Innovative multifunctional smart polymers are capable of offering resistance to corrosion, abrasion, and mechanical wear. Composites are created by embedding fibrous materials in a polymer matrix to produce a strong but light material. All these materials are characterized with functional features, as well as modifications to existing materials to obtain superior performance, lightweighting, self-repairing capabilities, and improved mechanical performance.
Advanced Sensors	Advanced sensing technologies is a group of next-gen sensing technologies comprising interactive touch-based/sophisticated touchless sensing mechanisms. These mechanisms are integrated with novel instrumentation and information systems used to detect, perform, and control operational tasks.
Artificial Intelligence and Machine Learning	Artificial Intelligence enables automated decision making with very high accuracy and speed based on data driven intelligence, coupled with self-learning abilities. Machine Learning is a core technology seen as a significant subset of AI. It allows machines to analyze data, learn, and predict outcomes.
	Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real-world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. Virtual reality (VR) is an experience taking place within a computer generated reality of immersive environments can be similar to or completely different from the real world.

Technology Definitions

Augmented and Virtual Reality	Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real-world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. Virtual reality (VR) is an experience taking place within a computer generated reality of immersive environments can be similar to or completely different from the real world.
Autonomous Vehicles	An autonomous car is a driverless/self-driving car, which is capable of sensing the environment and navigating without human input. Autonomous cars are equipped to detect their surroundings using a combination of technologies such as Radar, Laser lights, GPS, odometry, artificial intelligence, and computer vision among others
Big Data	Big Data refers to a set of data management tools, appliances and techniques for effective analysis of huge amounts of data sets towards deriving intelligence on business operations and customer interactions.
Blockchain	Blockchain is a distributed ledger technology (DLT), where every node in the distributed peer-to-peer (P2P) computer network maintains its own record of a transaction, leading to the elimination of the requirement for a trusted third party. Blockchain is a distributed database that maintains records in the form of blocks. Each block maintains a timestamp that is linked to the previous block. Once recorded, data in blocks cannot be altered or tampered with. The entire process is completed in real time by eliminating the need for any central authority or a third-party financial institution to verify the transactions.
Carbon Capture and Storage	Carbon Capture and Storage (CCS) is a collection of many technologies that can reduce greenhouse gas emissions by capturing, compressing and injecting greenhouse gases into deep underground rock formations. This prevents the entry of greenhouse gas into the atmosphere and prevents the escalation of climate change and global warming.
Circular Economy	A circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital. It is based on three principles: Design out waste and pollution; Keep products and materials in use; Regenerate natural system.

Technology Definitions

Cloud Computing	Cloud computing is the on-demand availability of computer system resources, especially data storage and computing power, without direct active management by the user. The term is generally used to describe data centres available to many users over the Internet. Recent advancements in cloud computing technology offer almost all the major computing resources, such as infrastructure, storage, platforms and so on to be used as services, collectively known as everything-as-a-service (XaaS).
Connected Living	The rise in the number of smart watches, smartphones, wearables, and other sensor based devices in an IoT environment is enabling the utilization of various connected services. These devices are becoming the 'remote controls' of our lives, acting as hubs for sensor-based health monitoring products and fitness apps, as well as controlling our homes and work tasks.
Cyber Security	Cybersecurity is the protection of internet-connected systems, including hardware, software and data, from cyberattacks. In a computing context, security comprises cybersecurity and physical security -- both are used by enterprises to protect against unauthorized access to data centres and other computerized systems
Digital Health	Digital health enhances the quality of care received by patients, which enables them to live a more independent lifestyle within the comforts of their home, office, hospital, or other healthcare facilities. The trend is more aligned towards proactive care, where patients (irrespective of their age or condition) are independently monitored, and manage appropriate interventions whenever needed. Digital health comprises of various sub-sectors, namely e-health, m-health, telehealth, health information technology, and telemedicine.
Digital Twin	A digital twin is a digital model or replica of a physical asset, product, process or system that allows a digital footprint of key assets or products from design and development through the end of the product lifecycle. It's basically a convergence of the virtual and physical world that helps businesses to detect physical issues sooner, predict outcomes more accurately, and build better products.
Distributed Generation	Distributed generation (DG) produces energy by utilizing various decentralised conventional (combined heat and power [CHP], genset) and renewable (solar photovoltaic [PV], wind turbines) energy sources. DG involves energy sources often placed closer to the consumers, ranging between a few kilowatts and approximately 10 to 50 MW, and dispersed geographically.

