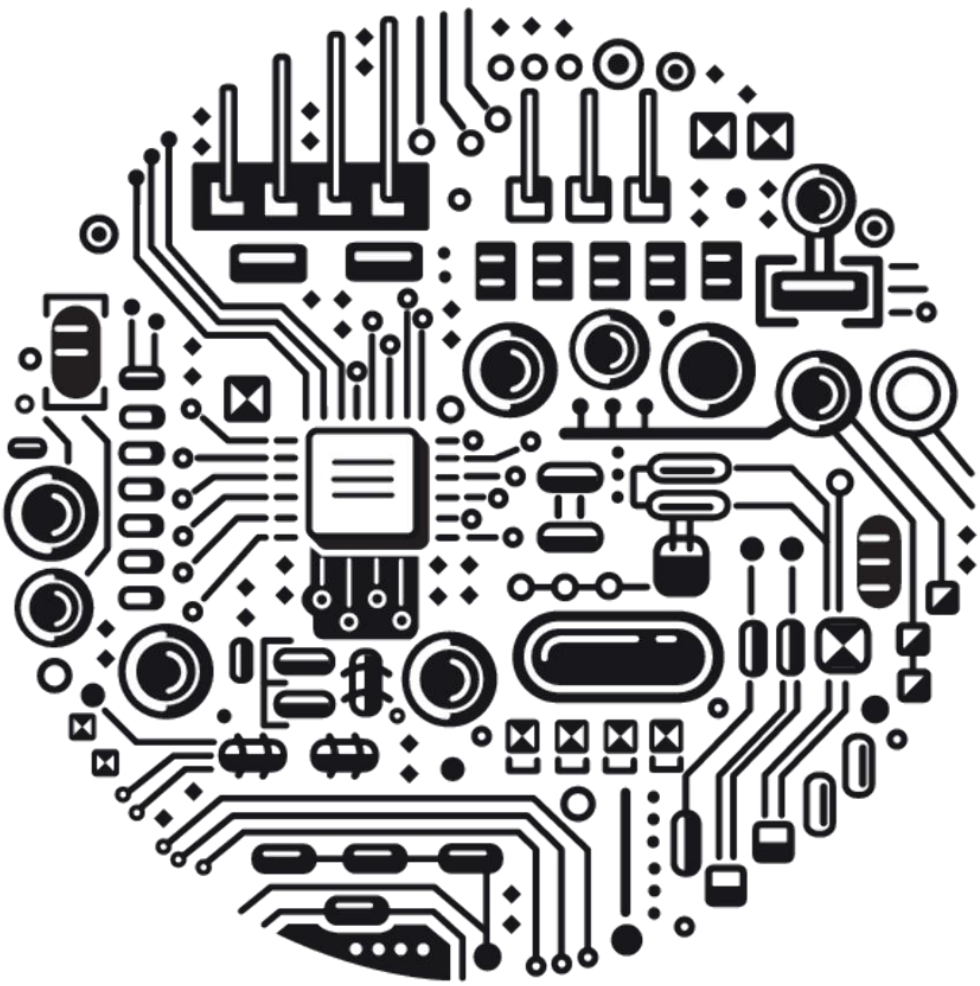

Scotland's digital potential with enhanced 4G and 5G capability

Final report for Scottish Futures Trust

August 2019

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Contents

Executive summary

Wireless connectivity and digitalisation benefit individual users and the wider economy

Enhanced wireless connectivity and digitalisation

- Faster, more ubiquitous and reliable connectivity
- Higher usage across more users
- Higher adoption of key technologies such as cloud, IoT, data analytics and AI

Benefits for users

- Increased efficiency through automation, flexible working and new digital processes
- Innovative new business models and products
- More inclusive society

Benefits for the economy

- Efficiency and innovation increase GDP, with greatest relative impacts in rural areas
- Higher exports and tax revenues
- New use cases boost competitiveness

This study considers alternative future digitalisation scenarios for Scotland...

Base case

- In this baseline scenario, digitalisation in Scotland evolves only gradually
- No material action to extend current 4G and 5G capabilities
- The digital divide persists

Evolution

- Evolution to faster speeds and wider 4G coverage
- Higher business adoption of digital technologies
- However, the full potential of 5G is unfulfilled

Revolution

- Revolutionary 5G networks with step-change in performance
- Transformative use cases drive efficiency and innovation
- Digital divide reduced to a minimum

... and estimates potential long-term economic impacts

	Evolution	Revolution
GDP	+ £6 billion	+ £17 billion
% increase	3.1%	8.3%
Jobs	+ 60,000	+ 160,000
Businesses	+ 1,000	+ 3,000
Tax revenue	+ £2.1 billion	+ £5.7 billion
Exports	+ £1.2 billion	+ £3.3 billion

Estimated increases relative to the counterfactual, in 2035

Potential 5G use cases could drive additional social impacts

Inclusion

- ✓ £700m gain from wider rural 4G coverage in Evolution scenario
- ✓ Improved access to healthcare, education and employment
- ✓ Support for sustainability of rural communities

Environment

- ✓ Reduced consumption from smart heating and automation
- ✓ Reduced emissions from smarter transport
- ✓ Smart energy grids facilitate integration of renewables

Digital public services

- ✓ Preventative healthcare
- ✓ Immersive, interactive educational content
- ✓ Efficient and highly integrated multimodal transport network
- ✓ Enhanced public safety

Source: Deloitte analysis

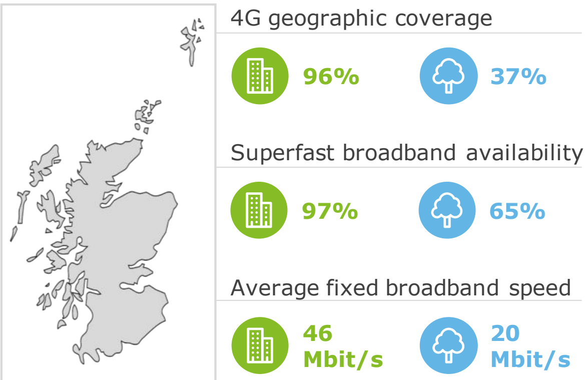
This study estimates the impacts of enhanced digitalisation and 4G and 5G capability

Scottish Futures Trust ("SFT") has commissioned Deloitte to undertake an assessment of the potential economic impact of enhanced digital capability in Scotland as regards wireless and mobile technologies such as 4G and 5G. This study builds upon a previous study published in 2015[1] and provides estimates of the economic impact that could be realised for Scotland under different future scenarios. To support the analysis and build upon existing understanding of the future impact of such technologies, potential 5G use cases are identified in areas that could strengthen Scotland's competitiveness and contribute to current areas of innovation.

Digitalisation in Scotland has improved recently, but there is scope for further growth

Superfast fixed broadband is now available to 92% of households in Scotland, while 78% of the landmass receives a 4G signal from at least one mobile operator. Improvements in coverage and quality of connectivity are translating to changes in consumer and business usage and experience. Consumers conduct a wide variety of activities online, while more businesses are adopting new technologies to drive efficiency and innovation – such as cloud computing, now used by 38% of businesses in 2017, compared to 27% in 2014.

Figure 1: Connectivity in Scotland's urban and rural areas, 2018



Source: Ofcom Connected Nations reports

However, reliable access to high-quality experience and services is not available to all users. The availability of connectivity remains limited in some rural areas, particularly with regard to 4G coverage; 63% of rural areas do not receive a 4G signal from all four mobile operators.

Anecdotal evidence suggests that mobile broadband speeds are also significantly lower in rural areas, though robust data measuring this is not available. To some extent, these differences reflect Scotland's relatively sparse population and uneven terrain, which increase mobile network deployment costs.

Addressing geographic differences in connectivity can reduce digital divides, with greater digital inclusion for older, lower-income consumers or those living in remote areas and wider access to existing and future digital services. This objective has been the focus of recent Scottish Government and SFT programmes.

Similarly, there remains a wide gap in the digital maturity of SMEs relative to large businesses. As a result, only around 7% of Scottish businesses are estimated to have attained a high level of digital maturity as digital champions or digital pioneers.[2]

5G has the potential to offer seamless connectivity and enable transformative use cases

The next generation of mobile network technology, 5G, will be deployed in Scotland over the coming months and years, with both public and private sector activity already underway to support this. 5G has the potential to offer greater reliability, much faster download and upload speeds, higher capacity to ease congestion and accommodate more connected devices or sensors, and lower latency, allowing an instant response with virtually no time lag. All of this will ultimately enhance the user experience and enable new ways of doing things.

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[1] Deloitte (2015). 'The economic and social impacts of enhanced digitalisation in Scotland'
[2] Scottish Government (2017). 'Scotland's Digital Economy Maturity Index 2017'

5G differs from previous generations in that it is expected to integrate other wireless technologies, such as 4G, Wi-Fi and Internet of Things (IoT) technologies, as part of flexible networks that can be optimised in real-time. 5G could allow operators to provide multiple virtual networks using the same physical infrastructure (known as "network slicing") to provide a tailored and reliable service to different users with different technical requirements.

5G has the potential to support a wide variety of use cases simultaneously across sectors, typically involving a combination of the following capabilities.

Remote monitoring
Networks of sensors and devices used to monitor business processes and operations and end-user usage in real time.

Remote control and automation
Using real-time data, businesses can respond more quickly, by intervening manually or through automated processes.

Immersive content
Higher bandwidths and lower latency support high-fidelity content and lag-free two-way communications using AR and VR.

AI and ML analytics
New uses of data using artificial intelligence and machine learning tools.

Analysis and stakeholder input has identified key sectors of Scotland's economy that stand to benefit by building on current and future initiatives, as summarised below.

Healthcare. 5G use cases have the potential to drive efficiency and patient engagement, as well as inclusive access to treatment in Scotland's rural and remote areas.	✓ Current initiatives in Scotland include Fit Homes, using in-home sensors to monitor patient health, and use of IoT to monitor hospital beds and automate maintenance.
Transport. 5G connectivity along Scotland's transport networks could support passenger productivity and a more integrated, user-friendly and seamless transport system.	✓ An autonomous bus trial from Fife to Edinburgh is planned, and Transport Scotland is currently exploring mobility-as-a-service as a proof of concept.
Education. 5G could support engaging and tailored digital content. With adequate connectivity this could be accessed by students anywhere, any time.	✓ The e-Sgoil programme brings tele-education to the Western Isles, though there are no current initiatives focusing on the role of 5G.
Public services. Added to the above, other public services in urban areas particularly can benefit from 5G in the context of "smart city" use cases.	✓ Initiatives in Glasgow include smart lighting and water management; other cities feature in the Smart Cities Scotland programme.
Agriculture and aquaculture. New processes driven by data and connectivity could drive efficiency, contributing to the long-term sustainability of Scotland's rural economy.	✓ 5G RuralFirst trials include salmon health monitoring, autonomous tractors, soil analysis using drones and livestock monitoring through "connected cows".
Immersive content. 5G can support immersive content using AR and VR. Scotland's strong digital creative industries could drive innovation, including through immersive content in tourism, supporting rural and remote communities, or in education.	✓ The Portal AR app, created collaboratively by Google, VisitScotland, SDI, Talent Scotland and Scotland.org, provides immersive and educational content showcasing Scotland's landmarks to users in any location
Energy and resources. 5G has the potential to drive efficiencies throughout the supply chain and support Scotland's low-carbon objectives.	✓ Public bodies in Scotland are exploring use cases such as smart lighting, smart heating and smart electric vehicle charging hubs.

Overall, 5G networks can benefit urban areas, where initial deployments are likely to focus, but also rural and remote areas, where they could facilitate remote access to key services and contribute to the sustainability of the rural economy. Plans for future 5G deployment(s) in Scotland are currently in early stages, with industry, academia and the public sector involved in various trials and small-scale deployments. At the same time, 4G networks have not yet reached their full potential and further improvements in 4G connectivity in Scotland can provide an initial platform for new uses of digital technology even as 5G is still being developed and rolled out.

Scenarios show how digitalisation and 4G and 5G capability could evolve in Scotland

Scenarios have been developed in consultation with SFT to illustrate a range of possible outcomes for Scotland's digital future. Recognising that digitalisation is an ongoing process, the scenarios look ahead to 2035 and focus on the role of wireless capability within a wider digital ecosystem. As such, the scenarios also capture improved outcomes in areas that support the potential of wireless connectivity, such as fixed broadband connectivity, IoT, cloud computing and data analytics.

Two scenarios have been developed:

- **Evolution** – An improvement of current capabilities and usage, whereby Scotland's internet usage and adoption of key technologies increase significantly. The potential of current technical standards such as 4G is exploited, but the full potential of 5G is not. Two variants of this scenario are considered, where 4G geographic coverage reaches 65% and 90% respectively by 2035,[3] with all other assumptions held constant.

- **Revolution** – A transformative state of the world in which pervasive, high-performance 5G connectivity is at the heart of a rapid acceleration in digital transformation. Flexible and reliable networks provide a tailored service enabling a plethora of innovative use cases. The digital divide is reduced to a minimum and the vast majority of businesses are able to leverage new technologies to generate efficiencies and revenue growth opportunities.

Each scenario is expressed in terms of incrementally improved outcomes compared to a base case scenario that represents how Scotland may evolve based only on current trends, in the absence of further material actions to improve 4G and 5G capabilities, or to accelerate digitalisation more broadly.

Scenarios are described in more detail in Figure 2 on the next page.

[3] This is based on 4G coverage provided by all four mobile network operators

Figure 2: Summary of scenario specifications to 2035

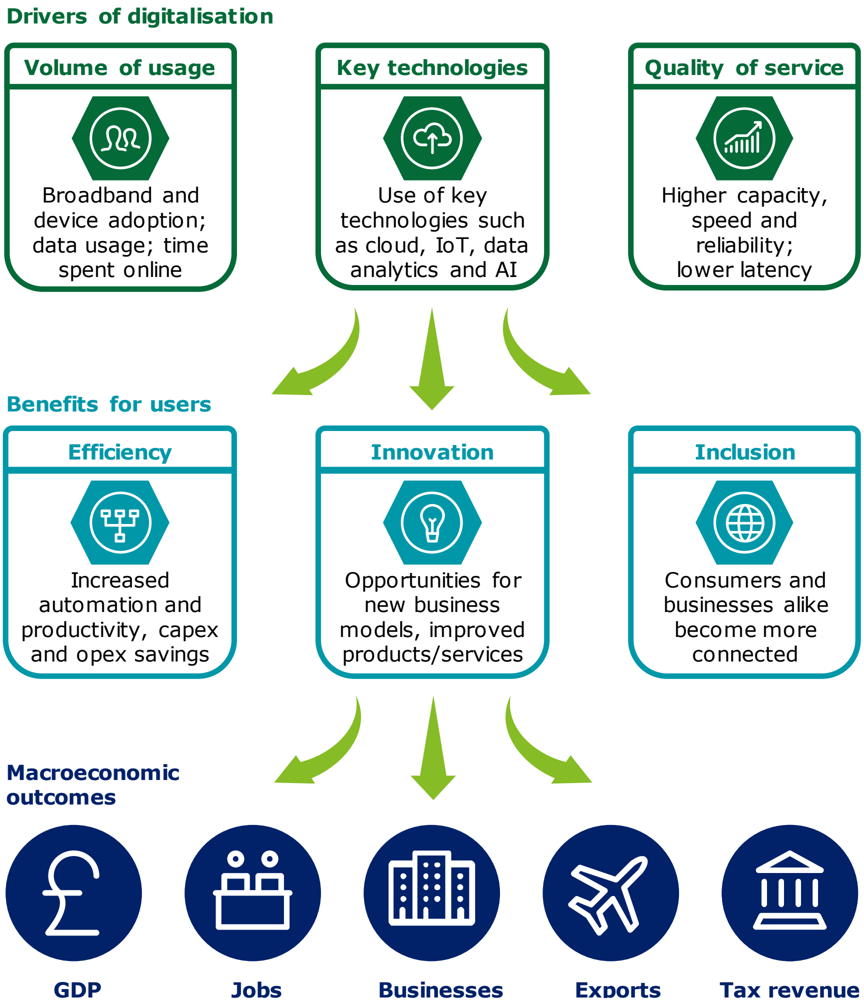
	Base case	Evolution	Revolution
Connectivity	• Modest improvements in internet service • Improvements predominantly occur in urban areas • Household internet penetration reaches 92% by 2035	• Material increases in speed and coverage • Increased 4G coverage improves service in rural areas • Household internet penetration reaches 96% by 2035	• Gigabit speeds become commonplace • Low latency, high capacity and reliability unlock new use cases • Household internet penetration reaches 99% by 2035
Business	• Limited progress in adoption of key technologies • Increases mainly in urban areas and large firms • 30% of businesses use IoT by 2035	• Most businesses adopt cloud and e-commerce • The digital divide narrows but many firms are still basic users of technology • 45% of businesses use IoT by 2035	• Digital transformation across sectors • New technologies and use cases are more accessible to all types of businesses • 70% of businesses use IoT by 2035
Public sector	• Many public services remain "analogue" • Digital services are mainly used by younger, higher-income, urban citizens • 55% of citizens use online public services by 2035	• Improvement in public sector digitalisation • A wider base of users is able to benefit from digital public services • 70% of citizens use online public services by 2035	• Ubiquitous digitalisation across the public sector • Advanced IoT solutions create large efficiencies in public service delivery • 90% of citizens use online public services by 2035
Consumer	• Gradual increases in adoption and usage • Digital divide persists across regions and demographic groups • Online banking adoption reaches 60% by 2035	• Faster adoption of new leisure and health devices • A wider base of users benefits from use of online services • Online banking adoption reaches 75% by 2035	• Consumers use a plethora of in-home and portable devices for convenience • Immersive audio-visual content is ubiquitous • Online banking adoption reaches 90% by 2035

Source: Deloitte analysis

The scenarios are not intended as forecasts of future digitalisation in Scotland, rather as alternative views on how digitalisation could evolve. They are outcome-based and do not explicitly consider the extent of underlying infrastructure required and the potential costs of this. Effectively the scenarios assume that the necessary improvements in infrastructure, and other areas such as digital skills, take place in order for the specified scenario outcomes to be realised.

The economic impact associated with each scenario is estimated based on the framework summarised in Figure 3. Key drivers of digitalisation are identified as the volume of usage of online services and devices, the rate of adoption of key technologies among businesses, and the quality of service available. These drivers generate benefits for users, including efficiency gains, innovation and a greater degree of digital inclusion. Benefits for individual users ultimately lead to economy-wide gains in aggregate.

Figure 3: Economic impact framework



Source: Deloitte analysis

As set out in the report, the estimates of economic impacts draw upon third-party macroeconomic data and evidence from the existing economic literature that quantifies the linkages between digitalisation and economic outcomes. The analysis considers how increased digitalisation could enhance Scotland's economy, given its current characteristics. In the long-term, technology could bring about structural changes to Scotland's economy; however, this dynamic effect is not explored in this study.

In the most transformative scenario, Scotland could add £17 billion to GDP by 2035

Economic modelling indicates that, in the most optimistic case under the Revolution scenario, a transformative development of 4G and 5G capability as part of an advanced digital ecosystem **could increase Scotland's GDP by up to £17 billion** by 2035, relative to the base case. This would represent a return to Scotland's historical long-run trend growth rate of 2%, from the GDP growth rate of 1.5% otherwise assumed in the base case.[4]

This compares to a previous estimate that the potential GDP impact from Scotland becoming a World Leader in digitalisation could be around £13 billion in 2030.[5] While the two studies are not directly comparable, the estimated impact for the Revolution scenario indicates a significant economic opportunity, notwithstanding recent improvements in Scotland's digitalisation.

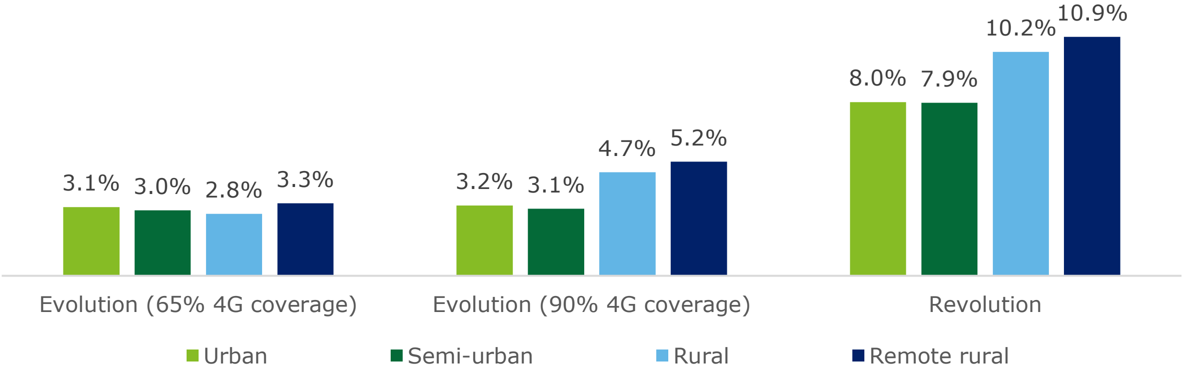
On the other hand, in the more modest Evolution scenario, an improvement of Scotland's existing wireless and digital capabilities **could increase Scotland's GDP by up to £7 billion** by 2035, relative to the base case. This would represent an improvement in GDP growth with the annual growth rate reaching 1.7%, though still below the historic long-run average growth rate of 2%.

Specifically, the economic impact in the Evolution scenario is estimated in the range of £6.3 billion to £7 billion in 2035, depending on the level of 4G coverage assumed. In other words, the impact of increasing 4G geographic coverage achieved by 2035 – from 65% to 90% – is estimated as £700 million in 2035, while holding all other Evolution scenario assumptions constant.

The impacts are proportionately larger for rural and remote rural areas of Scotland

In absolute terms, the GDP impacts are far larger in urban and semi-urban areas than in the rest of Scotland. However, this simply reflects that urban and semi-urban areas account for the largest proportion of economic output. In fact, it is rural and remote areas that see the largest proportionate impact in the most positive scenarios, as enhancements in 4G and 5G capability narrow the digital divide by allowing consumers and businesses to access superior, transformative services regardless of the location.

Figure 4: Increase in GDP relative to the base case, as a percentage of base case GDP in 2035



Source: Deloitte analysis

In particular, expanding 4G coverage from 65% to 90% as part of the Evolution scenario delivers an incremental impact mainly in rural areas, addressing current shortcomings that contribute to a digital divide. The Revolution scenario then builds on this by delivering additional benefits to both urban and rural areas, as adoption of digital technology becomes both more widespread and more transformative.

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[4] The base case GDP growth rate is based on third-party projections. No specific assumptions are made in this study about future macroeconomic shocks.
[5] Deloitte (2015). 'The economic and social impacts of enhanced digitalisation in Scotland'

The estimated impact on GDP reflects higher employment and productivity

The estimated GDP impacts are the product of two factors: higher employment due to increased economic activity and higher labour productivity due to more efficient ways of working.

In the Revolution scenario, it is estimated that around 160,000 net new jobs would be created by 2035 in the Scottish economy relative to the base case, representing an increase of around 6% compared to the projected level of employment in 2035. In the Evolution scenario, it is estimated that 58,000-68,000 net additional jobs could be created by 2035, representing an increase of around 2.2-2.6% compared to the level of employment in the base case.

