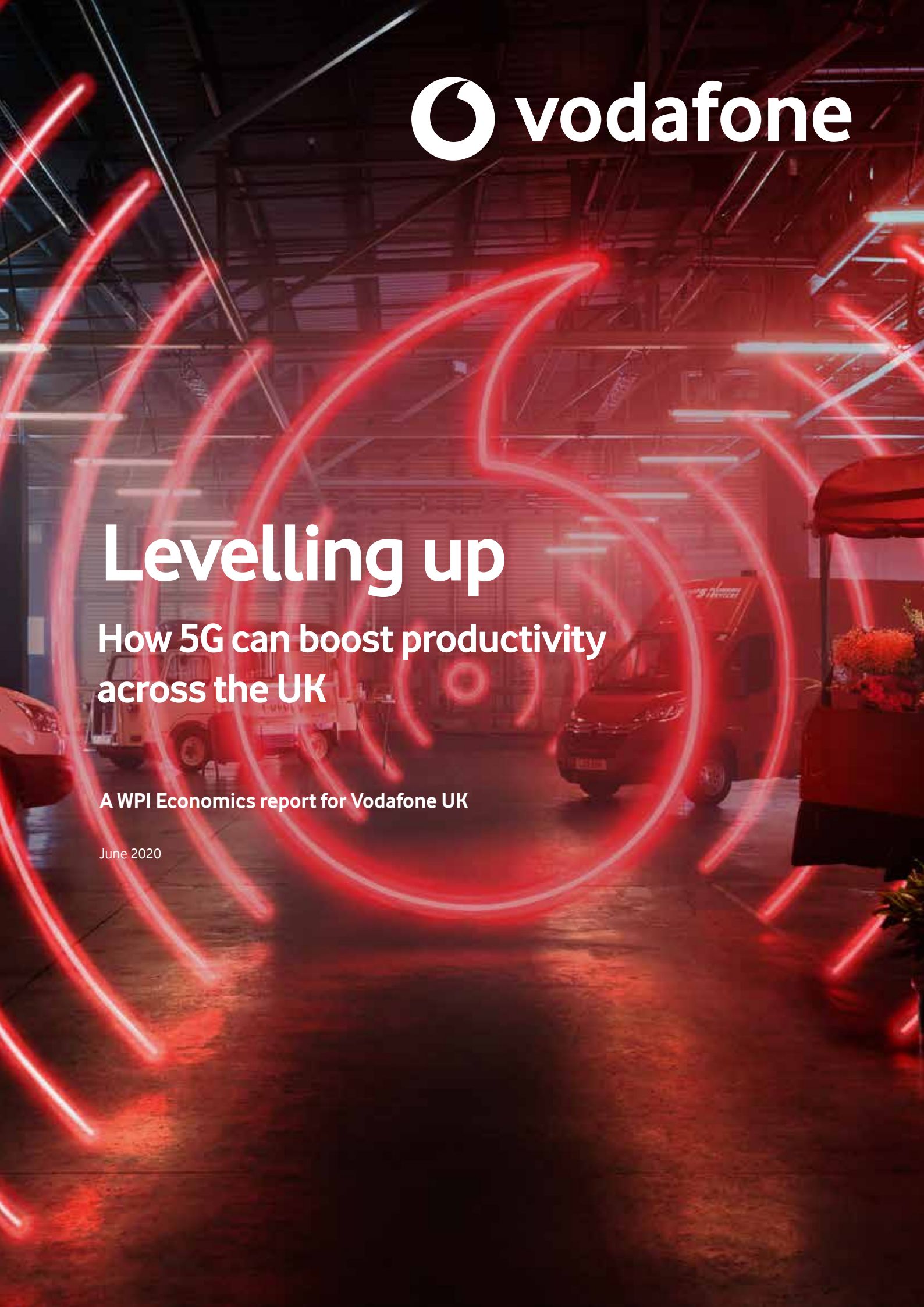


Levelling up

How 5G can boost productivity across the UK

A WPI Economics report for Vodafone UK

June 2020

Contents

About this report

This WPI Economics report, commissioned by Vodafone UK, contributes to the growing literature that highlights the vast potential of the rollout of 5G (the fifth-generation mobile network) for individuals, families and society as a whole. This report focusses on one element of this in particular, the potential productivity gains, to show how the benefits of 5G could be felt across every region and nation of the UK in the years to 2030.