Technology Definitions

Drones	The Air Navigation Order 2016 (ANO) defines small unmanned aircraft (SUA) as "any unmanned aircraft, other than a balloon or a kite, having a mass of not more than 20 kg without its fuel but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight." [1] Typically, an unmanned aircraft (drone) will be controlled by a ground-based remote pilot, with a communications system linking the two. This is collectively referred to as an unmanned aircraft system (UAS). A drone is also sometimes referred to as a remotely piloted aircraft system (RPAS). However, as technology progresses, drones are becoming increasingly automated, and may one day become fully autonomous without the need for a remote pilot.
Edge Computing	Edge computing brings computer data storage closer to the location where it is needed. Computation is largely or completely performed on distributed device nodes. Applications, data and computing power is closer to the user.
Electric Vehicles	An electric vehicle, also called an EV, uses one or more electric motors or traction motors for propulsion.
Energy Storage	Energy storage is the capture of energy produced at one time for use at a later time. A device that stores energy is generally called an accumulator or battery.
Intelligent Transport Systems (ITS)	Intelligent transport system (ITS) describes technology and communications used to improve efficiency and safety for transport users. It includes monitoring equipment such as CCTV and traffic detection sensors, speed control and queue management via gantry signals; and informing travellers using Variable Message Signs (VMS), Web services, smartphone apps, news feeds, social media, and radio broadcasts. It also encompasses the growing field of connected and autonomous vehicles, which are expected to have significant benefits for road safety and in transforming how real-time traffic monitoring and analysis can be carried out.
Intelligent Waste Systems	An intelligent waste management system implemented combines the utilization of waste containers with the technology of fill-level sensors. This results in smart bins that can monitor the fill levels of waste containers for more efficient waste collection.
Internet of Things (IoT)	Internet of Things (IoT) connects multiple smart devices and objects to a single network over the Internet. It allows data exchange in a secure manner, providing opportunity for deeper and comprehensive analytical insights. This interconnection will help generate new business models and produce new revenue streams for organizations. Reduction in overall cost through improved asset utilization, process efficiencies, and productivity is driving adoption across businesses. There are three layers that typically make up an IoT device namely, a physical layer, a network layer and an application layer. The physical layer includes the hardware (e.g., sensors and networking gear), the network layer includes the data collected by the physical layer to different devices, and the application layer includes protocols and interfaces that devices use for communication.

Technology Definitions

Li Fi	Li-Fi is a wireless optical networking technology leveraging light-emitting diodes (LEDs) for data transmission
Nanotechnology	Nanotechnology ("nanotech") is manipulation of matter on an atomic, molecular, and supramolecular scale. Nanotechnology as defined by size is naturally very broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, energy storage, microfabrication, molecular engineering, etc. This enables the development of new materials with dimensions on the nanoscale to direct control of matter on the atomic scale.
Photonics	Photonics is essentially the science that involves generation of a photon (light), its detection, as well as manipulation via transmission, emission, signal processing, modulation, switching, amplification, and sensing. Most importantly, photonics involves the proper use of light as a tool
Quantum Computing	Quantum Computing is a field of computing that leverages the principles of quantum mechanics to process information using qubits rather than bits, which form the base of classical computing. Quantum computing operates using two fundamental principles of quantum physics – superimposition and entanglement. The superimposition of qubits allows them to represent both 1 and 0 at the same time, while using entanglement, the cubits can be correlated with each other whereby the state of one cubit can be dependent on the state of the other. Quantum technologies are being explored to provide secure communication networks, better computing power, sensors, and metrology. Future application areas cover quantum-enabled satellites, unhackable Internet networks, more accurate atom clocks, cryptography, and simulation systems.
Renewable Energy	Renewable energy comprises sources of energy generation that don't get depleted over a period of time unlike conventional fossil fuels, such as coal, petroleum, and natural gas. Sources of renewable energy include solar, wind, geothermal, wave, tidal, hydro, and biomass. These energy sources can be utilized for both heating and power generation purposes.
Robotics and Automation	The Robotic Industries Association (RIA) defines a robot as a re-programmable, multifunctional manipulator designed to move material, parts, tools or specialised devices through variable programmed motions for a variety of tasks. Automation is the creation of technology and its application in order to control and monitor the production and delivery of various goods and services. It performs tasks that were previously performed by humans. Automation is being used in a number of areas such as manufacturing, transport, utilities, defence, facilities, operations and lately, information technology.

Technology Definitions

Satellite Communications Technology	Satellite communications technology is becoming an important element in the 5G ecosystem, thereby complementing fixed and wireless terrestrial communication. In the IoT industry, satellites will be used most prominently in the military, oil and gas, and aviation markets. Due to their differences in capabilities, satellites will not compete directly with terrestrial technologies, such as cellular and fibre optics. Satellite technology will, instead, be used as a complimentary technology to fill in communication gaps that are present globally. Additionally, satellite will remain the only option for maritime, aviation, and offshore oil and gas IoT applications. Satellite technology is unique in that it can be used to provide network coverage to nearly any location on the planet, regardless of infrastructure. This coverage is important for IoT used in markets where continuous coverage in remote or difficult to reach locations is necessary.
Smart Buildings and infrastructure	Smart buildings make use of intelligence, control, and the built environment, both internal and external, to deliver energy efficiency, sustainability, and occupant comfort as some of the key objectives. The buildings must have high adaptability to the changes in the environment and to the occupants' needs.
Smart Grid	Smart grids bring in capabilities such as communication and automation to energy infrastructure and make it more reliable and stable. One of the key differentiating factors of a smarter system is the data fidelity associated with it. With better sensing and communication capability, the amount of data generated and transferred will be extremely high in case of every smart system, including the grid. Some of the important features of smart grids include two way communication enabling better end user interaction, smarter and more effective management of loads, demand and generation sources through better monitoring and improved energy reliability through the addition of distributed energy resources.
Social Media	Social media refers to Web technology that facilitates creation and sharing of community-based input, interaction, content-sharing and collaboration via networks. Websites and applications that are dedicated to social forums, curation, bookmarking, wikis and microblogging amongst others represent the different types of social media. The rising use of social media sites and apps including Facebook, Twitter, Instagram,Snapchat and WhatsApp.
Wearables	Wearables are body-worn electronics, which have manifold capabilities right from activity tracking, personnel monitoring, vital signs monitoring, fatigue management, user alert monitoring, end-user mind control, sound control, and brain control capabilities. Advancements in communication technologies, analytics, artificial intelligence, and wireless sensors are encouraging developments in this space.

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