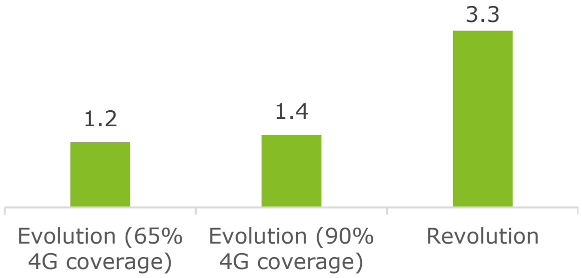
As well as increased total employment, productivity per worker is estimated to increase. In the Evolution scenario, annual productivity per worker increases by a weighted average of £650 by 2035. In the Revolution scenario, this impact is more than doubled, with a weighted average increase of £1,600.

Digitalisation supported by enhanced 4G and 5G capability could stimulate business creation and exports

Enhanced wireless capability can support the development of a more digitalised society, creating new demand for digital services across sectors, with opportunities for new business models and products. Business start-up costs may also fall due to wider adoption of flexible working practices and cost-reducing technologies such as cloud computing.

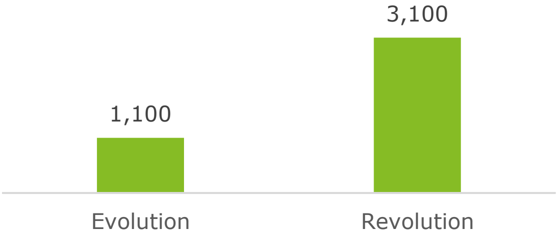
As a result, there is an estimated increase in the number of businesses and growth in export volumes, both of which are indicative of increased global competitiveness for Scotland.

Figure 5: Incremental annual exports relative to base case in 2035 (£ billions)



Source: Deloitte analysis

Figure 6: Net new businesses created relative to base case in 2035



Source: Deloitte analysis

In the longer term, provisional analysis suggests that further benefits may be realised

Looking further ahead into the future, indicative economic impacts to 2050 have been estimated for the Revolution scenario, assuming that digitalisation continues to deliver material incremental benefits beyond 2035. These estimates are based on a higher level approach than the core 2035 estimates presented in Section 5.2 and do not make any assumptions about specific technological developments beyond 2035. They are inherently more uncertain and should be interpreted as indicative.

Based on an extrapolation of the projected annual impacts to 2035 under the Revolution scenario, it is estimated that continued enhancements in 5G capability and use cases could generate up to £34 billion by 2050, representing a 13% increase on Scotland's projected base 2050 GDP.

Transformative use cases could support a more inclusive and greener society

In addition to economic impacts, enhanced wireless capabilities could also generate positive social impacts. In summary, new use cases can increase digital participation, leading to greater social inclusion and wider access to key services and opportunities, while specific use cases in sectors such as education, healthcare, transport and energy can enable the delivery of high-quality public services whilst minimising negative impacts on the environment.

Figure 7: Summary of potential social impacts from enhanced 4G and 5G capability

Inclusion

- ✓ Greater inclusion, equality and participation, including for vulnerable groups
- ✓ Wider access to more flexible employment
- ✓ Easier access to healthcare, education and online shopping
- ✓ New use cases in agriculture, aquaculture and tourism support rural communities

Environment

- ✓ Reduced consumption from smart heating and automation
- ✓ Automated processes reduce use of energy and resources
- ✓ Reduced emissions from smarter transport ecosystem
- ✓ Smart energy grids facilitate integration of renewables
- ✓ 5G enables higher energy efficiency

Digital public services

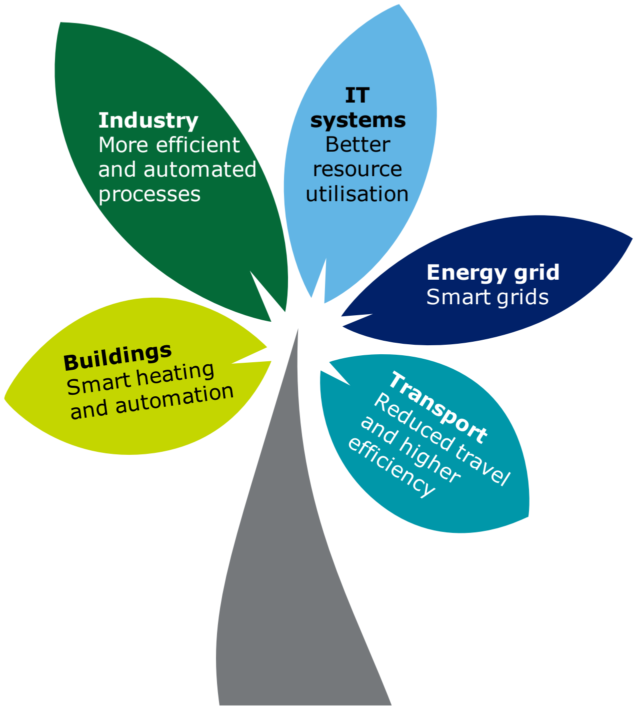
- ✓ Preventative healthcare with greater patient engagement
- ✓ Immersive and interactive educational content
- ✓ Efficient and reliable transport ecosystem with a high degree of multimodal integration
- ✓ Public safety enhanced by new uses of technology to respond in emergency or disaster situations

Source: Deloitte analysis

Enhanced connectivity can support wider Scottish Government objectives, for example as set out in the **Low Carbon Strategy**.[6] Specific innovations as set out in Figure 8 on the next page can contribute to more efficient energy use and lower emissions. 5G has been linked to more efficient and automated processes, for example in manufacturing, which could reduce use of energy and resources, while wireless connectivity may be used to support smarter energy grids that are better suited to integrating renewables and promoting new green technologies such as electric vehicles.

[6] https://www2.gov.scot/resource/doc/331364/0107855.pdf

Figure 8: Summary of potential environmental benefits



Buildings
Wireless connectivity can enable sensor-based smart heating and cooling processes to reduce consumption, while smart appliances could automatically coordinate to optimize energy use

Industry
Automated processes in sectors ranging from manufacturing to agriculture can increase efficiency, reducing energy and resource usage

IT systems
Though more connected devices and sensors could increase energy use, 5G is expected to support higher energy efficiency, and related technologies such as cloud can reduce emissions compared to legacy IT systems

Energy grid
A smarter energy grid with wirelessly connected devices facilitates the integration of renewables and could allow real-time optimisation of demand and supply

Transport
Wireless connectivity reduces the need for travel and it can support smart traffic management, CAVs and ride-sharing, potentially reducing congestion

Source: Deloitte analysis of public sources

More generally, improved digital connectivity is key to maximising opportunities for remote and flexible working, reducing the need to travel and the associated emissions, as well as potentially increasing productivity and reducing the digital divide. In this way, enhanced digital connectivity can contribute to increased economic growth and productivity that is both sustainable and inclusive.

Realising these benefits may require concerted action to overcome barriers

The benefits identified above have been analysed over a timeframe of approximately 15 years, recognising that the economic benefits from digitalisation are typically realised gradually and can require long-term commitments by policymakers and industry to address key challenges.

First, benefits are largely reliant on the availability of adequate connectivity. Improving 4G coverage and performance, and achieving large-scale 5G deployments, will rely on key enablers including spectrum access, the availability of underlying fibre infrastructure and the development of new commercial models for network deployment and specific use cases.

Even where adequate connectivity is available, at present there is still uncertainty about which particular use cases will have the most transformative impact. Given the nascent state of 5G, use cases identified to date are largely theoretical and the business case for these remains unclear. Further research and collaboration across government, industry and academia – building on current initiatives such as the 5G RuralFirst programme – is likely to play an important role in establishing use case feasibility and the likely costs and demand involved.

Finally, an accelerated rate of digital transformation may only be achievable by improving awareness and understanding of 5G and complementary technologies such as cloud computing, data analytics and AI. Awareness and understanding appear patchy at present, with some organisations – such as SMEs and some local government bodies – potentially at risk of falling behind the curve.

Given these barriers, concerted action may be required to capitalise on the 5G opportunity – as summarised in the box below.

Maximising future gains for Scotland

Recent initiatives exploring 5G use cases in Scotland show promise, but are largely limited to small-scale trials and idiosyncratic applications at present. Several stakeholders are pursuing different initiatives in isolation, potentially leading to fragmented approaches. Against this backdrop, Scotland could benefit from:

- Increased collaboration and knowledge-sharing across stakeholders, bringing together experience, resources and networks in order to identify key synergies and lessons learned;
- Holistic thinking to consider the opportunity of seamless 5G connectivity for the benefit of entire communities, without restricting to individual sectors or use cases;
- Development of longer-term planning, setting out roles, responsibilities and processes to convert successful proof-of-concept trials to large-scale commercial opportunities; and
- Measures to increase awareness and understanding of 5G across stakeholders, including local authorities and SMEs, and to provide hands-on support as necessary.

Key to all use cases is the availability of seamless connectivity, with the underlying fibre infrastructure extended as far as possible. Appropriate commercial models will be necessary to facilitate this:

- In urban areas, further exploration of commercial models could support cost effective network deployment that makes use of local authorities' existing physical infrastructure.
- In rural areas, new approaches to infrastructure and spectrum sharing may need to be explored, as well as any innovative technical solutions that can lower costs, working to continue current public and industry initiatives to address rural coverage.

1 Introduction

1.1 Purpose of the study

Scottish Futures Trust (SFT) has commissioned Deloitte to undertake an assessment of the potential economic impact of enhanced digital capability in Scotland as regards wireless and mobile technologies such as 4G and 5G.

The analysis updates and builds on a previous study for SFT of the economic and social impacts of enhanced digitalisation in Scotland.[7] The previous study estimated the potential benefits for Scotland from achieving World Class or World Leading digitalisation.

The current study specifies outcome-based scenarios showing how different trajectories for future 4G and 5G capability could affect Scotland's digital outlook more widely, and in turn generate economic benefits of varying magnitudes. In relation to 4G capability specifically, the study also considers the role of geographic coverage. Economic modelling is used to estimate the potential impacts of each scenario across a wide range of metrics.

To complement the quantitative analysis, this study seeks to identify potential 5G use cases – in other words, specific situations where 5G could enable new ways of doing things or otherwise enhance current approaches. The analysis focuses on areas that build upon Scotland's digital competitiveness and on current innovation.

1.2 Summary of approach

The study has been informed by a review of relevant literature and data sources, as well as input from industry and public sector stakeholders that was provided to SFT and Deloitte. More detail is provided in the relevant sections of this report and its appendices.

The specification of scenarios has been based on a set of indicative scenarios provided by SFT and has been developed in collaboration with SFT. The detailed scenarios set out in this report build upon these indicative scenarios with more detailed metrics and assumptions. The scenario specification has been informed by third-party data sources and discussions with stakeholders.

The modelling of economic impacts has been based on a similar framework to that used in the previous study for SFT, published in 2015. This framework uses third-party economic data and a range of existing evidence about the drivers of economic impacts in order to estimate how each scenario could affect Scotland's economy. Updates have been made to the methodology so that it reflects the latest available data and evidence on key drivers of economic impact.

The discussion of potential 5G use cases has been based on input received from various stakeholders, as well as previous work in this area by Deloitte[8] and other literature.

1.3 Limitations

The scenarios set out in this report are not intended as forecasts of future digitalisation in Scotland, rather as alternative views on how digitalisation could evolve. They are outcome-based scenarios in the sense that they do not explicitly consider the supply-side requirements, such as the fibre infrastructure and spectrum availability that may be needed to support the demand profiles, or the specific services or activities that consumers and businesses undertake to generate aggregate-level outcomes. Effectively the scenarios assume that any necessary improvements in infrastructure,

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[7] Deloitte (2015). 'The economic and social impacts of enhanced digitalisation in Scotland'
[8] For example see Deloitte (2018). 'The impacts of mobile broadband and 5G'

and other areas such as digital skills, take place in order for the specified scenario outcomes to materialise.

As set out in Annex C, the estimates of economic impacts are reliant on third-party macroeconomic data and evidence from the existing economic literature that quantifies the linkages between digitalisation and economic outcomes. The analysis is static in the sense that it does not estimate potential changes in Scotland’s sectoral mix that could arise as a result of increased digitalisation.

1.4 Structure of this report

The remainder of the report is structured as follows:

- Section 2 gives an overview of the current state of digitalisation in Scotland, highlighting progress made since the previous study and the scope for further improvement;
- Section 3 examines the potential new opportunities offered by 5G and the benefits this could bring across a variety of use cases;
- Section 4 sets out different scenarios showing how digitalisation and 4G and 5G capability could evolve in Scotland, which will act as the basis for economic modelling;
- Section 5 presents the outputs of the economic modelling, showing the potential gains that could be achieved across these scenarios;
- Section 6 outlines social impacts that could be realised, with specific regard to digital participation, the quality of public services, and the environment;
- The annexes provide details on the stakeholders consulted for this study, the original specifications of the indicative scenarios envisioned by SFT, and the methodology.

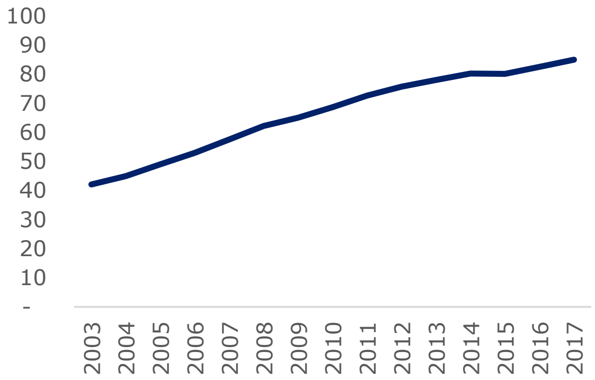
2 Digitalisation in Scotland

2.1 High-level trends

Over the past fifteen years, the percentage of households in Scotland with an internet connection has more than doubled – from 42% in 2003 to 85% in 2017 – transforming internet usage in Scotland from a peripheral activity for a minority of the population to a ubiquitous part of daily life.

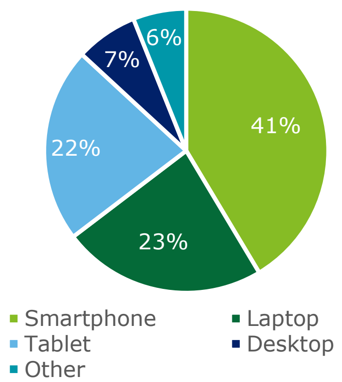
However, even as internet usage itself becomes widespread, other dimensions of connectivity can still constrain what consumers and businesses are able to do. The speed and reliability of connectivity are key to many use cases, with new demand for connectivity that is available anywhere, anytime.

Figure 9: Percentage of Scottish households with an internet connection, 2003-2017



Source: Scottish Government – Scottish Household Survey

Figure 10: Primary device for internet usage in Scotland, 2017



Source: Ofcom Technology Tracker

Changes in usage patterns reflect the increasing importance of wireless connectivity, as the smartphone is now the primary device used to go online.

Furthermore, demand for on-the-move connectivity is growing rapidly, with time spent online outside of home or a place of work or study having increased over four-fold, from 2007 to 2017, for the average UK user.[9]

As smartphone capabilities expand, users develop greater expectations for the quality of connectivity. Higher bandwidths are needed to support high-fidelity audio or video streaming, or applications that make use of emerging technologies such as augmented reality (AR) and virtual reality (VR).

The same trends apply to business and public sector users, as wireless connectivity continue to feature more prominently across to all types of organisations, with applications ranging from remote working and teleconferencing to more advanced use cases using new types of connected sensors and devices, as part of the Internet of Things (IoT).

The remainder of this section will provide context for the study by summarising the state of digitalisation in Scotland today. The analysis highlights changes observed since the previous study on the economic and social impacts of enhanced digitalisation in Scotland published, and scope for further improvement.

[9] Ofcom (2018). 'Adults' Media Use and Attitudes Report'

The section considers changes observed in the following areas:

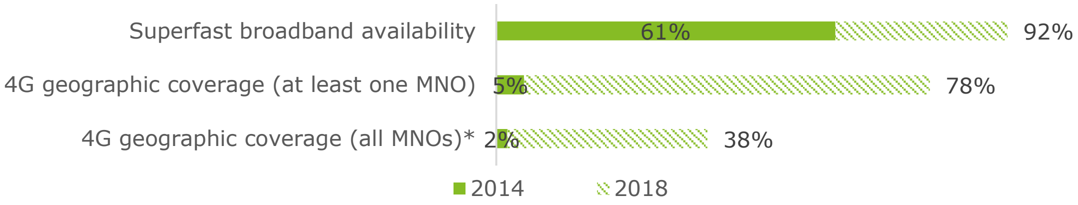
- Availability and quality of fixed and mobile connectivity;
- Business usage of digital services and key technologies;
- Consumer usage of digital services and devices; and
- Public sector digitalisation and uptake of online public services.

2.2 Trends in fixed and mobile connectivity

As in other developed countries, fixed and mobile internet services are widely used by the vast majority of Scotland's population, with 84% of households having an internet connection.[10] However, reliable access to high-quality services has not been available to all users. At the time of the previous study, more than a third of households did not yet have access to superfast fixed broadband,[11] and a third of Scotland's landmass was not covered by any mobile service at all. Rollout of national 4G networks was still in its early stages, with only 5% of Scotland covered by at least one 4G service.

The availability of both fixed and mobile services has improved in the last four years, as shown in Figure 11.

Figure 11: Superfast broadband and mobile service availability in Scotland, 2014 and 2018



Source: Ofcom Connected Nations reports.[12] * For 2014 this data shows coverage from at least 3 of the 4 MNOs.

As well as industry efforts, public interventions are contributing to this trend.[13] For example:

- The Digital Scotland Superfast Broadband programme is investing over £400 million to support fibre broadband rollout and has met its target of providing access to fibre broadband to 95% of Scottish premises by December 2017.
- A separate programme, Community Broadband Scotland, has supported rollout in some remote rural areas.
- The Scottish Government's £600 million Reaching 100% Programme (R100) will provide all premises in Scotland with access to superfast broadband at speeds of 30 Mbps or greater.
- The Scottish 4G Infill programme is providing £25 million of funding to address mobile 'notspots' across Scotland and fund new base stations to provide coverage in around 50 to 60 new areas.

[10] Ofcom (2018). 'Ofcom Technology Tracker, H1 2018'
[11] Defined by Ofcom as a connection providing at least 30Mbit/s download speed
[12] Mobile voice coverage figures for 2014 have been adjusted down by 10% for approximate comparison on consistent basis, correcting for a change in Ofcom's methodology. See Ofcom Connected Nations 2017 report, paragraph 3.22.
[13] Audit Scotland (2018). 'Superfast broadband for Scotland – Further progress update'

Nevertheless, there appears to be clear scope for further improvement, particularly with regard to mobile coverage. Almost half of Scotland's landmass is still not covered by basic mobile coverage from all operators, while more than 60% is not covered by a 4G signal from all operators.

In these respects, Scotland still lags behind the rest of UK. While superfast broadband availability and indoor 4G coverage is almost on a par with the UK, geographic coverage of 4G services is markedly lower. Anecdotal evidence suggests that mobile broadband speeds are also significantly lower in rural areas, though robust data measuring this is not available. To some extent this is likely to reflect Scotland's relatively sparse population and uneven terrain, which increase mobile network deployment costs.

Figure 12: Superfast broadband and 4G availability in Scotland and the UK, 2018

Scotland		UK
92%	Superfast broadband availability	94%
44%	Ultrafast broadband availability	50%
99%	4G indoor coverage (at least one MNO)	99%
75%	4G indoor coverage (all MNOs)	77%
78%	4G geographic coverage (at least one MNO)	91%
38%	4G geographic coverage (all MNOs)	66%

Source: Ofcom Connected Nations reports

Due to incomplete geographic coverage, there is a clear digital divide geographically in access to reliable and fast connectivity. Around a third of households in rural Scotland still cannot access superfast broadband services, and vast areas are unable to access mobile voice and 4G services from all operators, although to some extent this is subject to change as a result of the aforementioned programmes.

Figure 13: Superfast broadband and mobile service availability in Scotland, 2018

4G geographic coverage	96%	37%
Superfast broadband availability	97%	65%
Average fixed broadband speed	46 Mbit/s	20 Mbit/s

Source: Ofcom Connected Nations reports

4G coverage in rural areas may improve further as a result of new coverage obligations set by Ofcom, though at the time of writing these obligations are still subject to consultation[14] and have not yet been allocated to operators. In any case, the threshold set by Ofcom for these obligations is based on speeds of at least 2 Mbit/s, which still allows for the possibility that speeds in rural areas will be far slower than those in urban areas, which typically exceed 20 Mbit/s.

Expanded availability of fixed and mobile connectivity in recent years is reflected in levels of uptake. Superfast broadband penetration has increased from 16%[15] of premises in 2014 to 40% in 2018.[16] However, around half of households with access to superfast broadband are currently still not subscribing to the service. Concurrently, the average fixed broadband speed has doubled from 21 Mbit/s[15] to 42 Mbit/s[17] and average household monthly data usage has approximately quadrupled to reach around 200 GB per month.[17]

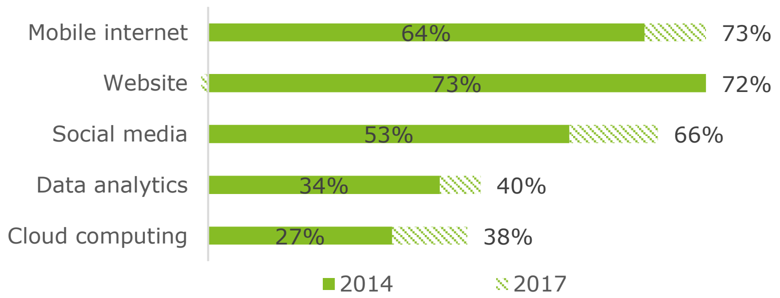
With regard to mobile connectivity, 4G subscriptions have now become the norm, with 87% of smartphone users (who account for 82% of all mobile phone users)[10] holding a 4G subscription, up from just 30% in 2014.[18]

However, the quality of internet service received in practice can vary greatly. Average fixed broadband speed in 2017 was 46 Mbit/s in Scotland's urban areas, but only 20 Mbit/s in rural areas.[17] The digital divide in mobile performance may be even greater. Though a speed differential has not been measured to date, statistics on 4G coverage only capture the provision of 4G services that deliver at least 2 megabits per second, which is less than a tenth of average 4G speeds across the UK, and is lower even than typical 3G speeds.[19]

2.3 Trends in business usage

Recent years have seen improvements in business adoption of key technologies such as cloud computing, data analytics and IoT, which have been demonstrated to support a range of benefits, from driving cost reduction and efficiency to enabling the development of innovative new services.

Figure 14: Adoption rates amongst Scottish businesses for key digital technologies, 2014 and 2017



Source: Scottish Government – Digital Economy Business Survey

The rapid growth in the usage of cloud computing is particularly notable, as the technology is now being used in some form by over a third of Scottish businesses. Among these businesses, the most common cloud-based applications are email services and office software such as word processing and spreadsheets.