About WPI Economics and authors

WPI Economics is a specialist economics and public policy consultancy. We provide a range of public, private and charitable clients with research, modelling and advice to influence and deliver better outcomes through improved public policy design and delivery.

Matthew Oakley, Director

Matthew founded WPI Economics in 2015. He is a respected economist and policy analyst, having spent well over a decade working in and around policy making in Westminster. He has previously been Chief Economist at Which?, and Head of Economics and Social Policy at Policy Exchange. He began his career as an Economic Advisor at the Treasury. He holds an MSc in Economics from UCL.

Christina Bovill Rose, Analyst

Alongside working at WPI Economics, Christina is currently undertaking an MSc in International Public Policy from UCL, where she is also a research assistant to a Professor in Public Policy. Prior to this, she worked in policy and research in the charity sector, with a focus on youth and community work and education.

wpieconomics.com info@wpieconomics.com @wpi_economics

About Vodafone

Vodafone UK connects people, businesses and devices to help our customers benefit from digital innovation. Our services span mobile, fixed line, broadband and the Internet of Things (IoT). We employ around 11,000 people across the UK, and operate more than 400 retail stores nationwide.

Having made the UK's first mobile phone call and sent the first text, Vodafone has a history as a tech pioneer. In 2018 we made the UK's first live holographic call using 5G, and were the first to start carrying live 5G traffic from a site in Salford, Greater Manchester. Today we serve over 18 million mobile and fixed line customers in the UK, with 4G network coverage at 99%. Vodafone has launched 5G in 44 places across the UK so far. Our customers voted us the UK's Best Mobile Network at the 2018 Trusted Reviews Awards for the second year in a row. To help deliver Gigabit UK, we are rolling out full fibre broadband across 12 towns and cities in partnership with CityFibre, reaching one million homes and business by 2021.

Our ReConnect programme is supporting women and men back into work after a career break, our IoT technology is working to create a low-carbon society, and our free Digital Parenting magazine is helping families across the UK to navigate the online world safely. For two years running, we have been named one of the UK's 25 Best Big Companies to Work For by the Sunday Times, and a Top 100 Employer by Stonewall.

We are part of Vodafone Group, one of the world's largest telecommunications companies, with mobile operations in 22 countries, partnerships with mobile networks in 42 more, and fixed broadband operations in 17 markets. As of 31 March 2020, Vodafone Group had 362 million customers, including 115 million mobile customers, 25 million broadband customers and 22 million TV customers in Europe and 168 million mobile customers in Africa.

For more information about Vodafone UK, please visit: **www.vodafone.co.uk**

Foreword

Most parts of the world have been rocked by the seismic events of recent months. We don't know yet what overall impact this global coronavirus pandemic will have on the way we live, work and socialise. What I am certain of is this: we, as a nation, will come together and rebuild our local communities. We will work with Government to create the conditions for businesses to thrive once again. We will continue to support the needs of our health service and education systems. We will develop talent and ensure that the UK remains one of the most innovative and dynamic economies in the world.

The foundations for success will be based on rebuilding our local economies as quickly as possible. To achieve this requires a turbocharging of the Government's stated 'levelling up' agenda. We must ensure that every area of the country has the tools it needs to catch up with the more prosperous regions. They need to be able to attract talent and private investment. We firmly believe that a high quality education system and high quality infrastructure – both physical and digital – alongside financial support schemes, must be at the heart of plans to rebuild the nation.

5G isn't just the next generation of mobile network technology, it is a step-change in both speed and capacity, allowing us to unlock the potential which we know exists in every corner of the UK. Offering speeds up to 10 times faster than 4G and a huge boost to network capacity, the benefits will be felt across the economy. As previous research Vodafone commissioned has shown, we now have an enormous opportunity to create a wave of new 'digital super towns'. Places with super-fast connectivity provided by 5G mobile networks, that can power and grow tech start-ups specialising in artificial intelligence, virtual reality, robotics and other cutting-edge technologies. Public services could be delivered to people in their homes at the touch of a button. Pre-existing industries, such as manufacturing, could be transformed through these new technologies.

Rolling out 5G as quickly as possible is crucial. 5G's faster speeds, and the capacity to handle huge amounts of data, will be critical to a whole range of businesses as they look to rebuild and respond to the changing demands of their customers.

Faster and more reliable mobile networks will lead to productivity gains and higher living standards all over the UK, which will underpin the growth of these digital super towns. Rolling out 5G as quickly as possible is crucial. 5G's faster speeds, and the capacity to handle huge amounts of data, will be critical to a whole range of businesses as they look to rebuild and respond to the changing demands of their customers.

Our research highlights just how big these gains could be were businesses to move from 4G to 5G. In the five years to 2025, cumulative benefits to UK output stand at more than £38bn, and for the five years to 2030, they stand at more than £120bn. Across the 10-year time frame this means a productivity-based boost to UK output worth more than £150bn. These benefits are also spread across each country and region of the UK. For example, the cumulative benefits to economic output in the North West in the five years to 2030 stand at £11.6bn, with £4.5bn in Greater Manchester alone.

Retailers are among those who are likely to gain first from new products and services driven by 5G. While technology and, in particular, the internet have historically presented a threat to the high street, a wave of 5G-led innovation could make shopping more rewarding, interactive and exciting for consumers. This would also have the knock-on effect of improving brand loyalty and, ultimately, sales.

And the use of big data analytics is already helping retailers to understand shopping trends and tailor their services accordingly. 5G could supercharge this data-driven approach and ignite further innovation.

The good news is that companies such as Vodafone are already committed to rolling out 5G networks across the UK. As a British company we want to work with our partners in local and national government to ensure the path is clear for us to continue to invest in improving the nation's connectivity. The Government has also recognised the importance of strong digital foundations – it has committed the UK to becoming a global leader in 5G technology and for 5G to reach the majority of the country by 2027.

This is a commendable aim. But I believe we can and have to go further and faster. Given the economic and societal benefits that 5G could play in unleashing a wave of new digital super towns with more job opportunities, reinvigorated high streets, more efficient businesses and better public services, I urge the government to bring its ambition forward by two years. If we can bring 5G to the majority of the UK population by 2025, then we will be going a long way to creating the conditions required for us to rebuild the economy and the nation.

Nick Jeffery, CEO, Vodafone UK

Executive Summary

Everyone, everywhere can benefit from the rollout of 5G. But with the right investment decisions it can make a particular difference to those parts of the country that have previously been left behind. The places that have suffered most from a lack of investment and poor connectivity – physical as well as digital – are those that stand to benefit most from new technology that will connect people, devices, businesses and public services faster, more securely and more reliably than ever before. For a Government committed to "levelling up", this is an exciting prospect. The Covid-19 outbreak has also demonstrated the importance of digital connectivity, both now and in the future. Many businesses have had to find new ways of working together remotely and have largely done so successfully. In the future, many companies may want a more flexible way of working, and digital connectivity will be crucial to that. Covid-19 also transformed almost every aspect of family life, from Zoom birthday parties to Netflix screenings with friends and parents using online tools to home school their children while schools were shut.

This report shows how 5G will supercharge and transform the economy and drive growth in nations, regions and towns right across the UK.

This report outlines examples of where the benefits of 5G are already being realised and sets out some of its potential future uses. In our hospitals, the technology will help our surgeons work with more precision than ever, while people in remote communities will have access to the kind of care that would once have required hours of travel. In our schools, teachers will be able to share rich virtual experiences with their classes and children will be able to explore the solar system, the human body and the ocean floor like never before. In our towns and cities, 5G could help to revolutionise traffic and congestion management, reducing delays and allowing quicker access for emergency services.

But the report also shows that some of the core benefits of 5G come simply from the improved speed and capacity that it brings – enabling businesses and consumers to fully embrace the opportunities previously offered by 4G.