[14] Ofcom (2018). 'Award of the 700 MHz and 3.6-3.8 GHz spectrum bands'
[15] Ofcom (2014). 'Infrastructure Report 2014'
[16] Ofcom (2018). 'Connected Nations 2018 – Scotland report'
[17] Ofcom (2017). 'Connected Nations 2017 – Scotland'
[18] Ofcom (2014). 'Ofcom Technology Tracker, Q1 2014'
[19] Opensignal (2018). 'Mobile Networks Update: UK (October 2018)'

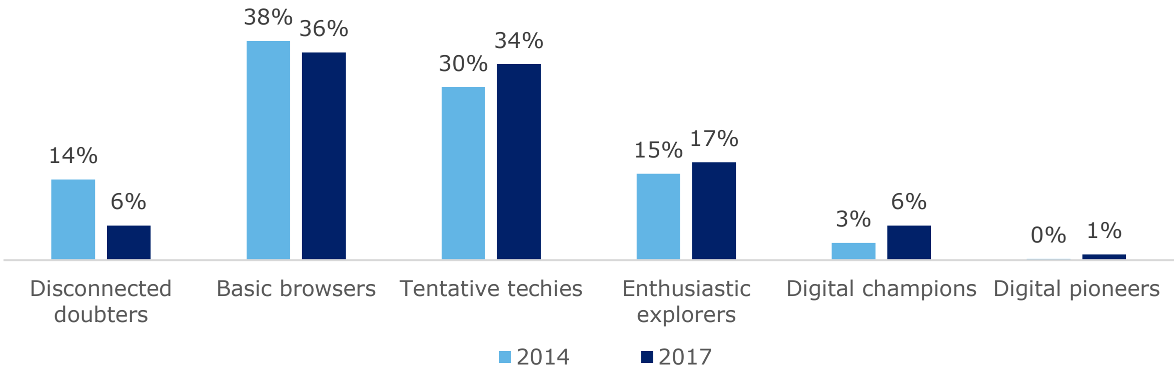
Data analytics is also increasing, whereby organisations employ solutions such as data mining, data visualisation and database tools. Data analytics can be used for myriad purposes, such as deriving business insights that enable faster and more effective decisions, or reveal client preferences, market trends and issues in supply chain processes. The value of data analytics increases as a result of wider technological innovations, such as IoT, which allow larger volumes of valuable real-time data to be captured.[20]

The figures included above also reflect the changing ways in which businesses carry out online business, as the proportion of firms actively using social media is now almost on a par with the proportion who have a website, the latter having now stabilised. For some small businesses, creating a social media profile may be an easy and effective alternative to creating and maintaining a website.

Despite these advances, there remains clear scope for improvement, particularly in achieving further growth in cloud computing and data analytics adoption. For example in Finland, a leading country for cloud adoption, an estimated 65% of enterprises currently use cloud computing.[21]

The Scottish Government's Digital Maturity Index reflects the scope for further progress. Based on indicators of digital maturity such as the type of internet connectivity used, the adoption of digital technologies, and the quality of employees' digital skills, only 7% of Scottish businesses are classed as digital pioneers or digital champions, although this is up from 3% in 2014.

Figure 15: Digital Economy Maturity Index in Scotland, 2014 and 2017



Source: Scottish Government – Digital Economy Maturity Index

A key result of the most recent iteration of the Digital Economy Maturity Index released in 2017 was that there remains a considerable gap in the average digital maturity and capability of SMEs (businesses with less than 250 employees) relative to large businesses (businesses with 250 or more employees). Despite large companies comprising only 6% of the total number of businesses surveyed, they accounted for 19% of all businesses classified as digital champions, and 20% of all businesses classified as digital pioneers.

2.4 Trends in consumer usage

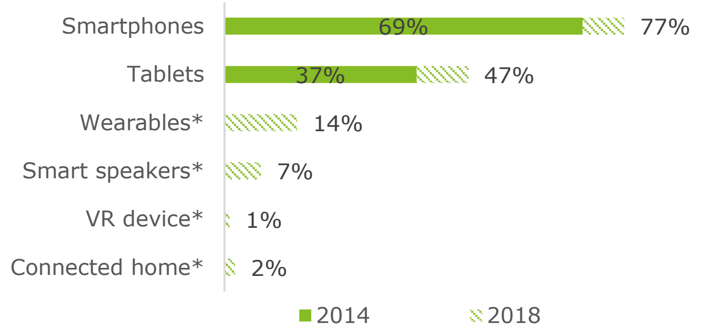
In recent years, consumer usage has continued to evolve rapidly, with consumers making use of a wider range of connected devices to engage in a greater number of activities than ever before.

Adoption of smartphones and tablets has continued to grow, with smartphones clearly remaining the preferred device for everyday online tasks. Beyond this, new types of connected devices have started to gain significant traction with consumers, including wearable devices such as smart watches and fitness trackers which have achieved mainstream appeal with 14% adoption. Newly

[20] Cebr (2016). 'The Value of Big Data and the Internet of Things to the UK Economy'
[21] Eurostat (2018). 'Cloud computing - statistics on the use by enterprises'

introduced smart speakers by companies such as Amazon and Google which are already being used by 7% of people in Scotland and rank as the fastest-growing connected device in the world currently.[22]

Figure 16: Adoption rates amongst Scottish consumers for major connected devices, 2014 and 2018

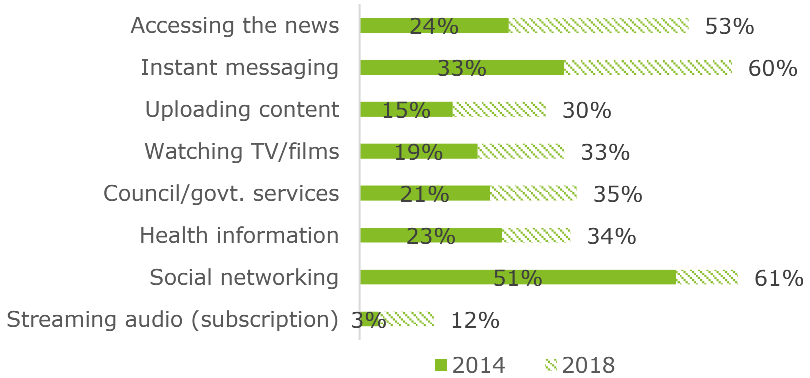


Source: Ofcom Technology Tracker

Consumer are increasingly opting to conduct more everyday activities online. Online services can offer superior ease of access, ease of use and cost, and consequently yield significant benefits in the form of enhanced convenience, and time and financial savings. The magnitude of this change is reflected in the 100% increase since 2007 amongst UK consumers in the average number of time spent online per person per week, from 12 hours to 24 hours.[23]

Leisure activities such as social networking and streaming audio-visual content remain among the most popular, but activities such as accessing the news, using online public services and accessing health information have also seen rapid growth.

Figure 17: Online activities with largest increase in usage amongst internet users in Scotland



Source: Ofcom Technology Tracker

As online services continue to become more expansive in scope and develop greater functionality, consumers may yet benefit from further convenience benefits and time savings. However, some socio-demographic groups are at risk of being excluded from these benefits:[24]

- Whereas 99% of adults aged 16-24 use the internet in Scotland, only 63% of those aged 60 or older do.

- In the 20% most deprived areas, 19% of adults do not use the internet, compared to only 7% in the 20% least deprived areas.

[22] Deloitte (2018). 'Technology, Media, and Telecommunications Predictions 2019'
[23] Ofcom (2018). 'Adults' Media Use and Attitudes Report'
[24] Scottish Government (2017). 'Scotland's People Annual Report 2017'

The geographic divide in connectivity may also contribute to reduced usage of online services in rural and remote areas, where coverage can be limited and average speeds are lower, as set out in Section 2.2.

2.5 Trends in the public sector

Since the previous study, the availability of online public services and information has increased, resulting in the percentage of Scottish adults making use of their local authority's or the Scottish Government's websites increasing from 20% in 2014[18] to 30% as of 2018.[10] The most common uses are looking for information, downloading and sending forms, asking questions, making complaints and making payments.[24]

Data is not available to quantify public sector usage of digital technologies in the same level of detail as for consumer and business usage. However, recent trends indicate some progress, with public sector digitalisation featuring on the Scottish Government's agenda since the publication of the 2011 digital strategy,[25] and reflected in achievements such as:

- The formation of Revenue Scotland, a centralised Scotland-wide tax collection system with an online platform which is now used for 98% of all tax returns;[26]

- The launch of mygov.scot, which has replaced DirectScot.org, the Scottish Business Portal, miscellaneous Scottish Government websites with duplicated content, and traditional paper-based services with a consolidated, first point of access for all online public services for both citizens and businesses alike;

- The establishment of the Scotland Wide Area Network (SWAN), an exclusive and secure public services for all public service organisations, including schools, hospitals, GP surgeries, pharmacies and local council offices that has already generated £30m in savings;[26]

- The digitalisation of the provision of healthcare, with NHS Scotland revamping their online support for young people struggling with mental health, and adopting Patientrack – an electronic monitoring and pre-emptive warning system to provide healthcare professional with real-time data for at-risk patients.

While these developments show tangible progress, the fact that 70% of adult citizens in Scotland are estimated to still not be making use of online public services indicates scope for further progress, and some risk of excluding particular socio-demographic groups. A particularly relevant consideration may be Scotland's ageing population. Latest estimates suggest that 18.9% of Scotland's population is aged 65 or over,[27] slightly higher than the corresponding figure for the United Kingdom of 18.3%.[28] Such users may stand to benefit particularly from digital public services, particularly if they are less able to travel, but equally they may face barriers in digital skills and access to suitable connectivity.

[25] Scottish Government (2011). 'Scotland's Digital Future: A Strategy for Scotland'
[26] Scottish Government (2017). 'Realising Scotland's full potential in a digital world: a digital strategy for Scotland'
[27] National Records of Scotland (2017). 'Projected Population of Scotland (2016-based)'
[28] Office for National Statistics (2017). 'Table A1-1, Principal projection - UK summary'

3 The 5G opportunity

This section explores the capabilities that 5G networks are expected to offer and the potential use cases it could support in the future, with a focus on use cases that build on Scotland's existing competitiveness and areas of current innovation across industry and academia.

3.1 Overview of 5G

What is 5G?

'5G' refers to the next generation of mobile network technologies that are due to be deployed commercially by mobile operators worldwide from 2019. 5G has the potential to enable improvements including much faster download and upload speeds, higher capacity to ease congestion and accommodate more connected devices, and lower latency,[29] which is crucial for any applications that require an instant response with virtually no lag (from online gaming to control systems for key infrastructure assets).

Figure 18: Summary of key theoretical capabilities of 5G

- **Data rates:** Peak data rates of 20Gbit/s (20x higher compared to 4G)
- **Latency and reliability:** Delays of 1ms (10x lower compared to 4G), with 99.999% reliability
- **Connection density:** 1,000,000 devices per square km (10x higher compared to 4G)
- **Mobility:** Support for high mobility up to 500 km/h, with low interruption time
- **Energy efficiency:** Increased efficiency so that energy consumption of mobile networks does not increase, despite the enhanced capabilities

Source: ITU, 2017, 'Minimum requirements related to technical performance for IMT-2020 radio interface(s)'

5G differs from previous generations in that it is expected to integrate other wireless technologies, including 4G, WiFi and IoT technologies, rather than simply replacing previous generations. In the long-term, 5G is expected to enable versatile networks that can be managed and optimised in real-time, offering seamless connectivity regardless of use. A key component of this is network slicing, which allows operators to provide multiple virtual networks using the same physical infrastructure. Each virtual network can be tailored to different end-users, or user classes, who may have different requirements.[30]

It should be noted that the above are theoretical capabilities based on current technical standards of 5G. As with previous mobile network technologies, the technical standards may evolve further over time, though equally the real-world performance for the average user would typically fall short of these standards. For example, current 4G networks based on LTE or LTE-Advanced technology are delivering average speeds of 10 Mbit/s to 40 Mbit/s in most countries, despite theoretical maximum speeds of 150 Mbit/s to 600 Mbit/s being supported, depending on devices used.[31]

[29] Latency refers to the time taken for data to travel between points in a network. Users of current networks typically experience latency of a fraction of a second, but this can still create a noticeable "lag".
[30] Ofcom (2018). 'Enabling 5G in the UK'
[31] Android Authority (2018). '4G vs LTE – what is the difference?'

For 5G, the fastest data transmission in laboratory trials has reached 1 terabit per second and field trials have reached 35 Gbit/s. Deloitte has predicted that 5G under real-world conditions will likely be slower than 35 Gbit/s but still markedly faster than 4G networks – and also faster than some fibre and cable solutions.[22] Equipment vendors have attempted to simulate real-world environments and achieved speeds of around 500 Mbit/s and 1.4 Gbit/s in different trials.[32]

What will 5G be used for?

In the short term, 5G is most likely to be used by mobile operators to ease network congestion in dense urban areas. However, in the medium and long term 5G has the potential to support a wide variety of more transformative use cases.

Three broad types of 5G usage scenarios have been envisaged in the literature, as summarised in Figure 19.[33]

Figure 19: Key usage scenarios for 5G

More data *Enhanced mobile broadband*	**More devices** *Massive machine-type communication*	**Instant response** *Ultra-reliable low latency communication*
• Enhances mobile broadband use with higher speeds and seamless experience, even in dense environments • Supports high-bandwidth tasks such as Augmented Reality (AR) and Virtual Reality (VR) apps	• Enables the connection of a very large number of connected devices (up to 1 million per sq km), supporting low-energy devices • Supports large-scale IoT deployments across sectors	• Enables applications that are heavily dependent on very low latency and high reliability • Supports ‘mission-critical’ applications, for example in transport, healthcare or energy

Source: Deloitte based on ITU, 2015, ‘IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond’

The three usage scenarios reflect the possibility that users may have very different technical requirements. For example, consumers may demand high bandwidth to stream immersive audio-visual content, while some business users may instead rely on low-latency and reliable connectivity across a large number of devices in order to monitor operations in real time. Hence, the ability of 5G to support separate virtual networks tailored to diverse requirements is likely to be key for simultaneously enabling a variety of specialised use cases.

Current industry expectations are that 5G may be used primarily in enhanced mobile broadband scenarios in the near future, delivering an evolutionary improvement of user experience for existing services.[34] The use of 5G for the development of more advanced IoT applications and new mission-critical applications may be longer-term prospects.[3035]

As a separate proposition, the use of 5G as an alternative to wired broadband in urban areas is receiving attention, particularly in the US, in contrast to the UK where wireless-only home internet is currently rare.[36] A study for Ofcom found that “*5G at a fixed location might … be a relevant solution in areas which could not otherwise be reached by a fixed network*”.[37] Other studies for the UK National Infrastructure Commission found that the potential costs and benefits of using 5G to

[32] Qualcomm (2018). ‘Qualcomm Network Simulation Shows Significant 5G User Experience Gains’
[33] Note that some specific use cases may combine elements of each usage scenario
[34] GSMA (2017). ‘The 5G era: Age of boundless connectivity and intelligent automation’
[35] Mobile World Live (2018). ‘Huawei signs 45 5G MoUs with operators’
[36] Deloitte (2018). ‘Technology, Media, and Telecommunications Predictions 2019’
[37] WIK-Consult (2018). 'The Benefits of Ultrafast Broadband Deployment'

provide home broadband in urban areas (for example '5G to the lamp-post') may make it a viable commercial proposition.[38]

Where and when will 5G be available?

The first commercial 5G networks are expected to become available in the UK in 2019 in selected urban areas, at the same time as the first 5G consumer devices, such as smartphones and smart hubs, become available. Mobile operators have announced that they will be introducing 5G in Scotland focusing on parts of Edinburgh or Glasgow in 2019.[39] However, initial deployments are unlikely to deliver performance levels that reach 5G's full potential – as with previous generations of mobile network technologies, this is expected to be a gradual process.

Deployment of 5G networks over large geographic areas may take several years. As the business case for large-scale 5G deployment is still at a nascent stage, there is uncertainty over how and where network infrastructure will be deployed beyond the densest of urban areas and the timeframe for this.

The benefits of 5G connectivity are largely dependent on deployment of a large number of "small cells", which are transmission systems with a short geographic range, unlike the base stations or towers traditionally used to deliver mobile coverage over wider areas. The business case for small cell deployments in more dense urban areas is naturally stronger. However, with the requirement for adequate fibre infrastructure to support higher traffic and backhaul requirements,[37][40] as well as other factors such as access to suitable sites for small cell deployments,[30] there remains a significant degree of uncertainty over the extent and timing of urban 5G deployment.

In rural areas, where population density is lower, the business case for 5G deployment may be particularly challenging. Nevertheless, some studies suggest that 5G does offer technical capabilities that make rural network expansion and upgrades more economical than with current technologies, even if initial deployments focus on dense urban areas.[41] Even with 5G, rural deployments may require compromises in terms of lower levels of bandwidth or higher latency than would be available in urban areas.[42]

5G may also bring changes in the supply chain, with new types of players and business models potentially emerging. 5G is expected to be deployed in the UK by the current MNOs initially, but eventually it is possible that sector-specific private networks or new types of intermediaries could become more common.[30]

[38] Tactis and Prism (2017). 'Costs for Digital Communications Infrastructures'; Frontier Economics (2017). 'Future Benefits Of Broadband Networks'.
[39] https://newsroom.ee.co.uk/ee-announces-5g-launch-locations-for-2019/
https://5g.co.uk/news/o2-launching-5g-london/4752/
[40] Backhaul refers to the transfer of data from mobile base stations to operators' core networks. See Deloitte (2017). 'Communications infrastructure upgrade - The need for deep fiber'
[41] Yu, Yiting (2016). 'Energy- and Cost-Efficient 5G Networks in Rural Areas'
[42] Oughton, Edward J. and Frias, Zoraida (2016). 'Exploring the cost, coverage and rollout implications of 5G in Britain'

3.2 Potential 5G use cases

To date, current wireless technologies have already enabled major new use cases for connectivity. For example:

3G Networks and WiFi	4G networks	IoT technologies
• 3G networks and WiFi – in combination with the advent of the smartphone – have contributed to the development of an app economy • This created a platform for new types of digital services and business models to be created	• 4G networks – in combination with more sophisticated smartphones and tablets – have enabled further innovation • Examples range from higher-definition streaming and use of AR and AI capabilities to create new ways of doing things	• More specialised network standards, such as NB-IoT and LTE-M, are facilitating new IoT use cases for devices that transmit small amounts of data • However, commercial use of these technical standards is still gradually developing

While there is certainly scope to further exploit existing network technologies, in the longer term 5G connectivity creates an opportunity to support a wider range of innovative use cases, particularly in combination with other technological trends.

Overview of potential use cases

Individual use cases for 5G typically involve satisfying needs for very high bandwidth, reliable ultra-low latency, and/or a high density of connected devices, in combination with technologies such as cloud computing, AR and VR that may be enhanced by 5G.

Wireless networks are crucial from transmitting data between devices, to the cloud, and back to end-user devices. Cloud services are becoming more sophisticated, increasingly integrating data analytics and AI capabilities that historically would only have been available to a select few organisations. Together these technologies allow new use cases to be built on top of wireless connectivity and real-time data, from video analysis, to automated vehicles, factories and drones. From an end-user perspective, 5G facilitates the use of immersive audio-visual applications that bring the underlying data to life for users and tailor it to their location and context.

Aside from the requirements of individual use cases, pervasive 5G connectivity may also be a pre-requisite to facilitate the concurrent adoption of a large number of different use cases. The higher aggregate capacity offered by 5G networks and the ability to create separate, tailored virtual networks could be used to support a much wider range of diverse and complex use cases simultaneously while maintaining a seamless user experience.

Potential 5G use cases typically involve one or more of the following elements:

Remote monitoring
Networks of sensors and devices used to monitor business processes and operations and end-user usage in real time.

Examples
- Healthcare – patient monitoring through wearables and in-home sensors
- Agriculture and aquaculture – soil and water conditions, livestock tracking
- Public services – smart bins, smart parking

Benefits
- More efficient and accurate
- Removes geographic barriers
- Environmental benefits from reduced travel
- More frequent and detailed data collected

Remote control and automation
Using real-time data, businesses can respond more quickly, by intervening manually or through automated processes.

Examples
- Healthcare – remote diagnosis, response and surgery
- Transport – traffic management, automated vehicles
- Manufacturing – automated production

Benefits
- Efficiency and cost savings
- Environmental benefits from more efficient use of resources
- Increased safety by removing human error

Immersive content
Higher bandwidths and lower latency support high-fidelity content and lag-free two-way communications using AR and VR.

Examples
- Media and entertainment – cloud-based gaming, AR and VR multiplayer games
- Education – tailored, interactive training
- Tourism – immersive content on tourist attractions

Benefits
- New revenue opportunities
- Removes geographic barriers
- Improved user experience and engagement

AI and ML analytics
New uses of data using artificial intelligence and machine learning tools

Examples
- Public services – video analysis for crime detection, accident prevention
- Infrastructure – predictive maintenance by using data insights to pre-empt faults
- Agriculture – crop spraying using video analysis

Benefits
- Efficiency and cost savings
- Improved safety
- New insights obtained from data

Specific use cases in key sectors are discussed in more detail in the remainder of this section.

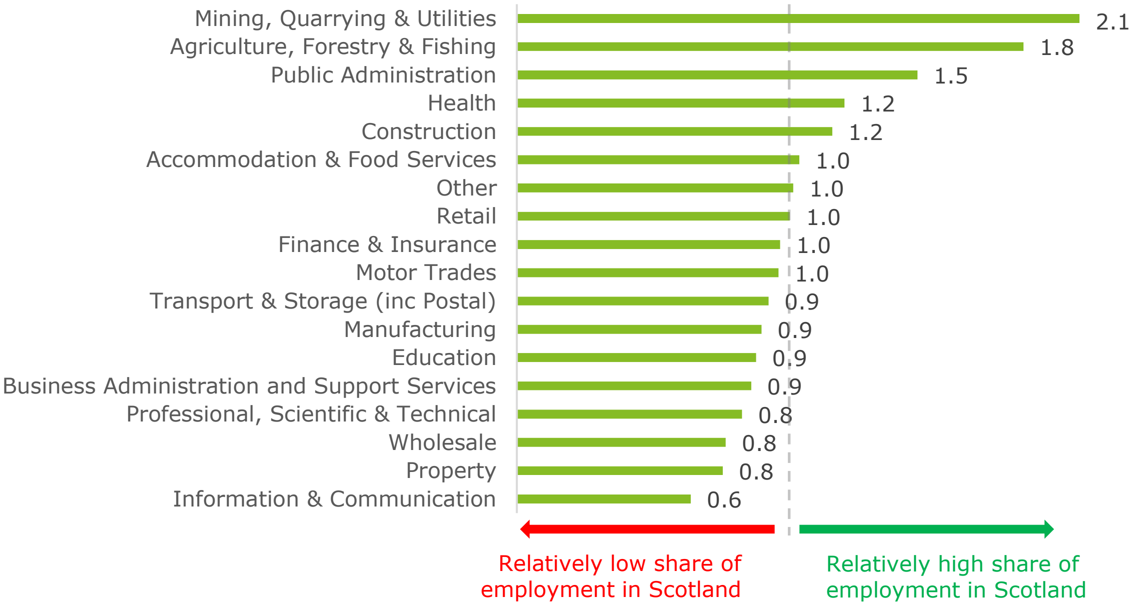
Implications for Scotland

New use cases enabled by 5G could have profound implications for Scotland. With a relatively low population density and approximately 330,000 residents living in remote rural areas, the potential benefits from remote service delivery may be particularly significant in Scotland, for example in terms of healthcare, education and training. The same logic would apply to remote control or automation use cases, where the large distances involved entail large potential gains from remote or automated processes that reduce the need for travel. More generally, the use cases examined in the rest of this chapter indicate potential benefits in dense urban areas, as well as use cases in tourism, agriculture and aquaculture that can support the sustainability of rural communities.