Regardless of how they are realised, the economic benefits of a 5G revolution could be immense. Based on a meta-analysis of existing research, this report assesses the potential benefits derived just from the productivity gains associated with business moving from 4G to 5G. In the five years to 2025, cumulative benefits to UK output stand at more than £38 billion, and for the five years to 2030, they stand at more than £120 billion.

These benefits are also spread across each country and region of the UK. For example, the cumulative benefits to economic output in the North West in the five years to 2030 stand at £11.6 billion, with £4.5 billion in Greater Manchester alone. Over the same time frame, cumulative benefits for Scotland stand at £9.3 billion. Again, these are not just country-level benefits, they are benefits that will be felt by businesses, employees and families right across Scotland.

These are significant economic benefits and they come from productivity increases alone. The potential benefits deriving from innovation and the commercialisation of ideas into new industries, products and services that are at the forefront of the Fourth Industrial Revolution come alongside and have the potential to be much larger.

However, these benefits are not guaranteed and, if the UK is to become a global leader in 5G, more still needs to be done. The key to unlocking the UK's potential to become a global digital leader is investment in 5G supported by full fibre. The Government has taken a number of welcome steps to support the rollout of digital infrastructure across the UK, including for example the 5G Testbeds and Trials Programme.

To unleash the full economic potential of 5G, Government needs to help create the policy, procurement and investment environment that will support these ambitions. This includes Government leading the way by committing to a 'smart by default' procurement strategy and removing barriers to 5G rollout in order to create the right investment climate. The Government has previously committed to rolling out full fibre and gigabit capable broadband to every home and business across the UK by 2025 and for the majority of the population to be covered by a 5G signal by 2027, and the recently-signed Shared Rural Network deal has an important part to play in filling coverage gaps in the more remote rural areas. But the Government should go further and adapt its current 5G strategy to create the conditions and support that could enable the rollout of 5G to the majority of the population by 2025.

We know that 5G has the potential to play a part in "levelling up" the UK economy. Now that the technology is being rolled out across the UK, it is down to politicians and business leaders to ensure that we all reap the benefits, wherever we live.

The UK's Technology Revolution

The UK is undergoing a digital revolution that is transforming the economy and how we live our lives. Advances from the Fourth Industrial Revolution, including artificial intelligence, advanced robotics, automation and the explosion of connected devices seen through the Internet of Things (IoT) will deliver products and services that would have once been regarded as impossible.

The impact of this is significant. The latest estimates show the digital sector contributing approximately £150 billion to the economy each year –7.7% of total UK output[i] – and accounting for 1.5 million jobs.[ii] This revolution is also a strong draw for investors, with the UK tech sector attracting £6.3 billion in venture capital investment in 2018.[iii]

The benefits do not only favour ambitious tech entrepreneurs, but the wider population too. For example, recent work commissioned by Vodafone from WPI demonstrated how the creation of digital super towns could unleash the digital potential in towns and cities right across the UK.[iv] The Government has also spoken of "unleashing the productive power of the whole United Kingdom", committing to rolling out gigabit-capable broadband and a £3.6 billion boost for deprived towns.

Underpinning this digital revolution is ever improving access to the internet through better mobile connectivity. Widespread web access was first introduced on 3G networks in the early 2000s. A few years later, the technology evolved into 4G mobile technology built on the Long-Term Evolution standard (LTE), which offered far superior connectivity. Now we have 5G which is a further evolution of LTE. This new generation of mobile network, underpinned by 4G infrastructure and complemented by narrowband IoT, will radically improve reliability, capacity and speed. In doing so it will transform business productivity, support business flexibility through – for example – remote working, drive improvements in our public services and bring families, friends and loved ones closer together.

What is NB-IoT?

Narrowband IoT (NB-IoT) is a form of low power internet of things technology that sends small packets of simple data. It might be used to monitor silo levels, pipe leaks, temperature, or any other conditions over a period of time. One example of a potential use case could be in the agricultural or farm industry, for instance by checking soil temperature, humidity levels, crops health and chemicals.

Due to the size of the data packets being sent, NB-IoT can be deployed at great scale and at very little cost. The minimal connectivity required allows devices to be deployed in areas of limited connectivity, including underground. The devices, which are battery powered, can run for 10 years or more without charge, reducing vastly the maintenance cost associated with other technologies.