For the purpose of this study, potential 5G use cases have been analysed in context of Scotland's existing areas of competitiveness and innovation. As a proxy to illustrate the sectors that are particularly important for Scotland's economy, Figure 20 shows an index based on the number of employees in each industry group in Scotland and in the UK as a whole. The values shown are calculated as each industry's percentage share of total employment in Scotland, divided by the same industry's share of total UK employment.

Therefore, a value greater than 1 in Figure 20 indicates that the industry group is relatively important for Scotland's economy. For example, 2.6% of Scotland's workforce is employed in Mining, Quarrying and Utilities, compared to 1.3% in the UK. The index value is calculated by dividing the sector's share of employment in Scotland (2.6%) by the same measure in the UK (1.3%), leading to a high index value of around 2. On the other hand, only 1.3% of Scotland's workforce is employed in Property, compared to 1.8% in the UK, leading to a low index value of 0.8 (1.3% divided by 1.8%).

Figure 20: Illustrative index – ratio of Scottish employment share to UK, by sector (2017)



Source: Deloitte analysis of data from the ONS UK Business Register and Employment Survey. The values are calculated as the industry share of total Scottish employment divided by the industry share of UK total employment.

As the analysis shows, key industry groups for the Scottish economy include the following, which together account for more than one quarter of total employment in Scotland.

Mining, Quarrying & Utilities – A key component of this industry group is the oil and gas extraction industry (index value of 8.6), though the electricity sector also accounts for a relatively high share of employment (index value of 1.5).

Agriculture, Forestry and Fishing – Fishing and aquaculture is a particular area of strength for Scotland (index value of 7.8), with farmed salmon being the UK's largest food export, though agricultural activities also rank highly (index value of 1.8).

Public Administration – Across the spectrum of activities related to public services, the public sector is a particularly prominent employer in Scotland relative to the UK as a whole.

Health – This includes hospital activities (index value of 1.3), which employ around 170,000 people in Scotland, as well as social work (index value of 1.3).

The remainder of this section explores potential 5G use cases in areas aligned with the key industry groups above. In addition, selected other industries where 5G, in conjunction with current industry and academic initiatives, could generate a transformative impact in Scotland are also discussed – namely, transport; immersive content (including applications in the media and entertainment sector as well as other sectors, such as education and tourism); and manufacturing and warehousing. The resulting economic and social impacts are analysed further in Sections 5 and 6.

Among current initiatives, 5G RuralFirst in one of several collaborative programmes being part-funded through DCMS and it is helping to demonstrate a range of potential transformative impacts for Scotland.

5G RuralFirst

5G RuralFirst is a co-innovation project led by Cisco and the University of Strathclyde, alongside a consortium of other partners from industry, government, and academia.

The project is currently developing rural test-beds and trials for 5G wireless and mobile connectivity, based primarily in the Orkney Islands, as well as Shropshire and Somerset. Through new approaches to deploying connectivity in rural areas, the project is trialling a variety of 5G use cases across key sectors such as agriculture, tourism, renewable energy and manufacturing that operate in rural environments. Examples are included in the following sections.

Energy and resources

The higher capacity of 5G could support a greater number of smart sensors and devices across the energy ecosystem, while reliable ultra-low latency connectivity supports more efficient automated processes to optimise generation, extraction, distribution or energy usage in real time.

The enhanced connectivity provided by 5G has the potential to enable new solutions for the energy market. In particular, "smart grids" are often discussed as a key 5G use case, while industrial IoT solutions supported by 5G could benefit companies involved in energy generation or oil and gas extraction.

While there is no universally agreed definition of smart energy grids, the mission describes these as "*energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand*".[43] Wireless networks are at the heart of this, allowing generation and demand to be monitored and controlled in real time.[44]

By making grids smarter, a range of benefits may be possible. For consumers, greater efficiency may translate to cost savings on energy bills. The energy system as a whole may be more secure, reliable and better able to transition towards low-carbon solutions.[44] In aggregate, the wider economy may benefit: in the UK the development of smart grids could lead to approximately £13 billion of Gross Value Added between now and 2050.[45]

- The low-carbon economy is a key area of focus for the Scottish Government.[46]
- Integrating renewable energy is challenging as its supply is volatile, while new developments such as electric vehicles could increase demand at peak times.
- Transport Scotland is already involved in trials using wireless networks to connect and remotely control electric vehicle charging terminals.
- The Ruggedised project in Glasgow is trialling a variety of smart grid solutions that could be enhanced by 5G connectivity, such as smart street lights using demand-side management, and smart electric vehicle charging hubs.

Aside from smart grids, the use of connected sensors and devices over 5G networks could have a variety of applications in areas such as energy generation and resource extraction. Despite obvious challenges, some wireless networks have been established in the North Sea.[47] Modern offshore drilling platforms have about 80,000 sensors generating vast volumes of data, while mobile devices are already being deployed in the oil and gas sector to track assets and employees.[48]

[43] European Commission (2018). 'Smart grids and meters'
[44] Department of Energy & Climate Change (2014). 'Smart Grid Vision and Routemap'
[45] Ernst & Young (2012). 'Smart Grid: a race worth winning?'
[46] Scottish Government (2010). 'A Low Carbon Economic Strategy for Scotland'
[47] https://www.subseauk.com/10123/tampnet-expand-offshore-4g-lte-coverage-to-the-west-of-shetland
[48] World Economic Forum (2017). 'Digital Transformation Initiative – Oil and Gas Industry'

5G networks could support further progress in this area by supporting more connected sensors and devices and providing low latency connectivity for new automated processes, which could replace current manual processes that are time-consuming, difficult or risky.

- The 5G RuralFirst project is trialling a connected wind farm use case. IoT sensors will enable equipment and weather monitoring to identify potentially dangerous weather conditions and minimise any adverse impacts.[49]
- A trial at Shetland Gas Plant is using a mobile robot to perform tasks such as reading dials and measuring temperature and gas concentration. In the long run this is expected to improve safety and reduce costs.
- The innovation centre CENSIS has worked with various partners to explore IoT use cases, including use of corrosion and moisture sensors to facilitate predictive maintenance models in the future.[50]

Agriculture and aquaculture

5G has the potential to support various farming and fishing use cases that rely on a large number of IoT sensors, while reliable low-latency connections could support efficient automated processes such as irrigation, and fast speeds can enable innovative use of ultra-high definition video for detailed monitoring of crops, livestock or fish.

Specific agricultural use cases discussed in the literature include remote monitoring of soil temperature and moisture, crop development and livestock, with more advanced use cases pairing IoT capabilities with remote control or automation to deliver optimised 'precision farming'. Examples of the latter include automated irrigation, or real-time aerial monitoring of crops and livestock through the use of drones. Where devices such as drones have cameras, video analytics tools can be used to automate processes in real-time, for example precise pesticide spraying where weeds have been detected. These systems may be able to perform tasks more efficiently and accurately than humans, freeing up workers to focus on less menial value-add tasks.

In this area, countries such as Japan provide an indication of what can already be achieved – which could yet be surpassed once 5G connectivity becomes widely available. Japan adopted a Smart Agriculture policy in 2014. The country has leveraged its strengths in robotics and ICT more broadly to create a number of partly or fully automated farms.

Many of the same principles apply to fishing and aquaculture, where sensors can be used to collect detailed real-time information to optimise operations and detect any problems pre-emptively. The availability of adequate connectivity in rural areas is likely to be a key enabler for many of these use cases.

[49] https://www.5gruralfirst.org/project/industrial-iot/
[50] https://censis.org.uk/2018/06/08/sensor-project-tackles-billion-pound-challenge-of-hidden-corrosion/

The 5G RuralFirst project is trialling a number of relevant use cases:

- Aquaculture health monitoring – Using IoT sensors to measure parameters such as pH and temperature inside and outside salmon cages.
- Autonomous tractors – Testing the use of 5G to control autonomous tractors in real-time, via drones.
- Drone soil analysis – Drones are used to analyse the soil and tractor control to spray fertilizer on needed areas.
- Livestock monitoring – Sensors are being used to monitor the health and behaviour of cows. In Scotland, WellCow is pursuing similar use cases.[51]
- Hyperspectral imaging – Testing if 5G can enable real-time soil analysis from a plane flying at 900 metres.
- AnimalCare – Use of AR content to offer remote support from veterinarians, enabling farmers to ask advice and see how to care for animals in real time.

Public services

5G can support smart city use cases where a dense deployment of sensors is used to efficiently manage public infrastructure and services, with network slicing technology to optimise network performance and reliability in real time across all of these services.

5G could unlock new opportunities for local authorities and other public bodies to deploy smart public infrastructure, with sensors installed in street furniture such as signage, street lamps, waste bins, traffic lights and parking meters to collect and send data and allow for intelligent management of public services.

These use cases can promote a range of socio-economic benefits, including:

- Increased public safety through a variety of use cases – for example, notifications on digital signs of oncoming emergency vehicles; warning systems using low-latency connectivity to predict potential collisions and alert emergency vehicle drivers; threat and crime detection using sensors combined with high quality audio, CCTV video and AI analytics.
- Lower costs through auto-dimming street lights, optimised heating and cooling of public buildings, and optimised waste collection.
- Higher revenue through optimised use of parking spaces using sensors to monitor availability in real time. Experience to date suggests that smart parking solutions could increase parking revenues by 27%.[52]
- Lower traffic congestion and environmental pollution through efficient public transport passenger loading and dynamic bus routing using real-time information on utilisation, smart parking solutions and traffic management systems, and pollution monitoring sensors.

[51] http://wellcow.co.uk/
[52] Accenture (2017). ‘How 5G Can Help Municipalities Become Vibrant Smart Cities’

Glasgow has seen a number of trials and initiatives for smart public service provision that could be strengthened by 5G networks. These include:

- Intelligent street lighting, with features such as remote control, air pollution detection, movement detection to monitor congestions and flows of people, and noise detection to enable real-time responses to disturbances.[53] Similar initiatives are taking place in Aberdeen, Perth and Stirling.[54]
- Smart water management to monitor water levels using cameras and sensors, to provide early warnings and enable flood responses.

Dundee, Edinburgh, Glasgow, Inverness, Perth, and Stirling are involved in smart waste management projects, including smart bins, route optimisation for collection, and improved data sharing.[54]

Glasgow City Council is currently exploring potential commercial models to facilitate 5G deployment across the whole city, making use of public infrastructure to host small cells. Various other local authorities are considering options to accelerate 5G rollout and the development of smart public infrastructure and services.

Healthcare

5G can support a connected, seamless ecosystem of devices to monitor and analyse patient health in new ways, with further potential use cases reliant on high reliability, ultra-low latency and high speeds for innovative applications of AI, robotics and high-fidelity imaging.

The healthcare sector is ideally suited to remote monitoring and service delivery use cases, particularly where this helps to serve patients in rural or remote areas. Initiatives in these areas can form part of a wider trend of digitalisation and virtualisation of healthcare, transitioning from costly hospital-based care towards decentralised remote care. In this way it can support both cost reduction and a shift to treating root causes of health problems, such as lifestyle and wellness.[55]

Specific use cases can include remote monitoring of patients' health data by healthcare professionals (or by AI software) utilising wearable medical devices or implanted bio-medical devices. This allows for the real-time collection and analysis to support a variety of applications such as assisted living, chronically-ill patients and preventive care.

5G's reliable low-latency capabilities could also enable innovative uses of robotics for remote surgery – where surgeons use tactile sensors to perform surgery remotely – potentially increasing access to specialised care for those in remote areas of Scotland. While remote surgery may only be used in relatively rare cases, it has the potential to save lives where it allows patients faster access to the necessary surgical expertise. Tactile applications and AR or VR content could also be used to train medical professionals through realistic simulations.

5G's ability to connect a large number of devices in dense areas may also facilitate further adoption of use cases that help to manage healthcare assets and resources more efficiently. This includes allowing hospitals to manage a high number of valuable assets, including beds, wheelchairs and monitors, as well as using data to develop personalised pharmaceutical dosages that may be administered remotely.[55][56]

[53] http://futurecity.glasgow.gov.uk/intelligent-street-lighting/
[54] Smart Cities Scotland (2018). '8th City Update – Issue 11, Q3 2018'
[55] 5G PPP (2015). "5G and e-Health'
[56] DotEcon and Axon (2018). 'Study on Implications of 5G Deployment on Future Business Models'

- The FitHome project involving Albyn Housing Society, Carbon Dynamic and NHS Highland is using sensors on doors, windows and appliances to monitor behaviour and use AI to detect possible deterioration in health.
- A Scottish hospital is using IoT to monitor its medical beds in order to automate bed maintenance, a traditionally manual process[57]
- An NHS pilot has seen Scottish ambulances use satellite connectivity to beam high-resolution images to hospitals while in transit, enabling earlier diagnosis and pre-emptive treatment. With the higher performance of 5G connectivity this could be achievable on a much wider scale.
- The 5G RuralFirst project is using IoT sensors to monitor water temperature in a school to prevent legionella bacteria growth. This could be a more cost-effective means of ensuring pupil health and safety.
- PillCam trials – which use cameras inside capsules to capture internal video images – in Scotland have demonstrated the need for high bandwidth connectivity to transfer data from GP surgeries to hospitals.[58]

Transport

5G networks may eventually support driverless vehicles and smart traffic management systems as part of a seamlessly integrated transport system, where connectivity is needed to provide an instant and reliable response across myriad devices and sensors. More generally, 5G networks could improve connectivity along transport networks and help ensure consistent passenger access to any service.

At a general level, connectivity along transport routes is key for supporting passenger productivity and the delivery of content. More specifically, innovative use cases may be dependent on such connectivity. The use of 5G technology is frequently discussed in relation to connected and autonomous vehicles (CAVs). These are vehicles that are:

- Connected: able to communicate with the surrounding environment, for example with other vehicles or infrastructure; and
- Autonomous: able to operate with reduced or no driver input.

There are alternative schools of thought regarding the role of 5G in the development and deployment of CAVs. For example, the view of the Society of Motor Manufacturers and Traders is that "*vehicles with some levels of automation do not necessarily need to be connected, and vice versa, although the two technologies can be complementary*".[59]

Nevertheless, a common view is that reliable and low-latency 5G connectivity could have various benefits. Various safety use cases, including warning services, may rely on advanced connectivity between the vehicle and the surrounding environment. Connectivity could serve to provide redundancy in cases of sensor failure or inability to function accurately, for example in extreme weather conditions. 5G connectivity could allow more efficient coordination between autonomous vehicles, for example driving closer together and reacting more quickly to prevent collisions, using 360-degree data rather than line-of-sight data collected through sensors.

[57] CENSIS (2018). 'NHS gets connected with new IoT trial to track hospital beds'
[58] Digital Catapult (2018). 'The UK 5G Ecosystem 2018 – 5G activities and capabilities in the UK'
[59] Society of Motor Manufacturers and Traders (2017). 'Connected and Autonomous Vehicles – Position Paper'

The potential economic and social benefits from CAVs could be vast, potentially including:

- Increased accessibility and mobility, for example for the elderly or disabled.
- Improved road safety, including the potential to reduce the number of fatalities.
- Productivity gains from improved connectivity on the move, and from vehicle autonomy freeing drivers to engage in other activities.
- Environmental benefits from reduced congestion and increased fuel efficiency.

In aggregate, KPMG estimates a £51 billion economic impact by 2030 from the development of CAVs, largely consisting of time savings and increased productivity, against estimated costs of £11 billion.

Benefits for Scotland could be particularly large due to its geography; for example, there may be large efficiency benefits from introducing automated deliveries to remote areas. Scotland's low population density could also entail lower risks of accidents, which creates favourable conditions for trialling and introducing CAVs.

More broadly, 5G could support a future vision of "mobility as a service", where planning, booking, paying for travel and route optimisation all take place seamlessly across transport models from a user perspective. Consistent and reliable connectivity is an obvious prerequisite for this. Deloitte research in the US has estimated that the breadth of future mobility use cases requiring connectivity is expected to generate data traffic of roughly 0.6 exabytes every month by 2020—about 9 percent of total US wireless data traffic.[60]

- Project CAV Forth will trial an autonomous bus service across the Forth Bridge from Fife to Edinburgh
- The 5G RuralFirst project will test the use of 5G to deliver connectivity for a ferry operating between two of the Orkney islands, filling a gap at one end of the journey where the ship loses WiFi from the main port
- Transport Scotland is currently exploring mobility-as-a-service as a proof of concept
- The Scottish Government Digital Directorate, Transport Scotland and SFT are investigating the creation of digital transport corridors by exploring models that could support more effective deployment of connectivity along the transport network

Immersive content

With 5G, faster connectivity and low latency can enable more sophisticated, immersive and user-friendly content using AR and VR. Such content is likely to emerge in the media and entertainment sector, but areas such as education and tourism also stand to benefit from availability of engaging and tailored content.

The higher bandwidth and lower latency offered by 5G are likely to enable the delivery of more sophisticated and immersive audio-visual content. This applies particularly using ultra-high definition standards such as 4K and 8K, or use cases involving AR, VR or multiplayer gaming which require extensive two-way communication in real time, as these rely both on high bandwidth and

[60] Deloitte (2017). 'Connecting the future of mobility'

low latency in order to function. To date, 4G's technical limitations are reported to have restricted development of AR and VR content.[61]

Scotland's audio-visual creative industries appear to be growing rapidly, for example with regard to TV and film production – where spend increased by 30% in 2017[62] – and video game production, where recent growth has been driven by mobile games.[63] For these industries, the new capabilities offered by 5G could be a source of further revenue growth.

Scotland may also be able to leverage its digital creative capabilities to sectors outside of media and entertainment, as a wider variety of AR and VR use cases could emerge if adequate connectivity is available. Immersive audio-visual content could be leveraged as a future tool to enhance traditional approaches to education and training by providing more tailored and engaging materials that take into account the learning preferences and abilities of different individuals. Research on the use of 5G in education appears currently less developed than in more commercial sectors, but international initiatives illustrate potential applications such as AR-enabled learning quests in the user's everyday environment, VR-enabled models of sub-atomic particles and entire galaxies, and a mixed reality game that aims to help students with autism improve their social skills.[64]

In tourism – another key sector for Scotland, employing 8% of the workforce – immersive content can create new forms of smart tourism. For example, 5G has been trialled to allow visitors of Roman Baths to experience reconstructions of the Baths at key moments in history, on a mobile AR app using 360 degree video.[65]

- The 5G RuralFirst project will test the use of 5G to provide connectivity to tour buses in Orkney, delivering VR content created by Historic Environment Scotland.
- The Portal AR app has been created in collaboration with Google and teams from VisitScotland, SDI, Talent Scotland and Scotland.org. It provides an array of AR portals allowing users in any location to enjoy immersive and educational content showcasing some of Scotland's key landmarks.
- The e-Sgoil programme is being used to deliver real-time, interactive lessons, to pupils throughout Scotland using HD video content. 5G could enable more immersive and sophisticated content to be used in the future.

Manufacturing and warehousing

5G networks could satisfy requirements for a high density of connected sensors and for reliable instant response in order to develop more sophisticated automated processes that can drive efficiency in factories or warehouses.

Modern factories and warehouses are characterised by a large number of devices operating together as part of complex coordinated processes. There is clear potential for wireless technologies to improve these processes as part of "Industry 4.0" – the broader trend of digitalisation in manufacturing. 5G-enabled remote control, monitoring and automation of equipment can enhance current processes, generating operational benefits and increased productivity in a wider number of factories at a lower cost.

[61] Seam et al. (2017). 'Enabling Mobile Augmented and Virtual Reality with 5G Networks'
[62] https://news.gov.scot/news/record-spend-on-film-and-tv-production
[63] https://www.heraldscotland.com/business_hq/15912624.scotlands-video-games-industry-on-the-rise-with-huge-upsurge-in-job-numbers/
[64] See https://www.5gedtechchallenge.com/
[65] https://www.bbc.co.uk/rd/blog/2019-02-5g-mobile-augmented-reality-bath

To some extent, current wireless networks may already provide adequate connectivity, but:

- Larger plants may benefit from 5G availability, as it can be difficult to provide adequate wireless connectivity via WiFi over a large area.

- Complex processes may benefit from the ultra-low latency, high reliability and high connection density offered by 5G.

Illustrating the limitations of current wireless technologies, some existing use cases have required proprietary network standards to be developed to satisfy the user's technical requirements. For example, Ocado, an online supermarket, invested in creating a bespoke patented system based on 4G technology to connect and control over 1,000 robots in its warehouse with low latency, which would not have been possible using standard wireless protocols.[66] Ocado uses wireless communications, cloud technology and a machine learning based analytics system to monitor thousands of robots in each warehouse, effectively as a remote healthcare system for robots.[67]

Evidence of the tangible impact that 5G could make in this area is still limited, though an academic study found a positive impact of implementing 5G-enabled maintenance solutions, including through increased production output, improved robustness and reduced maintenance downtime.[68]

- The 5G RuralFirst project is exploring the use of LiFi – the use of light to transmit information, instead of traditional radio frequencies. LiFi could be valuable for industry 4.0 use cases such as automated manufacturing environments, which could enjoy faster, more reliable connectivity that doesn't interfere with radio networks.
- The Scottish Manufacturing Advisory Services has supported innovative solutions such as automated delivery of material to production cells, to improve accuracy and reduce manual handling.[69]

3.3 Key enablers and barriers

Stakeholder interviews and existing literature indicate a number of issues that may need to be overcome in order for transformative 5G use cases to have a pervasive impact on the Scottish economy and society.

Inevitably, a prerequisite for many use cases is the availability of adequate connectivity. In the same way that current shortcomings in 4G coverage and quality of service are still a barrier in some cases, a similar situation could arise in relation to 5G. At this stage it is too early to judge how 5G deployment in Scotland is likely to develop, but key enablers are likely to be spectrum access and availability of underlying fibre infrastructure, in conjunction with developing an environment whereby existing and new assets can be shared to reduce the cost of deployment in less commercially viable areas.

Even where adequate 5G connectivity is available, at present there is still uncertainty about which particular use cases will have a transformative impact. Given the nascent state of 5G, use cases identified to date are largely theoretical and the business case for these remains unclear. Further research and collaboration across government, industry and academia is likely to play an important role in establishing use case feasibility and the likely costs and demand involved.

Finally, even where there is a strong business case, an accelerated adoption of use cases may rely on improving awareness and understanding of 5G and complementary technologies such as cloud

[66] Silicon UK (2016). 'Ocado Uses Unlicensed Spectrum For 'World's Densest 4G Network' At Warehouse'
[67] Deloitte (2018). 'Economic and social impacts of Google Cloud'
[68] Lundgren et al. (2017). 'The value of 5G connectivity for maintenance in manufacturing industry'
[69] Scottish Manufacturing Advisory Service (2018). 'Manufacturing 4.0 Review'

computing, data analytics and AI. Awareness and understanding appear patchy at present, with some organisations – such as SMEs and some local government bodies – potentially at risk of falling behind the curve. Organisational inertia or reluctance to adopt new use cases can also play a part, for example where concerns about data sharing and data security discourage businesses from considering new data-driven solutions.

The following page summarises the analysis of the 5G opportunity for Scotland and suggests some steps that may help to capitalise on this opportunity. Potential economic and social benefits are then analysed in detail in sections 5 and 6.

3.4 Summary

The 5G opportunity for Scotland

5G networks can benefit urban areas, in which initial deployments are likely to focus, but also rural and remote areas, where they could facilitate remote access to key services and contribute to the sustainability of the rural economy. Analysis suggests a number of key industries in Scotland that stand to benefit:

Healthcare. 5G use cases have the potential to drive efficiency and patient engagement, as well as inclusive access to treatment in Scotland's rural and remote areas.	✓ Current initiatives in Scotland include Fit Homes, using in-home sensors to monitor patient health, and use of IoT to monitor hospital beds and automate maintenance.
Transport. 5G connectivity along Scotland's transport networks could support passenger productivity and a more integrated, user-friendly and seamless transport system.	✓ An autonomous bus trial from Fife to Edinburgh is planned, and Transport Scotland is currently exploring mobility-as-a-service as a proof of concept.
Education. 5G could support engaging and tailored digital content. With adequate connectivity this could be accessed by students anywhere, any time.	✓ The e-Sgoil programme brings tele-education to the Western Isles, though there are no current initiatives focusing on the role of 5G.
Public services. Added to the above, other public services in urban areas particularly can benefit from 5G in the context of "smart city" use cases.	✓ Initiatives in Glasgow include smart lighting and water management; other cities feature in the Smart Cities Scotland programme.
Agriculture and aquaculture. New processes driven by data and connectivity could drive efficiency, contributing to the long-term sustainability of Scotland's rural economy.	✓ 5G RuralFirst trials include salmon health monitoring, autonomous tractors, soil analysis using drones and livestock monitoring through "connected cows".
Immersive content. 5G can support immersive content using AR and VR. Scotland's strong digital creative industries could drive innovation, including through immersive content in tourism, supporting rural and remote communities, or in education.	✓ The Portal AR app, created collaboratively by Google, VisitScotland, SDI, Talent Scotland and Scotland.org, provides immersive and educational content showcasing Scotland's landmarks to users in any location
Energy and resources. 5G has the potential to drive efficiencies throughout the supply chain and support Scotland's low-carbon objectives.	✓ Public bodies in Scotland are exploring use cases such as smart lighting, smart heating and smart electric vehicle charging hubs.

Maximising future gains for Scotland

Recent initiatives exploring 5G use cases in Scotland show promise, but are largely limited to small-scale trials and idiosyncratic applications at present. Several stakeholders are pursuing different initiatives in isolation, potentially leading to fragmented approaches. Against this backdrop, Scotland could benefit from:

- Increased collaboration and knowledge-sharing across stakeholders, bringing together experience, resources and networks in order to identify key synergies and lessons learned;
- Holistic thinking to consider the opportunity of seamless 5G connectivity for the benefit of entire communities, without restricting to individual sectors or use cases;
- Development of longer-term planning, setting out roles, responsibilities and processes to convert successful proof-of-concept trials to large-scale commercial opportunities; and
- Measures to increase awareness and understanding of 5G across stakeholders, including local authorities and SMEs, and to provide hands-on support as necessary.

Key to all use cases is the availability of seamless connectivity, with the underlying fibre infrastructure extended as far as possible. Appropriate commercial models will be necessary to facilitate this:

- In urban areas, further exploration of commercial models could support cost effective network deployment that makes use of local authorities' existing physical infrastructure.
- In rural areas, new approaches to infrastructure and spectrum sharing may need to be explored, as well as any innovative technical solutions that can lower costs, working to continue current public and industry initiatives to address rural coverage.

4 Future scenarios for digital Scotland

4.1 Overview of scenarios

Alternative scenarios have been developed in consultation with SFT to illustrate a range of possible outcomes for Scotland's digital future, looking ahead to 2035. The scenarios focus on the role of wireless capability within the wider digital ecosystem. As such, the scenarios not only capture enhanced 4G and 5G capability, but also improved outcomes in related areas, such as fixed broadband connectivity, IoT, cloud computing and data analytics.

Each scenario is expressed in terms of incrementally higher outcomes compared to a base case scenario that represents how Scotland may evolve based only on current trends, in the absence of material actions to improve 4G and 5G capabilities, or to accelerate digitalisation more broadly.

Evolution

The Evolution scenario entails a significant expansion of current capabilities and usage patterns.

- Users benefit from materially faster speeds and wider coverage, supporting near-seamless mobility, and driving higher adoption of connected devices and digital services across consumers, businesses and the public sector.
- However, digital divides still exist: rural populations do not experience the same improvements in speed and coverage as urban areas, and smaller organisations lag behind in their adoption of key technologies such as cloud computing and IoT.
- Although 5G networks are deployed in selected areas, the full potential of this technology is not exploited and overall average speeds reach the maximum theoretical levels offered by current 4G (LTE Advanced) technical standards.

To capture the impact of geographic 4G coverage specifically, there are two variants of this scenario, with coverage of 65% and 90% respectively achieved by 2035 (see Section 4.3).

Revolution

The Revolution scenario entails transformative improvements over current capabilities and usage patterns.

- This transformative scenario is driven by a successful rollout of 5G across Scotland together with supporting fibre infrastructure.
- Flexible and reliable networks provide a tailored service catering to all user needs in terms of bandwidth, latency, reliability and density of connected devices. These high-capacity networks support a plethora of new use cases that become pervasive across sectors.
- The digital divide reduced to a minimum, as all types of users benefit from high performance regardless of location, with gigabit speeds becoming commonplace. Small and large businesses alike can leverage new technologies to generate efficiencies and revenue growth opportunities.

4.2 Scenario specification

The scenarios have been developed using a range of metrics covering internet connectivity and usage by consumers, businesses and the public sector, as summarised in Figure 21.

The scenarios are not intended as forecasts of future digitalisation in Scotland, rather as alternative views on how digitalisation could evolve. In specifying these scenarios recent growth rates for each metric have been taken into account, as well as third-party projections where available.

Figure 21: Summary of scenario specifications to 2035

	Base case	Evolution	Revolution
Connectivity	• Modest improvements in internet service • Improvements predominantly occur in urban areas • Household internet penetration reaches 92% by 2035	• Material increases in speed and coverage • Increased 4G coverage improves service in rural areas • Household internet penetration reaches 96% by 2035	• Gigabit speeds become commonplace • Low latency, high capacity and reliability unlock new use cases • Household internet penetration reaches 99% by 2035
Business	• Limited progress in adoption of key technologies • Increases mainly in urban areas and large firms • 30% of businesses use IoT by 2035	• Most businesses adopt cloud and e-commerce • The digital divide narrows but many firms are still basic users of technology • 45% of businesses use IoT by 2035	• Digital transformation across sectors • New technologies and use cases are more accessible to all types of businesses • 70% of businesses use IoT by 2035
Public sector	• Many public services remain “analogue” • Digital services are mainly used by younger, higher-income, urban citizens • 55% of citizens use online public services by 2035	• Improvement in public sector digitalisation • A wider base of users is able to benefit from digital public services • 70% of citizens use online public services by 2035	• Ubiquitous digitalisation across the public sector • Advanced IoT solutions create large efficiencies in public service delivery • 90% of citizens use online public services by 2035
Consumer	• Gradual increases in adoption and usage • Digital divide persists across regions and demographic groups • Online banking adoption reaches 60% by 2035	• Faster adoption of new leisure and health devices • A wider base of users benefits from use of online services • Online banking adoption reaches 75% by 2035	• Consumers use a plethora of in-home and portable devices for convenience • Immersive audio-visual content is ubiquitous • Online banking adoption reaches 90% by 2035

Source: Deloitte analysis

The scenarios are described in more detail below.

Connectivity

Improvements in connectivity are a key component of the scenarios, capturing increases in the volume and ubiquity of usage, but also improvements the quality of service provided.

Figure 22: Summary of connectivity assumptions

Connectivity			
2018	2035		
	Base case	Evolution	Revolution
84% internet penetration	92%	96%	99%
2 million M2M connections	10 million	25 million	60 million
4.5 billion GB of data usage	20 billion GB	55 billion GB	130 billion GB

Source: Deloitte analysis, Ofcom Technology Tracker, Ofcom Connected Nations, Cambridge Consultants

The overall internet penetration, as measured by the percentage of online households, is high in Scotland but growth is slowing, with the possibility that a significant minority of the population remain disconnected or use only relatively basic services, including elderly or low-income consumers, or residents of rural areas. The scenarios illustrate step changes in this respect, with 99% of households having a home internet connection in the Revolution scenario as the digital divide narrows.

At the same time, networks are evolving to accommodate more IoT sensors and machine-to-machine (M2M) communications, as well as user-operated devices. Even in the base case scenario, the number of M2M connections is projected to increase from 2 million in 2018 to 10 million by 2035. However, the Evolution scenario delivers further growth by extending wireless coverage and improving quality of service materially above current levels. In the Revolution scenario, widespread 5G deployments support a much higher density of connected devices and simultaneously enable a greater variety of specialised applications.

The average real-world speed experienced by users also varies across scenarios:

- Even in the base case, download speeds are assumed to increase, but this only takes place gradually. Average speeds do not grow beyond the maximum speeds currently offered by superfast broadband connections and 4G connections in Scotland. For most users, there is not a material impact on what they are able to do.

- In the Evolution scenario, average speeds grow significantly faster. Mobile networks fully exploit the theoretical potential of current network technologies (for example, as defined by LTE Advanced standards), although these networks do not deliver on the full potential offered by 5G standards. User experience is generally seamless across most tasks and overall data usage is almost 3 times higher than in the base case by 2035.

- In the Revolution scenario, there is a further step change in average speeds. The technical capabilities of 5G are exploited, as part of a full-fibre future with flexible integrated networks. Gigabit speeds become commonplace. Even where sub-gigabit speeds still exist in rural and remote areas, the speeds are materially higher. As a result, overall data usage is almost 7 times higher than in the base case by 2035.

Business

The adoption of digital technologies by businesses can yield material gains in efficiency and innovation. Higher adoption rates are therefore a key component of the scenarios.

Figure 23: Summary of business usage assumptions

Business

2018	2035		
	Base case	Evolution	Revolution
31% trade online	45%	60%	80%
38% use cloud computing	50%	75%	95%
40% use data analytics	45%	60%	80%
21% use IoT	30%	45%	70%
7% are digital champions or pioneers	15%	25%	40%

Source: Deloitte analysis, Scottish Government – Digital Economy Maturity Index; Digital Economy Business Survey

In the base case, business' digital capabilities develop relatively slowly. Around half of businesses make some use of cloud computing and conduct some portion of business online by 2035, leading to benefits such as higher efficiency of IT services and increased revenue. However, this leaves many businesses excluded from these benefits, with a disproportionate share of these being small businesses or rural businesses. Moreover, even among those businesses adopting digital technologies, usage is often confined to specific areas (such as cloud storage or cloud-based email services), rather than wider digital transformation across the whole business.

In the Evolution scenario, business adoption of digital technologies increases from this baseline level. With expanded coverage out to rural areas and improved online connectivity overall, the majority of businesses now successfully sell online and use cloud computing or data analytics as a means to optimise their operations. However, overall adoption and sophistication of usage are still constrained by legacy business models and a degree of inertia, meaning that only 25% of businesses are digital champions or digital pioneers by 2035.

In the Revolution scenario, by 2035 the majority of businesses critically depend on the use of a range of digital technologies for their day-to-day operations. These technologies are no longer seen in isolation, but they are used together as part of holistic business strategies. High-performance 5G networks deliver vastly expanded capacity and tailored services to support a much wider range of IoT and audio-visual applications, including those that rely on low latency or high bandwidth, reliability, mobility and connection density. As a result, IoT becomes a key component of most businesses' operations and is often combined with AI and analytics to create even larger efficiencies, new insights, innovative approaches and new revenue streams.

Public sector

As in the private sector, adoption of key technologies within the public sector is a key driver of economic and social benefits that is recognised in the scenarios. Coupled with the willingness and ability of citizens to use digital public services, there is the potential to create new, more efficient ways for public services to be delivered, and for citizens and institutions to interact.

Figure 24: Summary of public sector usage assumptions

Public sector 2018	2035 Base case	2035 Evolution	2035 Revolution
30% of citizens use government/local authority online services	55%	70%	90%
0.11 million M2M connections used for public service delivery	1 million	3 million	8 million
- 0.09 million for smart city services	0.5 million	1.5 million	4 million
- 0.02 million for healthcare	0.4 million	1.4 million	3.8 million
- 0.00 million for emergency services	0.1 million	0.1 million	0.2 million

Source: Deloitte analysis, Ofcom Technology Tracker, Cambridge Consultants

Enhanced wireless and digital capabilities have the potential to improve both the accessibility of public services and their quality. By making more services and information available online, public bodies can generate benefits in terms of convenience, time savings and cost savings, as well as supporting citizens who may particularly benefit from remote access (such as those in remote areas, or elderly citizens with limited mobility). On top of this, the rapid development of IoT solutions for the public sector is creating entirely new ways for public bodies to deliver services in an efficient and inclusive way.

In the base case, the range of public services and information available online increases only slightly beyond current levels. Almost half of the population still does not regularly use public services online by 2035. The use of connected devices for public service delivery gains some traction but is mostly limited to simplistic applications in selected urban areas.

In the Evolution scenario, the range of public services and information available online expands significantly beyond what is available today. With increased penetration of both broadband and 4G, and wider geographic coverage, more people engage with public services online – with 70% of citizens making some use of online services – and make use of these services more often. The extension of geographic 4G coverage, together with broader digitalisation across the public sector, enables additional deployments of IoT devices for public service delivery. This includes solutions such as remote monitoring for healthcare patients in rural and remote areas, with material efficiency benefits as well as improved patient engagement and care.

In the Revolution scenario, digital transformation in the public sector is pervasive. Online platforms for public services are sufficiently comprehensive and easy-to-use such that they become the primary means for most of the population to access public services and interact with institutions. As in the private sector, high-performance 5G networks deliver vastly expanded capacity and tailored services to support a much wider range of IoT and audio-visual applications, including those that rely on low latency or high bandwidth, reliability, mobility and connection density. The use of IoT becomes pervasive across areas such as smart street lighting, remote healthcare monitoring and waste management.

Consumer

Improvements in connectivity are also reflected in consumer usage of online services and connected devices, which has the potential to widen further.

Figure 25: Summary of consumer usage assumptions

Consumer	2035		
2018	Base case	Evolution	Revolution
52% use online banking	60%	75%	90%
77% use smartphones	90%	95%	99%
47% use tablets	55%	65%	75%
14% use wearables	20%	30%	50%
7% use smart speakers	15%	25%	45%
2% use smart home appliances	10%	20%	30%

Source: Deloitte analysis, Ofcom Technology Tracker

Consumers stand to benefit greatly from enhanced 4G and 5G capability. As geographic coverage and average speeds continue to increase, the number of people that benefit from time savings and increased convenience will increase concurrently with the magnitude of these benefits. Higher speeds could expand the scope of possibilities for everything that makes use of the internet such that existing connected devices and online services will develop improved functionality – such as the emergence of 4K/8K videos as the norm – which will be complemented by the introduction of new, more transformative products and services – such as Mobility-as-a-Service (MaaS).

In the base case, consumer usage remains focused on audio-visual content, consumed mainly in HD and 4K formats. Smartphones and tablets are widely used, but mainstream adoption of other consumer devices is more limited. A majority of consumers derive cost and time savings from convenient services such as online banking, but a digital divide persists. For example, 40% of consumers still do not use online banking by 2035, which includes a disproportionate share of older and lower income consumers in rural and remote areas.

In the Evolution scenario, more consumers expand their usage to new types of devices for leisure and wellbeing, such as wearable devices and smart speakers. Services such as online banking and online shopping become ubiquitous, with consumers across most sociodemographic groups drawing the benefits of these.

In the Revolution scenario, consumers confidently adopt a much wider range of connected devices to suit every need. For example, smart home devices such as alarm, lighting, thermostats and appliances gain mainstream adoption, leading to increased security, convenience and cost savings. Usage of helpful online services becomes ubiquitous, with almost everyone using services such as online banking. Audio-visual content remains a key area of focus for consumers and this content becomes more advanced; even when on the move, users can easily access immersive, high-fidelity content using AR and VR technologies that is tailored to their location and context.

4.3 Variants of the Evolution scenario

As discussed in Section 2.1, geographic 4G coverage is a clear area for improvement in Scotland. Geographic 4G coverage from all four MNOs was estimated as 38% in late 2018, though this has been growing. Coverage from individual operators was estimated to range from 51% to 68%.

In order to isolate and estimate the potential impact of increased geographic coverage, two separate variants of the Evolution scenario have been developed in consultation with SFT:

- In a lower coverage variant, it is assumed that 4G geographic coverage from all MNOs reaches **65%** of Scotland’s total landmass by 2035; and

- In a higher coverage variant, it is assumed that 4G geographic coverage from all MNOs reaches **90%** of Scotland’s total landmass by 2035.

Aside from the different assumptions about the extent of geographic 4G coverage from all four MNOs, the two variants are identical with respect to all other assumptions and parameters.

The scenarios specified in this Section are the basis for the economic modelling of impact estimates, as set out next in Section 5.

5 Economic impacts

This section presents and discusses the estimated economic impacts that could be observed in Scotland under each of the scenarios set out in the previous section.

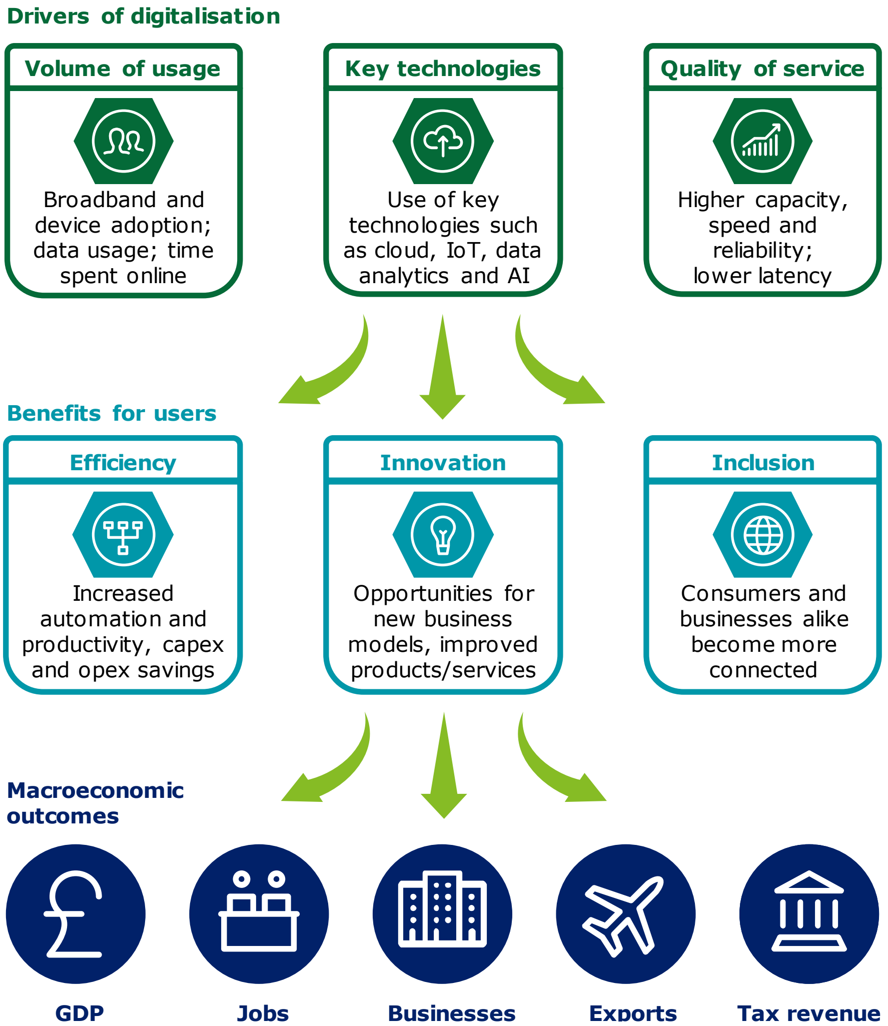
5.1 Economic impact framework

An economic model has been built to link the assumptions specified in each scenario to estimated macroeconomic outcomes. By comparing these outcomes against the base case it is possible to estimate the economic impacts associated with each scenario.

The overall approach adopted builds on the previous study on enhanced digitalisation in Scotland and includes an additional driver of digitalisation: quality of service, for which speed is used as a proxy, but which can also encompass features such as the latency and reliability of networks.

The framework for modelling economic impacts is summarised in Figure 26 below.

Figure 26: Economic impact framework



Source: Deloitte analysis

The high-level logic of the economic impact framework is as follows:

- Key drivers of digitalisation are identified as the volume of usage of online services and devices, the rate of adoption of key technologies among businesses, and the quality of service available.
- These drivers generate benefits for users, including consumers, businesses and public sector organisations. Benefits include efficiency gains, innovation and a greater degree of digital inclusion.
- Benefits for individual users ultimately lead to economy-wide gains in aggregate.

An extensive literature exists around the estimation of linkages between digitalisation and economic impacts. While studies often face data measurement and methodological challenges is establishing causality, there is a clear consensus that these linkages can create large economic impacts.[8] Findings from this literature are used to calibrate the economic modelling.

The framework is explained in more detail below. Detailed information on the calculations performed and on the data sources used is provided in Annex C.

Drivers of digitalisation

Volume of usage

There is a wide existing literature indicating that increased internet usage – for example in terms of penetration rates or volumes of data used – leads to material economic benefits. For example, a recent empirical study across 75 countries found that a 10% increase in fixed and mobile broadband penetration increases GDP by 0.8% and 1.5%, respectively.[70] A separate cross-country study found that a doubling of mobile data use is associated with an increase in GDP per capita growth of 0.5 percentage points.[71]

Enhanced 4G and 5G capability would be expected to generate benefits through increased volume of internet usage, in terms of the number of users but also the frequency and intensity of this use.

Key technologies

As well as the volume of internet usage, the nature of that usage is key to determining the resulting economic benefits. In particular, the adoption of key digital technologies by public and private sector organisations has been shown to generate efficiency and innovation. For example, a study for the European Commission estimated that the net benefits from cloud computing across the EU could exceed €200 billion annually by 2020.[72] In the UK, a study by CEBR examines the economic impact of big data and IoT and estimates that these technologies will collectively account for 2.7% of the UK's GDP from 2015 to 2020.[73]

Enhanced 4G and 5G capability can stimulate adoption of various complementary technologies, including IoT, cloud computing, analytics and AI. The economic impact framework focuses on cloud computing, IoT and data analytics, as technologies where sufficient data and evidence is available to integrate into the economic model.

Quality of service

A third key driver of digitalisation is the quality of connectivity. With higher quality of service, further economic benefits are possible even if the numbers of users and the technologies

[70] ITU (2018). 'The economic contribution of broadband, digitization and ICT regulation'
[71] Deloitte (2012). 'What is the impact of mobile telephony on economic growth?'
[72] Deloitte (2016). 'Measuring the economic impact of cloud computing in Europe'
[73] Cebr (2016). 'The Value of Big Data and the Internet of Things to the UK Economy'

adopted do not change, because new use cases may become possible thanks to higher speeds and reliability, for example, or lower latency. While there are many dimensions of quality, only download speeds have been measured and examined in sufficient detail in the existing literature. Therefore, speed is used in the economic framework as a proxy for overall quality of service.