How 5G is built on 4G infrastructure

In the UK, 5G rollout is – initially – an evolutionary upgrade of 4G infrastructure to deliver 5G. 5G is not a new network and the frequencies used for 5G in the UK are close to the current 4G frequencies. This means with a small antenna upgrade, or additional one where required, mobile operators will be able to use the same masts currently providing 4G services for 5G as well.

The potential of 5G is significant. New technologies and existing industries, products and services use more and more data and require more connections, but are set to be transformed by the connectivity enhancements brought about by 5G. Globally, it has been estimated that there could be over 65 billion connected devices by 2025. This is compared to around 9 billion in 2017. Recent estimates suggest that data consumption in the UK increased by 217% between 2014 and 2018.[v] Importantly, as well as increased demand, new technologies will also need improved connectivity performance. For example, low latency, near real-time interactivity, will be required to realise the potential of connected and autonomous vehicles and augmented reality.

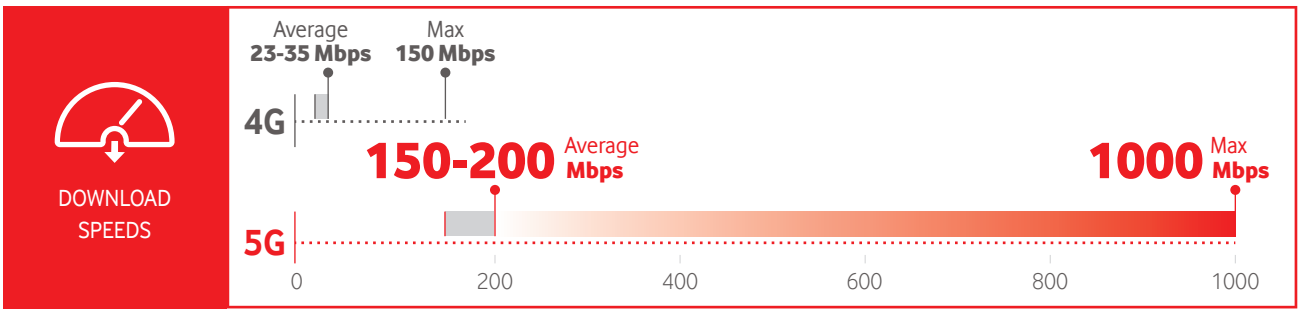
Theresa May's Government made a start on creating the right conditions for 5G rollout across the country. For example, a 5G Testbed and Trials Programme is being used to explore the benefits and challenges of 5G deployment. The current Government has also highlighted its ambition to continue this work and politicians are increasingly talking up the opportunities that 5G offers.

But a comprehensive 5G network across the UK, and the significant benefits that this would bring, are not guaranteed. This report explores what makes 5G different, what the advantages could be across a range of issues and, importantly, how **5G can play a role in levelling up the regions and nations across the country**.

What Is 5G And Why Is It Different?

4G was launched in 2012, and it introduced a new wave of faster mobile broadband. In the coming years, 4G will continue to improve but 5G will provide a step change in the quality and reliability of mobile internet connections. Being built – at least initially in the UK – on top of 4G network infrastructure, 5G is set to deliver an even greater evolution in mobile connectivity performance.

But unlike previous generations, 5G is about much more than ultra-quick downloads, speedier uploads and web pages that are faster than ever to open. Instead, it is also the gateway for the massive expansion of IoT, with further innovation enabled by 5G expected to be revolutionary for business, and the management of our public services. The opportunities are almost limitless. Exactly how this will happen can be seen by exploring the capabilities of 5G.



Increasing capacity and opening up Massive IoT: 5G will increase network capacity. Allowing connections with one million devices per square kilometre, it will help end the frustrations of people unable to access the internet in crowded places like train stations and sporting events.[vi] It also stands to build on and supercharge the potential of IoT, with new 5G networks including smart devices, healthcare devices, connected buildings, vehicles, transport infrastructure, and everyday items such as home appliances.

Enabling critical communication: A core benefit compared with previous generations is 5G's low latency. In simple terms latency measures the delay between when data is sent and when it is received and is, for example, what results in buffering when streaming content. However, the real importance of low latency is that it will open up opportunities for the use of mobile networks where very quick response times are necessary, for example in areas like remote surgery and driverless cars.