Recent studies have established an empirical link between download speeds and wider economic impacts. For example, a 2018 study for Ofcom analysed data across 35 OECD countries from 2002 to 2016, concluding that an increase in speed from 2Mbit/s to 8Mbit/s is associated with an increase in GDP of 0.9%.[74] This corroborates the findings of a previous study, which estimated that a 100% increase in speeds could increase GDP by 0.3%.[75]

Benefits for users

Efficiency

A key benefit of digitalisation is the efficiency it can enable by streamlining processes and flows of information, including through wireless connectivity specifically. For example, a 2014 study in the UK found that the faster speeds provided by 4G could enable time savings with an economic value equal to £11 billion annually.[76] International evidence supports this, with 86% of US businesses reporting that 4G helps them to get more work done on the move[77] and a more recent academic study in Germany finding that mobile internet significantly boosts firm-level productivity.[78]

The specific technologies captured by the framework have also been shown to have efficiency benefits. For example, a recent Deloitte study found that cloud computing adoption on average leads to staff time savings of 2 to 3 hours per week and a saving of $3,800 on IT capex for an illustrative small company.[67] A 2016 study estimates that big data and IoT adoption in the UK typically generates cost savings between 10% and 20%.[73]

Innovation

Digitalisation has already contributed to disruptive innovation in almost every sector, from audio-visual streaming services in the media sector, through sharing economy platforms for on-demand food delivery and ride-hailing services, to mobile banking and financial services apps.

Enhanced 4G and 5G capability will contribute to future innovation, as highlighted by potential use cases discussed in Section 3.2. Again, the role of complementary technologies is likely to be important. For example, 70% of cloud computing adopters have reported using cloud to develop new products, services or business models, to enter new markets, or to enable other innovations. Many such innovations rely on adequate wireless network capabilities – for example, a digital tracking system over large geographic locations, a smart parking solution with over 50,000 sensors, and real-time translations on a mobile app for up to 300,000 concurrent users per second.[67] Similarly, 71% of small businesses and 85% of large businesses surveyed in the UK have reported that IoT and big data can help their organisation to innovate.[73]

Inclusion

Extension of network coverage and elimination of not-spots can equalise access to adequate internet services, and to any services that rely on fast and reliable connectivity in order to function, reducing the digital divide that currently persists between urban and rural Scotland. At

[74] Koutroumpis (2018). 'The economic impact of broadband: evidence from OECD countries'
[75] Rohman & Bohlin (2012). 'Does broadband speed really matter for driving economic growth? Investigating OECD countries.'
[76] Capital Economics (2014). 'Improving connectivity – stimulating the economy'
[77] Arthur D. Little (2012). 'The Business Benefits of 4G LTE'
[78] Bertschek & Niebel (2016). 'Mobile and More Productive? Firm-Level Evidence on the Productivity Effects of Mobile Internet Use'

the same time, wider adoption of smartphones, tablets and other types of connected devices – both by consumers and by employees in the workplace – can help to create a more inclusive digital society. Further development of 4G and 5G capabilities can remove some of the key barriers to adoption of use cases across sectors and help to include many more businesses in the process of digital transformation, including small businesses who may otherwise lack the resources to overcome these barriers (for example by deploying a private network).

Macroeconomic outcomes

The above factors, in aggregate, have the potential to improve Scotland's overall economic performance. Key metrics considered in the economic framework are summarised below.

Gross Domestic Product (GDP)
By enabling greater productivity and business efficiency, stimulating innovation, and better connecting consumers and businesses, digitalisation can materially increase economic activity and output, resulting in additional gross domestic product. As set out above, the existing literature establishes a link between GDP and adoption of fixed and mobile broadband, and related technologies such as cloud and IoT. While any projections of the impact of 5G remain uncertain at this stage, a recent study estimates that the 5G value chain will generate $76 billion of output in the UK in 2035.[79]

Jobs
Any increase in GDP is typically the result of a combination of increased employment and increased worker productivity. The generation of additional economic activity and output, the creation of new business models, products, and services and the subsequent implications on organisational structure stimulate labour demand and creates new jobs across a variety of economic sectors. While there is the possibility of job losses arising due to technological change, for example where automation reduces the need for human effort, historical analysis suggests that the net result is typically positive.[80]

Businesses
Increased adoption of digital technologies such as cloud computing, the availability of online marketing options, and the development of remote working practices reduce some of the start-up costs for businesses, whilst technology also generates entirely new revenue opportunities and business models. In combination, these trends incentivise the creation of new businesses. For example, one academic study finds that mobile broadband is associated with an increase in entrepreneurship,[81] while Deloitte research has found that 4% of businesses using cloud computing report that they could not operate at all without cloud.[67]

Exports
The benefits of digitalisation can contribute to Scotland's international competitiveness, with an increasing share of businesses engaging in e-commerce and specific use cases strengthening key sectors, as set out in Section 3.2. This in turn can provide a boost to exports.

Tax revenue
Assuming tax structures are broadly unchanged, any increase in economic activity and output is expected to result in increased tax revenue for government. In the long run this can be reinvested into public services to deliver additional social and economic benefits.

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[79] IHS Markit (2017). 'The 5G economy: How 5G technology will contribute to the global economy
[80] Deloitte (2015). 'From brawn to brains – The impact of technology on jobs in the UK'
[81] Alderete, María Verónica (2017). 'Mobile Broadband: A Key Enabling Technology for Entrepreneurship?'

5.2 Core estimates of economic impact

As set out in Section 4, the scenarios that have been modelled are:

1. **Base case** – a baseline scenario that assumes only gradual improvements to Scotland's 4G and 5G capability over the projection period (2018-35), without any material new actions to enhance future digital capabilities;

2. a) **Evolution (65% 4G coverage)** – an evolution of current capabilities and usage, whereby Scotland's internet usage and adoption of key technologies rise significantly. The potential of 4G technical standards (including LTE Advanced) is fully exploited and 4G geographic coverage from all MNOs reaches 65%.

   b) **Evolution (90% 4G coverage)** – an alternative variant of the Evolution scenario in which 4G geographic coverage from all MNOs reaches 90%, bridging the digital divide between urban and rural Scotland. Mobile broadband penetration and internet usage are assumed to increase as a result, but all other assumptions remain the same as in Evolution (65% 4G coverage).

3. **Revolution** – a transformative state of the world in which pervasive, high-performance 5G connectivity is at the heart of a rapid acceleration in digital transformation. Flexible and reliable networks provide a tailored service enabling a plethora of innovative use cases. The digital divide is reduced to a minimum and the vast majority of businesses are able to leverage new technologies to generate efficiencies and revenue growth opportunities.

These scenarios do not explicitly consider the supply-side requirements, such as fibre infrastructure and spectrum availability that may needed to support the demand profiles, or the specific services or activities that consumers undertake to generate aggregate-level outcomes. Effectively the scenarios assume that the necessary investments in infrastructure, and other areas such as digital skills, take place in order for the specified scenario outcomes to materialise.

All economic impact estimates presented below are relative to the base case and therefore represent the incremental improvement that could be achieved against that baseline. In addition, all results are presented as the difference between the value under the base case and the value under the scenarios by the end of the projection period in 2035.

Impact on GDP and tax revenue

Economic modelling indicates that, in the most optimistic case as outlined by the Revolution scenario, digitalisation supported by enhanced 4G and 5G capability could increase Scotland's GDP by up to £17 billion by 2035 relative to the base case. This is equivalent to an increase in GDP per capita of around £3,000.

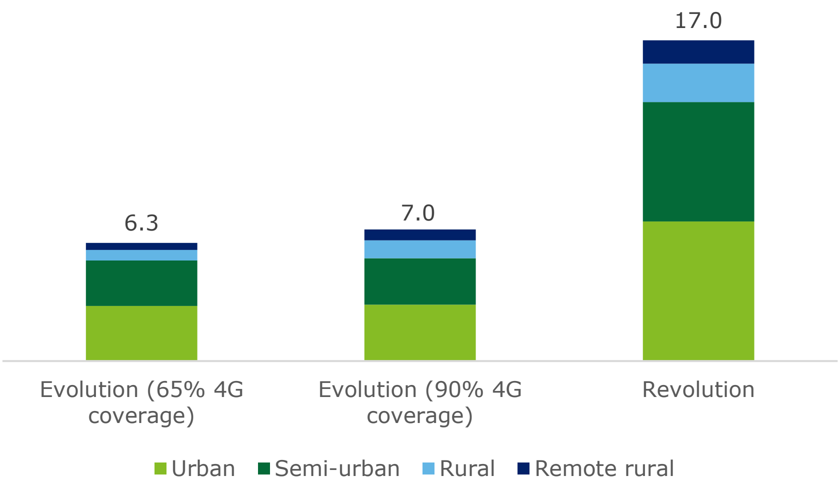
In the more moderate case of the Evolution scenario, the full potential of 5G and the use cases that it can support do not materialise. In this case, the incremental GDP impact relative to the base case is estimated to lie in the range of £6.3 billion to £7 billion by 2035, reflecting the variance between the two variants of the Evolution scenario. In this case, the impact is equivalent to an increase in GDP per capita of around £1,100 to £1,200.

The impact of increasing the level of 4G geographic coverage (from all MNOs) that is achieved by 2035 – from 65% to 90% – is estimated as £700 million by 2035, while holding all other assumptions of the Evolution scenario constant.

In terms of GDP growth, Scotland's GDP is assumed to grow at an average rate of 1.5% over the 2018-35 period in the base case, which is significantly below Scotland's long-run trend growth rate of 2%.[82] The value of 1.5% is derived from third-party projections and this study does not make any specific assumptions about potential future macroeconomic shocks.

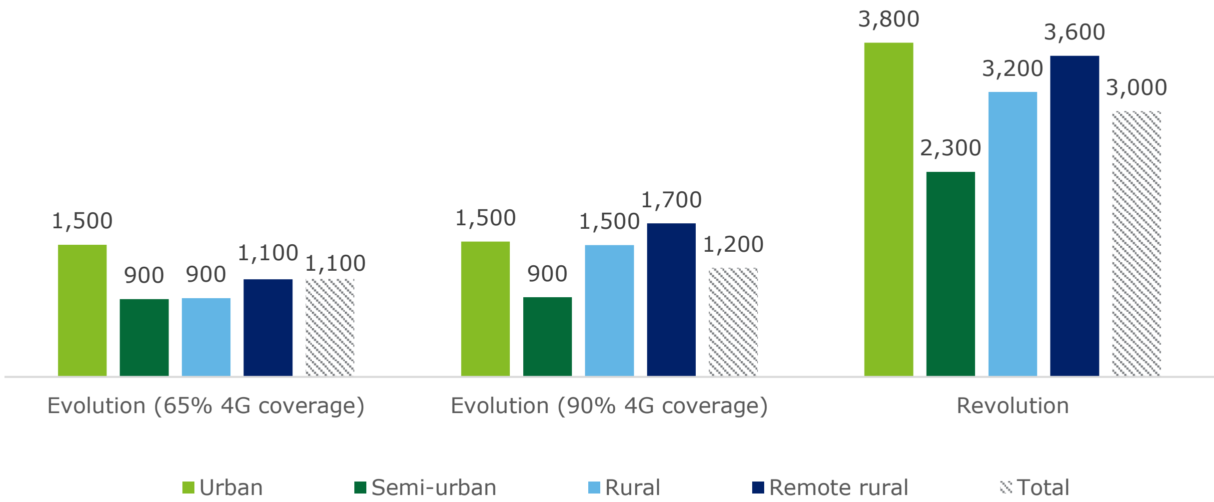
In the Revolution scenario, a combination of improvement in productivity and increase in employment fully restores the long-run trend growth rate of 2% over the 2018-35 period. In the Evolution scenario, the more moderate impact results in an average growth rate that remains below the long-run trend growth rate of 2%, at 1.7%.

Figure 27: Incremental GDP relative to base case in 2035 (£ billions)



Source: Deloitte analysis. Figures are rounded.

Figure 28: Incremental GDP per capita relative to base case in 2035 (£)



Source: Deloitte analysis. Figures are rounded.

[82] Scottish Government (2018). 'State of the Economy'.

Comparison to previous studies

The previous study for SFT published in 2015 estimated that the potential GDP impact from Scotland becoming a World Leader in digitalisation could be around £13 billion in 2030. In absolute terms, the current estimate of around £17 billion in 2035 for the Revolution scenario is larger than the impact estimated in the previous study.

However, the difference is smaller when the impacts are expressed relative to baseline GDP in the relevant year – 2030 and 2035 for the previous and current study respectively. When expressed in this way, the Revolution scenario has an estimated economic impact equal to 8% of 2035 GDP, compared to an estimated impact of 7% of 2030 GDP for the World Leader digitalisation scenario in the previous study.

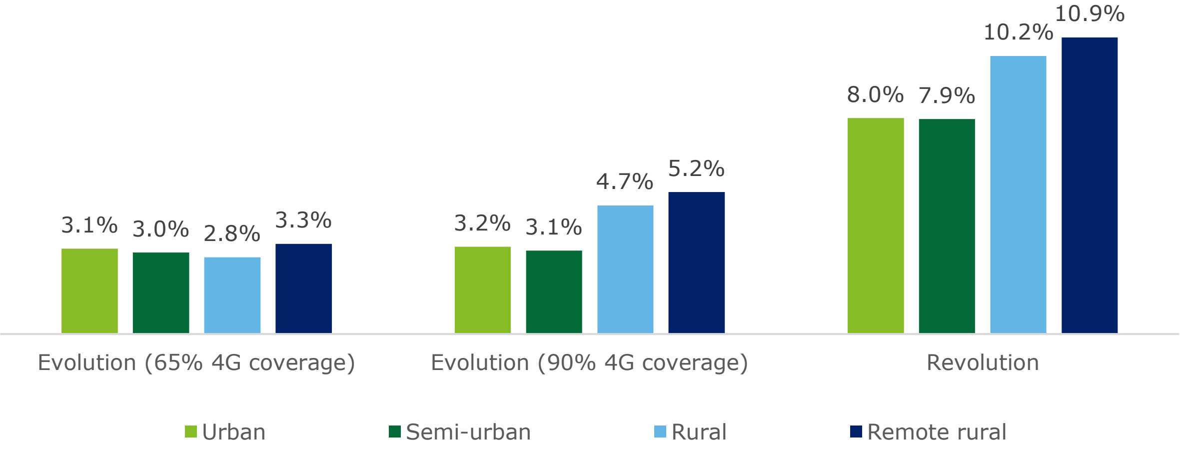
The two studies are not directly comparable due to the different time periods used, changes in the Scottish economy since the previous study, and updates made to the methodology based on the latest available literature and evidence. Nevertheless, the GDP impact estimated in the current study for the Revolution scenario suggests that, despite recent improvements in digitalisation of the Scottish economy, the economic opportunity from further improvement remains vast due to the transformative role that 5G could play in combination with other technologies and innovations.

The Evolution scenario could also be contrasted against the Incremental Improvement and World Class scenarios from the previous study. The Evolution scenario is estimated to result in increased GDP of around 3% in 2035 relative to the base case, compared to 2% and 5% in the Incremental Improvement and World Class scenarios respectively from the previous study. This reflects that the Evolution scenario is sufficient to deliver material economic improvements but, without a fuller exploitation of the potential of 5G and related technologies and use cases, it may not be sufficient to create a world class digital economy for Scotland.

For more detail, see Annex D.

In absolute terms, the GDP impact is far larger in urban and semi-urban areas than in the rest of Scotland. However, this is to be expected given that urban and semi-urban areas account for the largest proportion of economic output. In fact, it is rural and remote areas that see the largest *proportionate* impact in the most positive scenarios, as enhancements in 4G and 5G capability narrow the digital divide by allowing consumers and businesses to access superior, transformative services irrespective of geography.

Figure 29: Increase in GDP relative to the base case, as a percentage of base case GDP in 2035



Source: Deloitte analysis

In the 65% 4G coverage variant of the Evolution scenario, the relative GDP impacts are roughly the same across Scotland's regions. This reflects that a digital divide remains in place, with 35% of

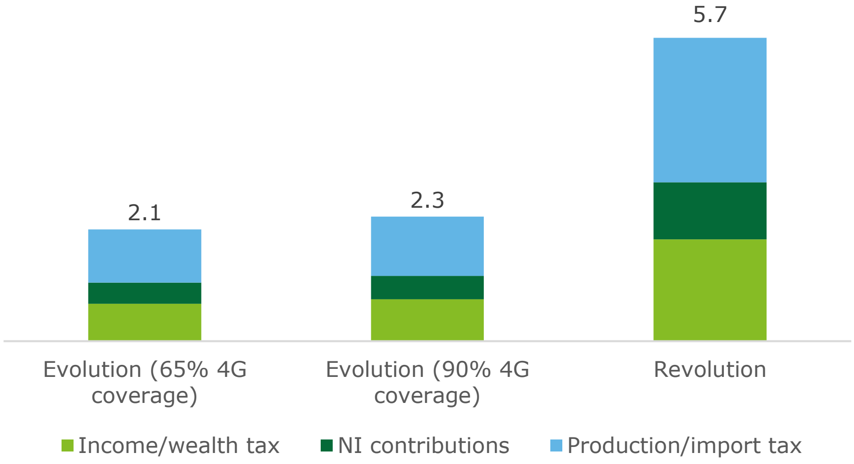
Scotland's landmass still not covered by a 4G signal from all operators, and urban areas continuing to benefit from markedly faster services.

In the 90% 4G coverage variant of the Evolution scenario, the increase in geographic coverage primarily benefits rural and remote areas, to the extent that they see a GDP increment of around 5% by 2035, compared to 3% in urban and semi-urban areas.

In the Revolution scenario, which builds upon the more positive 90% 4G coverage variant of the Evolution scenario, the economic impact is again skewed towards rural areas rather than urban areas. Even though urban areas overall continue to see the highest-performance networks and the highest business adoption rates of key technologies, the vast majority of rural consumers and businesses can access connectivity that fully caters to their requirements. As a result, the increase in GDP in remote areas is as high as 11%, compared to 8% in urban areas.

Increased economic activity and output expand the tax base, resulting in increased tax revenues.

Figure 30: Incremental annual tax revenue relative to base case in 2035 (£ billions)



Source: Deloitte analysis

Assuming existing tax structures broadly persist out to 2035, in the Revolution scenario total estimated tax revenues collected in 2035 increase by £5.7 billion, relative to the base case. In the Evolution scenario, it is estimated that the increase in tax revenues collected in 2035 will be £2.1-2.3 billion, relative to the base case.[83]

Impact on employment and productivity

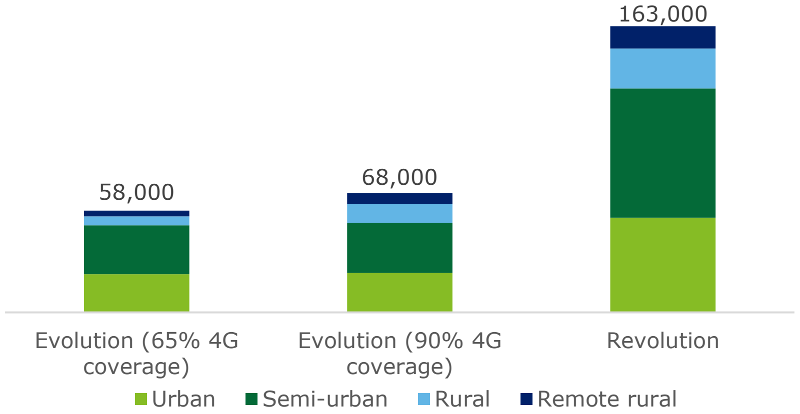
The long-term increase in GDP across these scenarios ultimately reflects a combination of two factors:

- An increase in the absolute level of employment, as increased economic activity entails the expansion of existing businesses and the creation of new ones, generating a substantial increase in labour demand, while mobile technologies can also facilitate wider labour force participation through remote and agile working; and
- An increase in productivity among those workers who are employed, due to the new ways of working enabled by wireless connectivity and related technologies.

[83] The tax revenue impact should not be considered as a fully distinct and additional impact on top of GDP as much of this revenue will be used by government to purchase goods and services, which is by definition counted under GDP

With regard to employment, the net number of new jobs created in Scotland could exceed 150,000 if the potential of wireless technologies is fully leveraged to further digitalise Scotland's economy.

Figure 31: Incremental jobs relative to base case in 2035



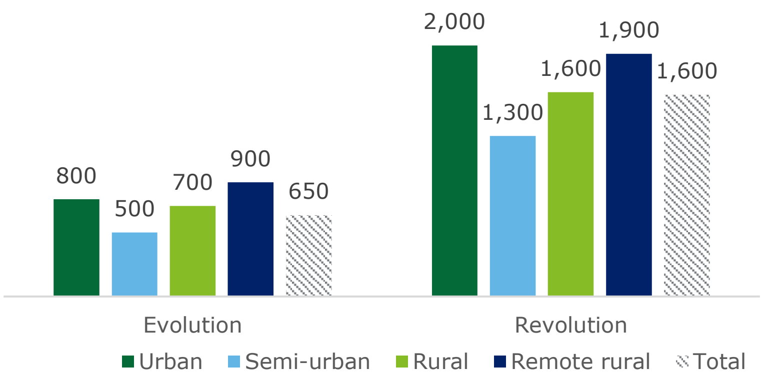
Source: Deloitte analysis

In the Revolution scenario, it is estimated that widespread digitalisation and enhanced 4G and 5G capability could create up to 163,000 additional jobs by 2035 for the Scottish economy relative to the base case, representing an increase of around 6% compared to the projected level of employment in 2035.

In the Evolution scenario, it is estimated that 58,000-68,000 additional jobs could be created by 2035, representing an increase of around 2% to 2.5% compared to the projected level of employment in 2035.

As well as an expanded labour force, productivity per employee is estimated to increase as more basic processes are automated, allowing employees to focus on higher value-add tasks. In doing so, they can make use of seamless connectivity and digital tools to collaborate more effectively, they can develop new revenue opportunities through e-commerce and m-commerce channels, and they can explore technological solutions to reduce costs and drive efficiency further, creating a positive feedback loop that may lead to yet higher productivity in the future.

Figure 32: Increase in productivity by 2035 (£ per employee)



Source: Deloitte analysis. Only a single set of outputs is produced for the Evolution scenario, because the modelling assumes for tractability that the productivity impact is the same across both variants of the Evolution scenario.

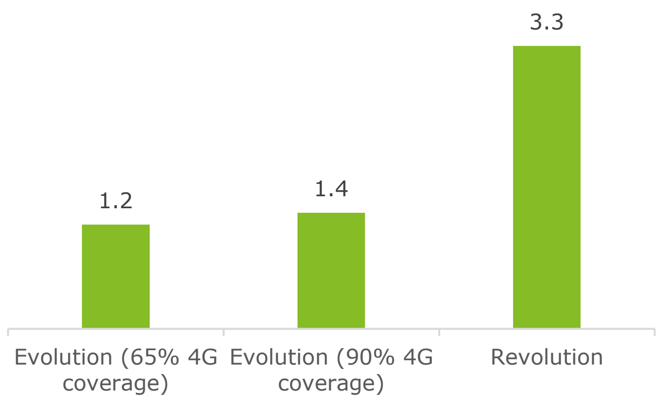
As 4G capability is enhanced, annual productivity per worker increases by a weighted average of £650 in the Evolution scenario. In the Revolution scenario, this impact is more than doubled, with the weighted average increase rising to £1,600.