Enhanced mobile broadband: With peak speeds that could ultimately reach 1Gbps, with 5G initially speeding up mobile internet downloads by up to 10 times.[vii] In practical terms that means consumers being able to download a full HD film in three minutes, compared to over 15 on 4G, and new opportunities for immersive alternative and virtual reality experiences.

Efficient network use: Different applications will need different things from the network. For example, some uses need low latency, but transfer only small amounts of data (IoT); others require large data transfers and have less need for super-low latency (mobile broadband). Network slicing with 5G will mean that virtual networks can be provided to meet the specific needs of the application in question. This means that the physical network can be optimised, and cost-effective solutions delivered.

Security: The UK's 5G network is an evolution of, and builds on, the current 4G network. In terms of security, it is more secure than open-access Wi-Fi, at least as secure as 4G and even enhances security in areas such as protection of customers from interception, impersonation and location tracking. As mobile operators continually build on experience, they are adding new 5G security tools which will seek to further enhance network security.

Viewed like this, it is clear that 5G has the potential to touch so many aspects of everyday life that its benefits will be far-reaching, both in terms of scale and variety.

By opening up these applications, it is clear that 5G could add profound economic, social and societal benefits to the UK. However, it is also clear that some of these potential uses, and the benefits that come with them, are difficult to imagine. The next sections of this report provides an analysis of the productivity benefits that we would expect to see from the rollout of 5G and how this increased connectivity can help level up our nations, regions and towns.

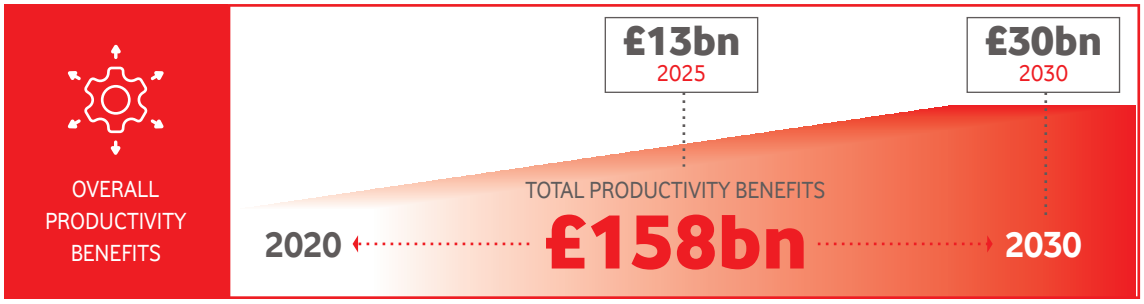
Estimating The Productivity Benefits Of 5G

The scale of the potential of 5G rollout is enormous, and the later sections of this report go into detail on what 5G rollout could look like in practice. To quantify the overall benefits, a number of studies have looked to estimate the potential size of specific markets supported by 5G and some of their potential benefits. For example, estimates suggest:

- Artificial intelligence could add £630 billion to the UK economy by 2035, increasing the annual growth rate of gross value added (output) from 2.5% to 3.9%;[viii] and
- IoT could lead to economic impacts of as high as $11.1 trillion globally in 2025.[ix,x]

Bringing some of these ideas together, a few studies have looked to estimate the overall economic potential of 5G. For example, one report suggests that the 5G value chain will boost global output by as much as £2.8 trillion by 2035 and support 22 million jobs. Of this, £60 billion worth of output and 600,000 jobs are in the UK.[xi]

Whilst this research provides an indication of the scale of benefits, they do come with a high degree of uncertainty. To tackle this, other research has looked to narrow the focus to understand the potential productivity benefits to businesses of moving from 4G to 5G. A range of studies have done this by surveying businesses and analysing the impacts of moving from 3G to 4G (and 2G to 3G).