Impact on new business creation and exports

Digitalisation can support flexible, highly digitalised businesses that rely on technologies such as cloud computing to avoid many of the costs traditionally associated with starting and operating a business (such as IT capex). In addition, improving connectivity creates new demand for digital services across sectors, with opportunities for businesses to expand and develop new product offerings, or for new businesses to enter the market.

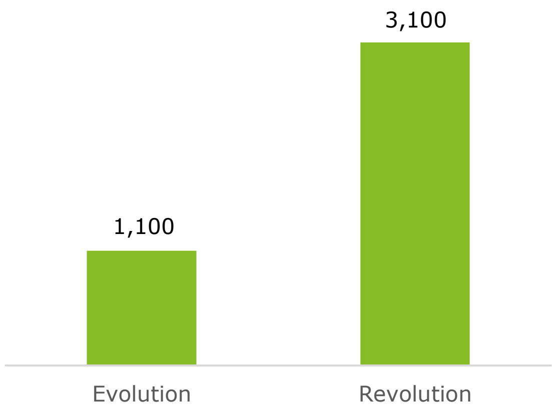
As a result, a key impact across the scenarios modelled is the estimated increase in new businesses – many of which are likely to be Digital Champions or Pioneers – and the growth in export volumes, both of which are indicative of bolstered global competitiveness for Scotland's key economic sectors.

Figure 33: Incremental annual exports relative to base case in 2035 (£ billions)



Source: Deloitte analysis

Figure 34: New businesses created relative to base case in 2035



Source: Deloitte analysis

In the Revolution scenario, more than 3,000 new businesses could be created by 2035, representing an increase of 1.5% compared to the projected total number of businesses in Scotland by 2035 in the base case. The estimated value of exports increases by more than £3 billion, compared to a current value of total exports of around £32 billion in Scotland.[84]

In the Evolution scenario, the number of new businesses created by 2035 is estimated between 1,200 and 1,400. The value of exports is estimated to increase by between £1.2 billion and £1.4 billion.

5.3 Longer-term estimates of economic impact

Looking further ahead into the future, illustrative economic impacts to 2050 have been estimated for the Revolution scenario to show what further gains may be possible.[85] These estimates are based on a less detailed approach than the core 2035 estimates presented in section 5.2 and they are inherently more uncertain. They should therefore be interpreted as indicative.

In the Revolution scenario, by 2035 the usage of 5G is already prevalent, in conjunction with key digital technologies such as cloud computing, data analytics and the IoT. While the adoption rates of these technologies may already be approaching a saturation point by 2035, there may be further improvements possible in terms of intensity and sophistication of usage, adoption of specific use cases – such as connected and autonomous vehicles, which may not gain widespread adoption by

[84] https://www2.gov.scot/Topics/Statistics/Browse/Economy/Exports/ESSPublication
[85] This analysis is not carried out for the Evolution scenario, as by construction the Revolution scenario is incremental to the Evolution and therefore already represents the further gains that may be possible.

2035 – and even entirely new technologies that cannot be anticipated at this point in time (such as a sixth generation of mobile network technology).

Based on an extrapolation of the projected annual impacts to 2035 under the Revolution scenario, it is estimated that economic impacts could reach up to £34 billion by 2050, representing a 13% increase on Scotland's projected 2050 GDP. This compares to the core estimate of an 8% increase in 2035 GDP for the Revolution scenario relative to the base case.

While the economic impact estimate presented does not make any assumption about specific technological developments beyond 2035, it gives an indication of the potential benefits that might be achieved from further progress.

A summary of the potential magnitudes of the economic impacts by 2050 under this progression of the Revolution scenario are presented in Figure 35, alongside with the core impact estimates by 2035 for reference.

Figure 35: Summary of core economic impact in 2035 and indicative longer-term estimates in 2050

	Evolution (2035)	Revolution (2035)	Revolution (2050)
GDP	+ £6 - £7 billion	+ £17 billion	+ £34 billion
GDP per capita	+ £1,100 - £1,200	+ £ 3,000	+ £ 5,500
% increase	3.1 - 3.4%	8.3%	13.2%
Jobs	+ 60,000 - 70,000	+ 160,000	+ 300,000
Businesses	+ 1,000	+ 3,000	+ 6,000
Tax revenue	+ £2.1 - £2.3 billion	+ £5.7 billion	+ £11 billion
Exports	+ £1.2 - £1.3 billion	+ £3.3 billion	+ £7 billion

Source: Deloitte analysis

6 Social impacts

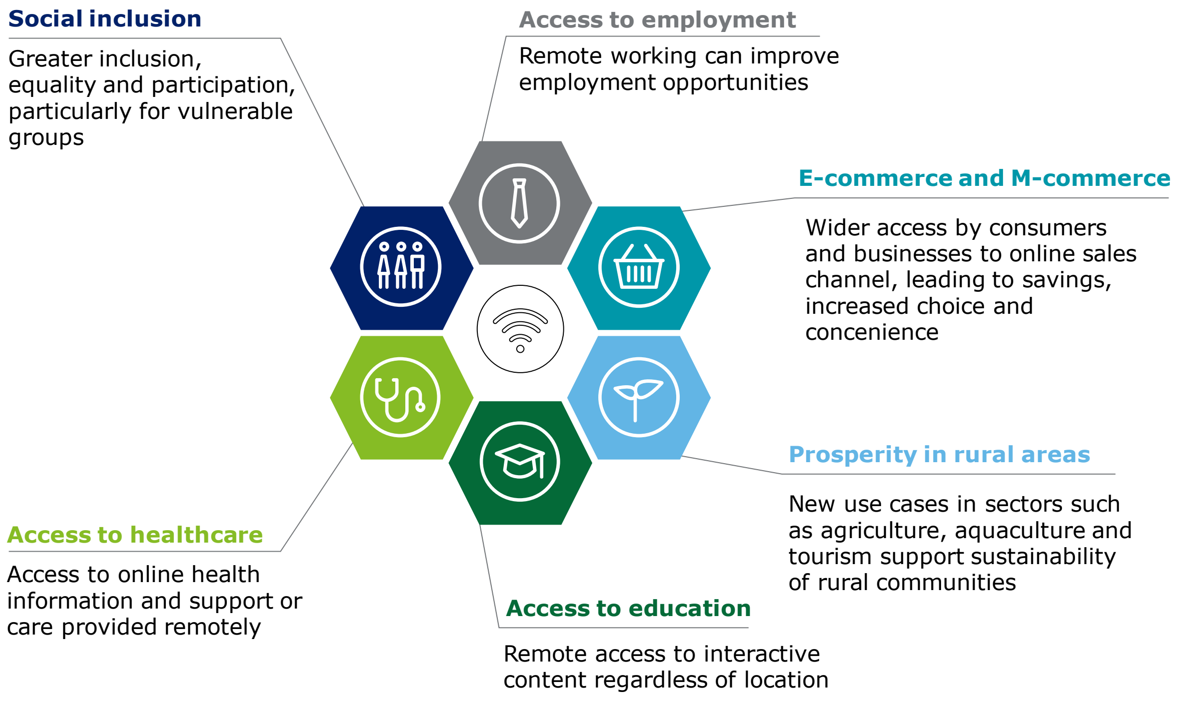
As well as the economic impacts estimated in Section 5, enhanced 4G and 5G capability has the potential to support a range of social impacts associated with digitalisation. This is reflected in the mobile industry's commitment to the United Nations' Sustainable Development Goals, which set out mobile's contribution in terms of poverty alleviation, gender equality, health, education and the environment. However, the mobile industry itself (through industry association GSMA) estimates that to date it has achieved less than half of mobile's potential in these areas.[86] This illustrates the scale of further gains still achievable in the future.

A detailed analysis of the social impacts of digitalisation for Scotland was provided in the previous 2015 study for SFT, with a focus on healthcare, education and digital participation. This section provides an updated view of social benefits with a focus on the role of wireless capability in promoting these, including through potential use cases previously discussed in section 3.2.

6.1 Digital participation and inclusion

Wider availability of adequate wireless connectivity can be a key component of addressing the digital divide that exists in Scotland and bringing the benefits of digitalisation to a wider group of consumers and businesses. This ranges from access to specific services that may be more convenient or of a higher quality, to the more general promotion of an inclusive society.

Figure 36: Potential impacts on digital participation and inclusion



Source: Deloitte analysis of public sources

[86] GSMA (2018). '2018 Mobile Industry Impact Report: Sustainable Development Goals'

For example, 81% of adults over the age of 55 report that being online makes them feel part of modern society and less lonely.[87] Around a quarter of internet users in Scotland use the internet to search and apply for jobs, widening access to employment opportunities.[24] Similarly, recent analysis by the Institute of Development Studies highlights the role of mobile-enabled services in helping increase inclusion of persons with disabilities.[88] This includes not only helping people to be accepted, maintain relationships and be involved in activities, but also providing new employment possibilities – such as allowing remote working for persons with severe physical disabilities.

Online services in rural areas also help to ensure all consumers can benefit from the availability of e-commerce and m-commerce. Around three quarters of internet users in Scotland buy goods online,[24] potentially benefiting from lower prices, wider choice, time savings and reduced need to travel. A study for the European Commission estimated that 5G capabilities will result in benefits from online purchasing of €8.3 bn per annum in the EU through promoting higher digital inclusion.[89]

The ability for companies and public organisations to deliver services remotely through wireless networks can increase breadth and equity of access to important services.

For example, wireless connectivity can make educational content accessible to anyone regardless of location or socio-demographic characteristics. In Scotland there are already examples of this through the e-Sgoil programme used for tele-education. The breadth of content that can be accessed is also expanding. Between 2015 and 2017, the number of education applications available on a smartphone increased by 60%, bringing the total to more than 750,000.[86] UNESCO has estimated that, based on current mobile data charges, reading a book of 1,000 pages on a mobile phone could cost around $0.02, compared a cost of $5–30 for paper books.[86]

In healthcare and social care, wireless connectivity can enable remote to access information, care and support. Already around one third of internet users in Scotland are accessing health information online,[10] which can contribute to greater health literacy and illness prevention, but this risks creating a divide with those who are not accessing this information. Telehealth and remote monitoring can enable a more inclusive healthcare system where geographic barriers or physical impairments are more easily overcome. 5G trials in Orkney are planned for mobile health units that visit communities every one or two weeks using a temporary "pop-up" network.

With regard to businesses, wireless connectivity and digitalisation can play a role in facilitating effective participation in Scotland's economy for all types of firms, even small firms or those in remote rural areas. This is reflected in around two thirds of Scottish companies now using social media, which can help them to connect to consumers and other companies.[90] However, this is heavily reliant on wireless networks as user access is mostly via smartphones.

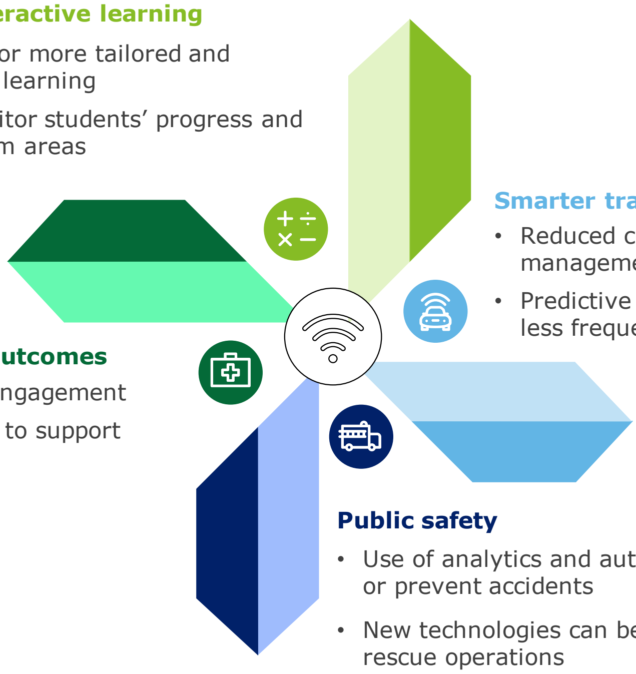
This is particularly relevant in those sectors that are most prevalent in rural areas, such as agriculture and aquaculture. As set out in Section 3.2, a variety innovative use cases in this area rely on wireless connectivity. Successful implementations, reliant on availability of adequate connectivity, could help to ensure profitability and sustainability for these businesses. Equally, rural and remote communities that rely on tourism can benefit from enhanced wireless capabilities, whereas lack of connectivity may otherwise discourage visitors and prevent new smart tourism use cases. For example, the 5G RuralFirst project will test the use of 5G to deliver connectivity for a ferry operating between two of the Orkney Islands, filling a gap at one end of the journey where the ship loses WiFi from the main port.

[87] Government Digital Service (2014). 'Government Digital Inclusion Strategy'
[88] Institute of Development Studies (2018). 'Mobile technology and inclusion of persons with disabilities'
[89] European Commission (2017). 'Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe'
[90] Scottish Government – Digital Economy Business Survey 2017

6.2 Increased quality of public services

As well as making public services more inclusive and easily accessible to all, wireless connectivity can enable the provision of higher quality services.

Figure 37: Potential impacts on quality of public services



The role of wireless connectivity in education has been recognised in the UK 5G Strategy, which argues that "augmented and virtual reality applications supported by 5G may allow students to learn in completely new ways by making lessons more interactive."[91] The tactile internet – where connectivity allows users to experience a realistic sense of touch using low-latency – could also enable new ways of teaching and training. Applications have been envisaged in fields ranging from medicine – where students could experience a realistic surgery simulation in a safe environment – to music, where new ways of teaching could emerge by providing tactile feedback.[92]

This can be part of a wider digitalisation of education, where mobile devices may play an important role in personalising the student experience and in collecting better data for teachers to monitor progress. A recent study by Jisc (a not-for-profit company providing digital solutions for education) argues that "individual access to a mobile device holds the promise to connect each learner into intelligent personalised systems that can suggest learning pathways, enable aggregated analysis and through better data capture of learner experiences enable much better decision making about all aspects of a students' education".[93]

In healthcare, 5G applications could support improved monitoring of people with health conditions, for example predicting if someone is likely to suffer a heart attack.[91] Telehealth can remove the need for unnecessary patient visits to a GDP surgery or hospital; it has been estimated that replacing just 5% of GP appointments with video-conferencing solutions could save individuals 3.3

[91] Department for Digital, Culture, Media and Sport (2017). 'Next Generation Mobile Technologies: A 5G Strategy for the UK'
[92] ITU (2014). 'The Tactile Internet'
[93] Jisc (2018). '5G and Education'

hours per year, as well as reducing time spent in waiting rooms with exposure to infections or viruses.[94]

More generally, the proliferation of new health apps and wearable devices could provide new types of data for health practitioners to assess patients and develop preventative treatments, as well as supporting greater patient engagement and health literacy. A survey in the US found that 96% of health app users think that apps help improve quality of life.[95]

Wireless use cases in the transport sector have the potential to deliver social, as well as economic, benefits for citizens. Already, innovations such as mobile travel planning apps have contributed to a more user-centred and efficient travel experience. In the future, wireless connectivity could allow consumers to benefit from greater choice in mobility options and dynamic pricing based on real-time supply and demand conditions, which could support more informed travel decisions.[96] Transport disruption could become less frequent if 5G enables new approaches to predictive maintenance based on data from IoT sensors, potentially saving the average rail commuter 2.6 hours per year.[94] A more seamless and connected transport ecosystem would also allow collection of better data for governments to gain new insights about which passengers face the greatest transport challenges, channelling any new investments accordingly.

Transport sector innovation could also translate to public safety benefits. Some studies have attempted to quantify social impacts of CAVs, such as lives saved. A study by KPMG estimated that CAVs could lead to 2,500 additional lives saved between 2014 and 2030 in the UK,[97] while a global study has estimated that globally *585,000 lives can be saved due to driverless vehicles from 2035 to 2045*.[98]

More broadly, wireless connectivity can strengthen public safety in other areas. The use of IoT sensors and AI analytics of CCTV footage can enable a more accurate and rapid response to any emergency events. For example, San Francisco’s implementation of real-time, location-tracking gunshot detection sensors reportedly helped reduce gun crime in neighbourhoods by up to 50%.[52]

Emergency services can offer improved support when adequate wireless connectivity is available. For example, connected ambulances can allow hospitals to track the condition of patients on the way to hospitals, so that staff can prepare ahead of time.[99] The use of drones could become critical in emergency situations, providing emergency services with greater visibility of incidents or natural disasters; in the UK the use of drones already being trialled to help find missing people and manage wildfires.[100] In South Korea, a platform for disaster and safety management is being developed to deploy drone surveillance and robots in search-and-rescue operations, with rescuers using augmented reality glasses to help them give emergency treatment at the scene.[101]

6.3 Environment

Digitalisation has the potential to reduce negative impacts on the environment and wireless connectivity can support this. Intuitively, the ability to connect, work and exchange information remotely is likely to reduce the need for travel and therefore promote environmental sustainability. A variety of specific uses of digital technology can contribute positively to the environment.

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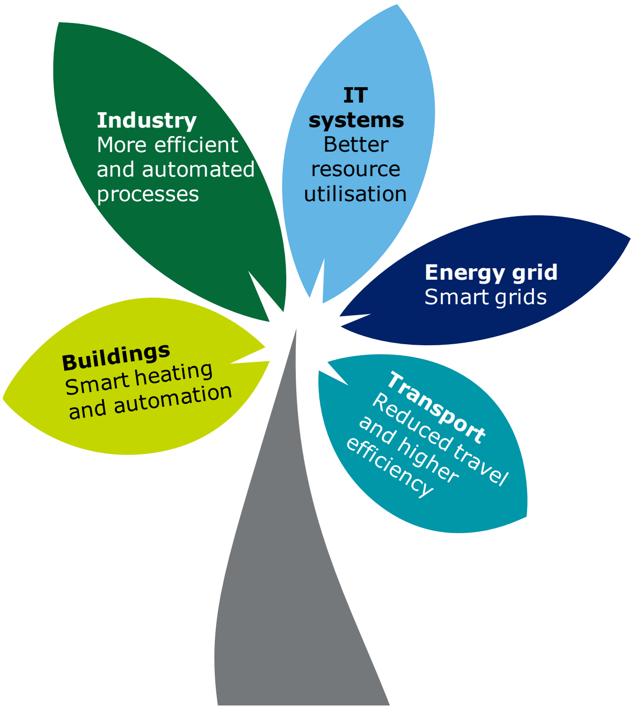
[94] O2 (2018). ‘The value of 5G for cities and communities’
[95] Research Now (2015), ‘US Survey, mHealth Apps: Supporting a Healthier Future’.
[96] World Economic Forum (2018). ‘Designing a Seamless Integrated Mobility System (SIMSystem) – A Manifesto for Transforming Passenger and Goods Mobility’
[97] KPMG (2015). ‘Connected and Autonomous Vehicles – The UK Economic Opportunity’
[98] Strategy Analytics (2017). ‘Accelerating the Future: The Economics Impact of the Emerging Passenger Economy’
[99] https://www.vodafone.com/business/news-and-insights/blog/gigabit-thinking/5g-mobile-networks-are-helping-us-build-a-better-future-today
[100] https://www.siliconrepublic.com/comms/5g-iot-emergency-services
[101] Ernst & Young (2019). ‘Four ways 5G connectivity will make cities smarter’

The Global e-Sustainability Initiative (GeSI) predicts that ICT has the potential to slash global GHG emissions by 20% by 2030 through helping companies and consumers to more intelligently use and save energy.[102]

Figure 38: Summary of potential environmental benefits



Buildings
Wireless connectivity can enable sensor-based smart heating and cooling processes to reduce consumption, while smart appliances could automatically coordinate to optimize energy use

Industry
Automated processes in sectors ranging from manufacturing to agriculture can increase efficiency, reducing energy and resource usage

IT systems
Though more connected devices and sensors could increase energy use, 5G is expected to support higher energy efficiency, and related technologies such as cloud can reduce emissions compared to legacy IT systems

Energy grid
A smarter energy grid with wirelessly connected devices facilitates the integration of renewables and could allow real-time optimisation of demand and supply

Transport
Wireless connectivity reduces the need for travel and it can support smart traffic management, CAVs and ride-sharing, potentially reducing congestion

Source: Deloitte analysis of public sources

Wireless connectivity can help companies and consumers to rely on cloud services for data storage, analytics and a host of applications. By doing so, cloud computing providers can take advantage of scale benefits and can achieve much higher rates of utilisation than users typically achieve individually using legacy IT technologies. As a result, a 2013 study estimated that achieving 80% adoption of selected cloud-based services in the UK could achieve carbon emissions reductions in excess of 600,000 tonnes.[103]

Several wireless cases have the potential to generate environmental benefits in specific areas.

For example, 5G can enable smarter use of public infrastructure, for example through auto-dimming street lights, optimised heating and cooling of public buildings, and optimised waste collection. Lower traffic congestion and environmental pollution can be achieved through efficient public transport passenger loading and dynamic bus routing using real-time information on utilisation, smart parking solutions and traffic management systems, and pollution monitoring sensors.

Smarter energy grids with advanced wireless connectivity can lead a more secure and reliable energy system that is better suited to integrating renewables and promoting new green technologies such as electric vehicles. By one estimate, 5G-enabled smart grids could eventually save 6.4 million metric tonnes of CO_2, the equivalent of taking nearly 1.5 million vehicles off the

[102] GeSI (2015). '#SMARTer2030 - ICT solutions for 21st century challenges'
[103] Think Play Do Group (2013). 'The Enabling Technologies of a Low-Carbon Economy: A Focus on Cloud Computing'

road.[94] Consumer participation and engagement may also be enhanced, for example by providing surplus energy generated or stored at home to be supplied to the grid.

Finally, a more seamless and integrated transport system with widespread use of CAVs and ride-sharing could lead to further environmental benefits. Smarter traffic management systems, enabling instant response to changes in traffic, could reduce congestion and reduce CO2 emissions by an estimated 370,000 metric tonnes per year.[94] The environmental impacts of CAVs could arise through:

- Transporting freight by platooning, which could improve efficiency and fuel economy.
- Reduced congestion from fewer accidents, reduced headway between vehicles and improved traffic management.

Estimates of the potential benefits are highly sensitive to the degree of automation and widespread adoption achieved, but with high adoption rates delays could be reduced by 30% to 40%, thereby reducing travel times and emissions.[104] A study for the European Commission estimates that 5G data capabilities will provide environmental benefits quantifiable as €38.3 million per annum in the EU, from reduced congestion.[89]

[104] Atkins (2016). 'Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow'

Annex A: Stakeholders consulted

Deloitte would like to thank the representatives of SFT who have provided helpful input throughout this study, and representatives of the following organisations who have provided input to SFT and Deloitte:

- Aberdeen City Council
- Argyll and Bute Council
- Department for Culture, Media and Sport
- Dumfries and Galloway Council
- Federation of Small Business
- Glasgow City Council
- Local Government Digital Office
- Nokia
- Northern Ireland Executive
- Ofcom
- Scottish Enterprise
- Scottish Government
- Transport Scotland
- University of Edinburgh
- University of Glasgow
- Welsh Government

Annex B: Indicative scenarios provided by SFT

As a starting point for this study, SFT has provided a set of indicative scenarios for the possible future development of 4G and 5G capability in Scotland. These indicative scenarios build upon the World Class and World Leader scenarios set out in the previous study on enhanced digitalisation in Scotland[7] and are reported below for reference.