Based on a meta-analysis of these results, this report estimates the potential productivity benefits of 5G rollout to businesses in the UK. This suggests productivity impacts on UK output of £13 billion in 2025 and £30 billion in 2030.[xii,xiii]

When the cumulative benefits are considered, the sheer scale of these benefits can be understood. In the five years to 2025, cumulative benefits to UK output stand at more than £38 billion and for the five years to 2030, cumulative benefits to UK output stand at more than £120 billion. Across the 10 year time frame this means a productivity-based boost to UK output worth more than £150 billion. This will be driven by 5G technologies such as 5G private networks, smart health devices and 5G enabled Smart Cities.

Estimates of productivity benefits for UK output can also be estimated for different parts of the UK. Table 1 demonstrates this analysis, showing the potential for 5G to drive productivity benefits and growth across each country and region of the UK. Increasing productivity across the regions through 5G technologies, and therefore increasing economic output and creating jobs could be a key tool in the Government's arsenal to level up these regions. For example, the cumulative benefits to economic output in the North West in the five years between 2026 and 2030 stand at £11.6 billion, with £4.5 billion in Greater Manchester alone. Over the same time frame, cumulative benefits for Scotland stand at £9.3 billion. Again, these are not just country-level benefits, they are benefits that will be felt by businesses, employees and families right across Scotland. And will be driven by technologies such as 5G enabled retail, smart public services and autonomous vehicles.

These are significant economic benefits and they come from productivity increases alone. The potential benefits deriving from innovation and the commercialisation of ideas into new industries, products and services that are at the forefront of the Fourth Industrial Revolution come alongside and have the potential to be much larger.

The next four sections outline a number of potential benefits of 5G rollout impacting on business productivity, the public sector, business opportunities and the high street.

Table 1: Potential productivity benefits of 5G mobile network on UK output, by area

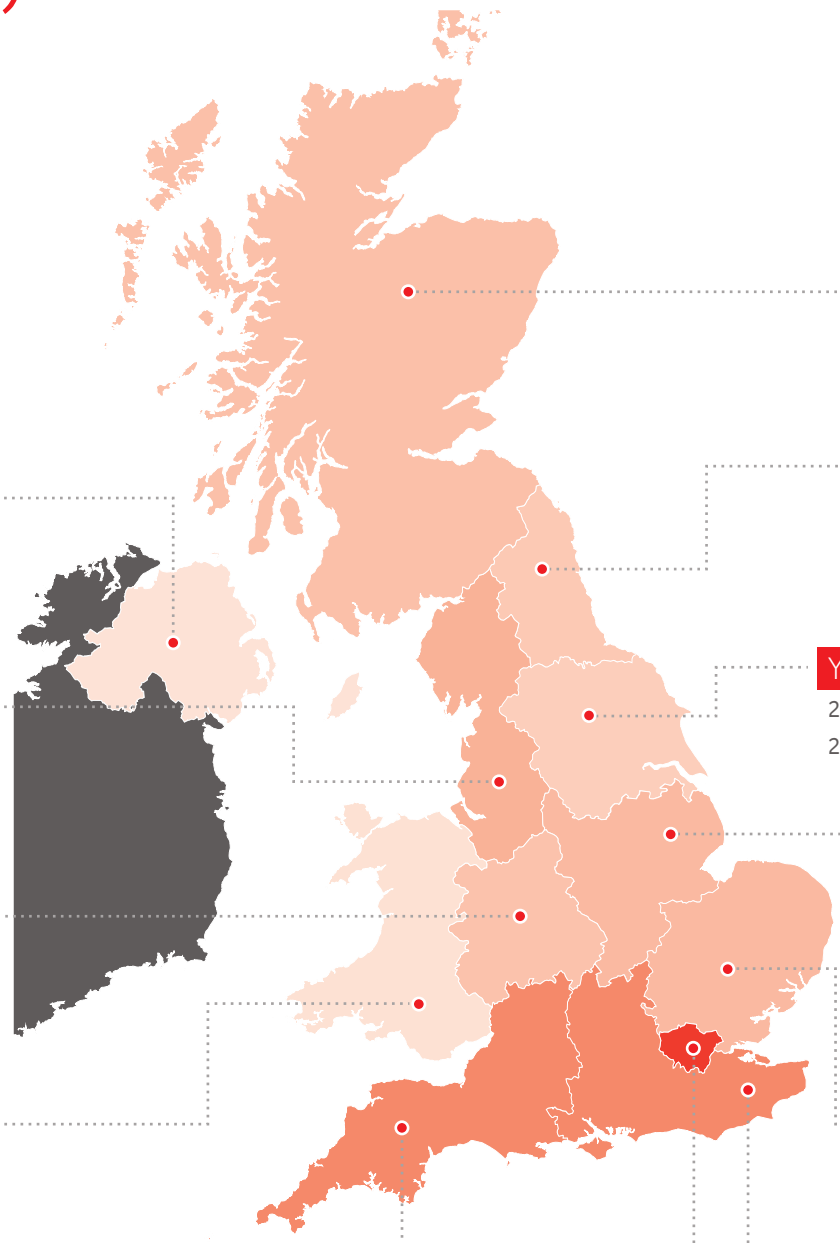
	2020-2025 (£ million)	2026-2030 (£ million)
NORTH EAST	**1,100**	**3,600**
Tees Valley and Durham	500	1,500
Northumberland and Tyne and Wear	700	2,100
NORTH WEST	**3,700**	**11,600**
Cumbria	300	800
Greater Manchester	1,400	4,500
Lancashire	700	2,200
Cheshire	700	2,100
Merseyside	700	2,200
YORKSHIRE AND THE HUMBER	**2,500**	**7,800**
East Yorkshire and Northern Lincolnshire	400	1,300
North Yorkshire	400	1,300
South Yorkshire	600	1,800
West Yorkshire	1,100	3,600
EAST MIDLANDS	**2,200**	**7,000**
Derbyshire and Nottinghamshire	1,000	3,100
Leicestershire, Rutland and Northamptonshire	1,000	3,000
Lincolnshire	300	900
WEST MIDLANDS	**2,800**	**8,900**
Herefordshire, Worcestershire and Warwickshire	700	2,300
Shropshire and Staffordshire	700	2,200
West Midlands	1,400	4,500
EAST OF ENGLAND	**3,200**	**10,200**
East Anglia	1,300	4,100
Bedfordshire and Hertfordshire	1,100	3,500
Essex	900	2,700