For the avoidance of doubt, the scenarios used for economic modelling are as set out in Section 4. However, the indicative scenarios below illustrate some of the considerations and principles taken into account, together with additional analysis, desk research and stakeholder consultation, in developing the final Evolution and Revolution scenarios set out in Section 4.

Scenario 1: 4G World

Scenario 1 captures a scenario of 4G capability, increased demand and expectation around the types of services and applications available from that currently available. Alongside this there is the expectation that services will be accessible wherever and whenever people want and the user experience will be good via a wireless and / or ‘nomadic’ connection. This accessibility will be the key driver for people, businesses and public service providers. There are also greater levels of inclusion, with the digital divide narrowing, as the simplicity of devices means a ‘fear of technology’ is removed for many alongside a greater level of digital competence amongst users.

Demand	Profile
General	Demand increases, as does the level expectation, over the services and applications available. Expectation services accessible wherever and whenever users demand. User experience is generally good.
Bandwidth Use	Audio-visual and social media use remains the most popular type of content. Users expect to be able to access this content wherever they are, whilst enjoying a good user experience.
Audio-Visual	Increased, and complementary, use of catch up services and over the top (OTT) providers to view content when on the move.
Smartphones, Tablet, Mobile, New Technology	Continued shift to smartphones and tablets, with connection through WiFi in building, with similar capability and experience whilst ‘out of house’ through wireless use. Demand for wearable technology continues to evolve: seen as part of the luxuries consumer market rather as a core product. Wearable medical devices will become more widespread. This technology will connect wirelessly, collecting data on a continual basis.

Capacity	The market will continue to build, however, the market (both across the value chain and existing business models) may be resistant to change and may limit the ability or its willingness to respond to the demand (and related investment) needs outlined above, leading to a slower availability, take up of or adoption of services, particularly in rural areas
Connectivity of Devices	Users will expect multiple devices to connect together with ease and receive services across devices seamlessly. The market will resolve interoperability issues affecting connectivity between different devices. M2M communications will increase the number of connected devices, which significantly exceeds the number of people connected. Much of this connectivity will be delivered wirelessly.
Public Services	Use of technology and services in cities will expand rapidly through Government interest and facilitation in driving smart cities. Users will expect a good experience about being able to access online public services regardless of where they are.
Online	Home and remote working will have increased, although the majority of demand will still be related to the physical workplace. This remote working will use wireless technology to enable such activity, again regardless of location. S&MEs will increasingly engage in the digital world to meet the needs of their customers. They will require more symmetrical networks to allow greater uploading and sharing of files. Consequently a greater degree of security and resilience will be required by users. S&MEs will look for bespoke services rather than accessing services which will have been created for larger businesses or the individual consumer. Cloud based services will continue to grow steadily, but uncertainties as regards ownership of data will result in uneven progress.
Download Speeds	Real world speeds of 20Mbps on average. Theoretical speeds of up to 300Mbps could potentially be achieved.
Infrastructure Architecture	Whilst 4G will build upon existing fibre and passive infrastructure, active kit and technology will need to be provided on a large scale basis to see 4G pushed further out. 4G for many will also be delivered via fibre enabled large mast / tower infrastructure.
Frequency Spectrum	800MHz, 1.8GHz, 2.6GHz
Latency	50 ms
Inclusion	The digital divide narrows as in terms of availability of high speed connectivity, but there may still be differing levels of confidence in being able to use services.

Scenario 2: 5G Experience

Scenario 2 captures a scenario of 5G capability and satisfied future demand, an expectation that ubiquitous coverage and connectivity are implicit in that they are taken for granted, and that fixed and WiFi / wireless seamlessly work with each other. Devices are also simple to use and utilise whichever connectivity is available or best delivers the service required. This capability will drive convergence and bundling.

Demand	Profile
General	Users will expect coverage and connectivity wherever they are and whenever needed. Data demand has grown exponentially given capability.
Bandwidth Use	Widely used for different services and needs. The norm will be symmetrical and high capacity broadband networks.
Audio-Visual	Continued demand for linear and non-linear television from across DTT and satellite, alongside a high degree of personalisation. High demand for IPTV and mobile viewing. Immersive and more effective transmission methods sought to further enhance the user experience. Move from 4K to 8K standards. Radio will increasingly be delivered by streaming to connected devices. VR / AR will be prevalent.
Smartphones, Tablet, Mobile, New Technology	Content will be stored on the internet closer to users to meet the need for instant access to such services (i.e. increased data centre capability and proliferation). Each home will be a home network with equipment readily available, easy to use and affordable and equipment will automatically connect to each new device.
Capacity	A significant increase in demand will require speeds based upon gigabit connectivity applying to both uplink and downlink. This fuelled by ongoing changes in user experience, new devices, technology and content. Resilience for all will be expected, delivered by having both fixed and mobile networks covering the country, with availability or capacity, reliability, low latent and noise levels. This group of service metrics will replace the current emphasis on speeds and regularly updated. Networks will be scalable and able to respond more rapidly to demand through virtual network management. SMEs require these metrics, together with greater transparency around quality of service and enforceable SLAs. Service differences in service provision across geographies will not be tolerated.
Connectivity of Devices	Deployment of connected devices will exceed expectations, driven by smart homes, smart cities, smart energy, e-Health and the growth in the intelligence of machines.

Public Services	Use of technology and services will expand rapidly across the country (outwith cities and populated areas) through continued Government interest and facilitation. There will be no distinction between densely populated and isolated communities in terms of services accessible and available.
Online	Demand will be user specific and not location specific. The distinction between individuals and small businesses will become blurred and with increased home and remote working, demand will drive better quality of service across all networks. The corporate market will continue as a distinct market. Improvement in performance networks will drive an ongoing expectation for even better networks. The majority of businesses will fully embrace working digitally as competitive forces make this essential. This will create further demand across the country. Voice traffic will shift predominantly to mobile and this with the Internet of Things will drive network expansion. Fixed lines will only be retained for broadband connectivity with copper being phased out. Cloud technology will be the norm.
Download Speeds	Real world speeds of 10-50Gbps. Theoretical speeds of up to 1Tbps.
Infrastructure Architecture	5G will build on LTE technology used in current 4G networks but will employ other technologies – some that are already available and others yet to be developed – in order to provide the capacity, speed and ubiquity needed to support the vast range of services and use cases envisaged for 5G. It will use software, cloud-based and other intelligent technologies to deliver a network that is efficient, flexible, scalable, agile and dynamic. It is likely to comprise lots of small-scale infrastructure deployments (aka small cells) in urban / populated environments rather than the smaller number of large masts in a 4G network. In rural environments, 5G will be delivered by fibre enabled large masts and towers. Ultimately 5G will be a converged wireless and fixed network infrastructure that provides services to the end device wirelessly, as envisaged in the 5GIC's Flat Distributed Architecture proposal.
Frequency Spectrum	700MHz, 2.3GHz, 3.4GHz, 3.6-3.8GHz, 24GHz+
Latency	1 ms
Inclusion	Broadband pricing will be relatively affordable given their interdependence with WiFi and mobile operators will price to encourage high data usage. Building upon the changes also identified in Scenario 1, the digital divide is almost eliminated.

Annex C: Methodology

This annex sets out in more detail the methodology used to estimate the economic impacts presented in section 5.

Guide for correct interpretation of results

All economic impact estimates in Section 5 are presented relative to the economic outcomes estimated for the base case, and represent the difference between the 2035 values under the base case and the 2035 values under the respective scenarios – the Evolution scenario (65% and 90% 4G coverage) and the Revolution scenario.

For example, the GDP impact estimate of £17 billion in 2035 under the Revolution scenario represents the difference between Scotland's GDP in 2035 under the base case, and Scotland's GDP in 2035 under the Revolution scenario. Similarly, the estimated jobs impact under the Revolution scenario of 163,000 jobs by 2035 represents the difference between the total number of people in employment in the Revolution scenario and in the base case in 2035.

Definitions for geographic categories

The four geographic categories used in this report – urban, semi-urban, rural, and remote rural – are an adaptation of the Scottish Government's 6-fold Urban Rural Classification[105] as outlined below:

Table 1: Definitions for geographic categories

Scottish Government 6-fold Urban Rural Classification	Definition	Corresponding category
Large Urban Areas	Settlements of 125,000 or more people.	Urban
Other Urban Areas	Settlements of 10,000 to 124,999 people.	Semi-urban
Accessible Small Towns	Settlements of 3,000 to 9,999 people and within 30 minute drive of a settlement of 10,000 or more.	Semi-urban
Remote Small Towns	Settlements of 3,000 to 9,999 people and with a drive time of over 30 minutes to a settlement of 10,000 or more.	Semi-urban
Accessible Rural	Areas with a population of less than 3,000 people, and within a 30 minute drive time of a settlement of 10,000 or more.	Rural
Remote Rural	Areas with a population of less than 3,000 people, and with a drive time of over 30 minutes to a settlement of 10,000 or more.	Remote rural

Source: Scottish Government Urban Rural Classification

This approach to defining different geographic categories is consistent with the previous study.

[105] https://www2.gov.scot/Topics/Statistics/About/Methodology/UrbanRuralClassification

Estimating projections for the base case

In summary, economic outcomes under the base case were estimated as follows:

- GDP has been projected using the 2018-35 projected compound annual growth rate (CAGR) for Scotland's GVA of 1.5% from Oxford Economics local forecasting service, to which Deloitte subscribes.[106]

- GDP splits across the four geographic categories are based on the distribution of GVA across local authorities (from the ONS) and data from the Scottish Government used to classify local authorities as urban, semi-urban, rural and remote rural. Based on this approach, the values of the assumed GDP splits are 46%, 39%, 10% and 5% for urban, semi-urban, rural, and remote rural respectively, and are assumed to stay constant throughout the projection period.

- Population projections are taken from the National Records of Scotland, which produces 2016-based population projections out to 2041. The CAGR for Scotland's population over the projection period is 0.24% according to the National Records of Scotland.

- Population splits across the four geographic categories were estimated based on the latest population estimates (by local authority) from the ONS, and data from the Scottish Government used to classify local authorities as urban, semi-urban, rural and remote rural. Based on this approach, the values of the assumed population splits are 35%, 48%, 11% and 6% for urban, semi-urban, rural, and remote rural respectively, and are assumed to stay constant throughout the projection period.

- Employment projections are based on the latest data from Oxford Economics, with a 2018-35 CAGR of 0.15%.

- Employment splits across the four geographic categories are based on the population splits as outlined above.

Calculation of GDP impact estimates

The calculation of the GDP impact estimates is dependent on six key drivers: fixed broadband penetration, mobile broadband penetration, cloud computing adoption, data analytics adoption, IoT adoption and average download speed (weighted across both fixed and mobile usage and across the four geographic categories).

Fixed broadband penetration

There is a well-established empirical link between fixed broadband penetration and GDP growth. The methodology uses evidence from a 2018 report by the ITU, which concludes on the basis of an econometric analysis of 75 countries that a 10% increase in fixed broadband penetration increases GDP by 0.8%.[70] This result is used in combination with the fixed broadband penetration levels assumed in each scenario to estimate the corresponding GDP impact.

Mobile broadband penetration

The aforementioned 2018 report by the ITU is also used to estimate the impact of mobile broadband penetration. Specifically, the report concludes that a 10% increase in mobile broadband penetration increases GDP by 1.5%.[70] This result has been applied to the mobile broadband

[106] This reflects the latest third-party projections and is lower than the assumption of 2% annual GDP growth in the previous study

penetration levels assumed across the base case and the scenarios to estimate the corresponding GDP impact.

Cloud computing adoption

A 2016 report by Deloitte for the European Commission estimates that the net benefits of cloud computing could reach up to €200 billion by 2020.[72] Taking this as a percentage of GDP, with the relevant currency conversions and base price level adjustments, this is approximately equal to 1.2% of the European Union's projected GDP in 2020.[107] This 1.2% share of GDP is divided by the assumed adoption of cloud computing across businesses in the European Union of 30% (based on historical figures being 19%, 21%, and 26% for 2014, 2016, and 2018 respectively) to infer that for every 1% increase in cloud computing adoption, there is an approximate 0.04% increase in GDP. This result has been applied to the cloud computing adoption rates assumed across the base case and the scenarios to estimate the corresponding GDP impact.

This is broadly corroborated by other studies of the economic impact of cloud computing, such as a 2010 study by Cebr which asserted that a 24% increase in cloud computing adoption would result in a 1.26% increase in GDP, implying an approximate 0.05% increase in GDP per 1% increase in cloud computing adoption.[108]

Data analytics adoption

The relationship between data analytics adoption and GDP in this study is based on a 2016 Cebr report on the economic impacts of big data - i.e. large volumes of data handled by data analytics solutions. In this report, it is estimated that an 11% increase in the adoption of data analytics solutions in the UK results in a 0.67% increase in GDP, which suggests that a 1% increase in the adoption of data analytics results approximately in a 0.06% increase in GDP.[73] This result has been applied to the data analytics adoption rates assumed across the base case and the scenarios to estimate the corresponding GDP impact.

IoT adoption

The aforementioned 2016 report by the Cebr also estimates that a 13% increase in IoT adoption in the UK produces a 0.23% increase in GDP, which suggests that a 1% increase in IoT adoption results approximately in a 0.02% increase in GDP.[73] This result has been applied to the IoT adoption rates assumed across the base case and the scenarios to estimate the corresponding GDP impact.

Average speed

The academic literature quantifying the GDP impact of broadband speeds has expanded in recent years. This study relies on a 2018 report by Ofcom which concluded on the basis of an econometric analysis, of 35 OECD countries from 2002 to 2016, that an increase in average broadband download speeds from 2Mbit/s to 8Mbit/s is associated with an increase in GDP of 0.9%. This suggests that a 10% increase in speed results in a 0.03% increase in GDP.[74] This result has been applied to the average speeds assumed across the base case and the scenarios to estimate the corresponding GDP impact.

The magnitude of this relationship between speed and GDP corroborates an earlier study in 2012 which also estimated that a 10% increase in speeds could increase GDP by 0.03%.[75]

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[107] https://www.imf.org/external/pubs/ft/weo/2018/02/weodata/weorept.aspx?pr.x=42&pr.y=2&sy=2018&ey=2023&scsm=1&ssd=1&sort=country&ds=.&br=1&c=998&s=NGDPD%2CPPPGDP%2CPPPPC&grp=1&a=1

[108] Cebr (2010). 'The Cloud Dividend'

While the study for Ofcom suggests that there may be diminishing returns from increases in speed, it also notes that the threshold at which diminishing returns take place may increase over time: "the upper speed threshold may be increasing over time as new services appear that help firms and individuals productively use the improved infrastructures". In this study there is no assumption of diminishing returns from higher speed, as the digital maturity of the economy is assumed to increase in the Evolution scenario and the Revolution scenario such that higher speeds can be used productively, for example through new use cases.

The economic impact estimates do not account for other elements of connectivity, such as low latency, which could have economic benefits, as there is no robust evidence yet available on this.

Calculation of productivity impact estimates

Productivity impact estimates are driven by fixed broadband penetration, cloud computing adoption, data analytics adoption, and IoT adoption, as set out below.

Fixed broadband penetration

A 2009 report by the LECG finds that, looking at the United States from 1999 to 2007, an average annual increase of 2.4% in fixed broadband penetration resulted in a 0.26% average annual increase in productivity.[109] This suggest that for every 1% increase in fixed broadband penetration, there is a 0.11% increase in productivity. This result has been applied to the fixed broadband penetration rates assumed across the base case and the scenarios to estimate the corresponding productivity impact.

Cloud computing adoption

The 2010 Cebr report on cloud computing suggests that the average UK SME's productivity increase by 0.4% upon adopting cloud computing.[108] This 0.4% divided by the assumed increase in cloud computing adoption in the report implies a 0.02% increase in productivity per 1% increase in cloud computing adoption. This result has been applied to the cloud computing adoption rates assumed across the base case and the scenarios to estimate the corresponding productivity impact.

Data analytics and IoT adoption

The literature for quantitative estimates of the impact of these factors on productivity is scarce, therefore the ratio between cloud computing's GDP impact and productivity impact has been applied to the GDP impacts of data analytics adoption and IoT adoption to approximate their impacts on productivity.

Calculation of employment impact estimates

GDP is a product of average productivity per worker and the number of employees in an economy. As such, all employment impacts across the scenarios are equal to the GDP impacts divided by the overall level of productivity per worker.

Calculation of new business creation impact estimates

The 2016 Cebr report on the value of big data and IoT estimates how much of the economic benefits that data analytics and IoT generate will come from the creation of new businesses (3% and 5% respectively).[73] These percentages are applied to the overall GDP impact estimate in this study to estimate the total economic impact from new business creation, and then this figure is divided by the average turnover of SMEs in Scotland in 2018 (using data from the Scottish Government) to approximate how many new businesses this partial GDP impact would likely entail.

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[109] LECG (2009). 'Economic Impact of Broadband: An Empirical Study'

Following this, the overall estimate for the number of new businesses created is disaggregated by the defined geographic categories using data from the ONS on business openings by geography.

Calculation of export and tax impact estimates

Exports and taxes have been estimated using historical data on the percentage of GDP they have represented in the past. Scotland’s exports to the rest of the world (excluding the rest of the United Kingdom) have consistently been worth around 20% of Scotland’s overall GDP, whilst Scottish Government’s tax revenues (excluding miscellaneous categories which are not pertinent for the purposes of this study, such as property taxes) have consistently equated to around 16% of Scotland’s GDP. Both percentage have been very stable with minimal year-on-year change for well over a decade, and have therefore been assumed to be suitable for use for the purpose of creating 2035 estimates.

Impact estimates from variable coverage assumptions in the Evolution scenario

As outlined in Section 4, two variants of the Evolution scenario have been produced to reflect two possible states of the world for geographic 4G coverage across Scotland – with 65% 4G coverage by all mobile network operators in the medium-coverage variant and 90% 4G coverage by all mobile network operators in the high-coverage variant.

The indicative economic benefits from this 25% differential in geographic 4G coverage have been estimated using high-level analysis from Ofcom on the benefits of extending 4G coverage to:

- residents of rural areas where coverage would be extended; and
- visitors to rural areas where coverage would be extended.

Estimates of these benefits were used to approximate how many new mobile subscriptions could result from extended coverage (subscriptions on either smartphones or tablets, from either new subscribers or existing subscribers taking out an additional subscription). The economic impact of this increase in the number of mobile subscriptions is then calculated with the use of the multipliers linking GDP and mobile broadband penetration from the 2018 ITU report as outlined above.

Annex D: Comparison of results to 2015 study

This annex compares the core estimates of economic impact from the current study to those in the previous study, with respect to the following metrics:

- GDP
- Productivity
- Jobs
- Businesses
- Exports
- Tax revenues

The number and specification of scenarios varies between the two studies. For ease of comparison, this Annex displays the estimated impacts for the most positive scenario in each study – the Revolution scenario in this study and the World Leader scenario in the previous study.

The comparison is provided for completeness, but it should be noted that the two studies are not directly comparable due to the different time periods used, changes in the Scottish economy since the previous study, and updates made to the methodology based on the latest available literature and evidence.

Table 2: Comparison of GDP impact estimates

Geography	**Previous estimate** (World Leader scenario, increase relative to the counterfactual in 2030)	**Current estimate** (Revolution scenario, increase relative to the counterfactual in 2035)
Urban	£5.4 billion	£7.4 billion
Semi-urban	£5.3 billion	£6.3 billion
Rural	£1.7 billion	£2.0 billion
Remote rural	£0.9 billion	£1.2 billion
Total	**£13.4 billion**	**£17.0 billion**

Source: Deloitte analysis. Figures are rounded.

The larger absolute GDP impact in the current study manifests across geographies. The proportionate breakdown of impacts across geographies remains similar; for example urban and semi-urban areas account for around 80% of the total impact in both studies, reflecting that those areas account for the majority of economic output.

Table 3: Comparison of productivity impact estimates

Geography	**Previous estimate** (World Leader scenario, increase relative to the counterfactual in 2030)	**Current estimate** (Revolution scenario, increase relative to the counterfactual in 2035)
Urban	+£800 per worker	+£2,000 per worker
Semi-urban	+£400 per worker	+£1,300 per worker
Rural	+£600 per worker	+£1,600 per worker
Remote rural	+£500 per worker	+£1,900 per worker
Weighted average	**+£600 per worker**	**+£1,600 per worker**

Source: Deloitte analysis. Figures are rounded.

The modelling of productivity impacts in the current study has been enhanced, relative to the previous study, to take into account the productivity impact of IoT and data analytics adoption, as well as the productivity impact of broadband and could computing as considered in the previous study. This change leads to higher productivity impact estimates in the current study.

With respect to distribution across the different geographies, this is broadly similar to the previous study with the largest impact in urban areas and the lowest in semi-urban areas. This reflects underlying estimates of the average level of productivity, which differs by geography.

Table 4: Comparison of jobs impact estimates

Geography	**Previous estimate** (World Leader scenario, increase relative to the counterfactual in 2030)	**Current estimate** (Revolution scenario, increase relative to the counterfactual in 2035)
Urban	+45,000	+54,000
Semi-urban	+89,000	+74,000
Rural	+27,000	+23,000
Remote rural	+16,000	+13,000
Total	**+177,000**	**+163,000**

Source: Deloitte analysis. Figures are rounded.

The estimated impact on additional jobs is similar to the previous study, but has decreased slightly. This is a result of the larger productivity impacts estimated in the current study, as set out above. Because GDP is a product of the level of employment and the degree of worker productivity,

As was the case in the previous study, the largest estimated impact in the current study is in semi-urban areas – this is because semi-urban areas account for a relatively large share of Scotland's population and overall employment than any other geography.

Table 5: Comparison of business creation impact estimates

Geography	**Previous estimate** (World Leader scenario, increase relative to the counterfactual in 2030)	**Current estimate** (Revolution scenario, increase relative to the counterfactual in 2035)
Urban	+2,200	+1,400
Semi-urban	+1,900	+1,200
Rural	+900	+400
Remote rural	+500	+200
Total	**+5,600**	**+3,100**

Source: Deloitte analysis. Figures are rounded.

The estimated impact on business creation has decreased since the previous study. This is due to the current study using updated evidence on the linkage between digitalisation and new business creation (as set out in Annex C), which has affected the magnitude of the results.

Distribution across the different geographies is similar across the two studies.

Table 6: Comparison of exports and taxes impact estimates

Metric	**Previous estimate** (World Leader scenario, increase relative to the counterfactual in 2030)	**Current estimate** (Revolution scenario, increase relative to the counterfactual in 2035)
Incremental exports	£2.9 billion	£3.3 billion
Incremental tax revenue	£4.5 billion	£5.7 billion

Source: Deloitte analysis. Figures are rounded.

The impact estimates for incremental exports and tax revenue are higher in the current study, which reflects the fact that these metrics are expected to increase with GDP. These metrics are not disaggregated by geography.