	2020-2025 (£ million)	2026-2030 (£ million)
LONDON	**9,100**	**28,800**
Inner London - West	4,100	12,800
Inner London - East	2,200	7,000
Outer London - East and North East	800	2,400
Outer London - South	700	2,000
Outer London - West and North West	1,500	4,700
SOUTH EAST	**5,700**	**17,900**
Berkshire, Buckinghamshire and Oxfordshire	1,900	6,100
Surrey, East and West Sussex	1,700	5,500
Hampshire and Isle of Wight	1,200	3,600
Kent	900	2,800
SOUTH WEST	**2,800**	**8,700**
Gloucestershire, Wiltshire and Bath/Bristol area	1,500	4,600
Dorset and Somerset	600	1,900
Cornwall and Isles of Scilly	200	700
Devon	500	1,600
WALES	**1,300**	**4,200**
West Wales and The Valleys	700	2,300
East Wales	600	1,900
SCOTLAND	**2,900**	**9,300**
North Eastern Scotland	400	1,300
Highlands and Islands	300	800
Eastern Scotland	1,200	3,800
West Central Scotland	800	2,400
Southern Scotland	400	1,100
Northern Ireland	**900**	**2,700**

Source: WPI Economics, ONS.

Notes: Due to rounding, figures may not sum.

UK map showing potential productivity benefits of 5G mobile network on UK output, by area (£ million)



Scotland
2020-2025 **2,900**
2026-2030 **9,300**

North East
2020-2025 **1,100**
2026-2030 **3,600**

Yorkshire & The Humber
2020-2025 **2,500**
2026-2030 **7,800**

East Midlands
2020-2025 **2,200**
2026-2030 **7,000**

East of England
2020-2025 **3,200**
2026-2030 **10,200**

South East
2020-2025 **5,700**
2026-2030 **17,900**

London
2020-2025 **9,100**
2026-2030 **28,800**

South West
2020-2025 **2,800**
2026-2030 **8,700**

Wales
2020-2025 **1,300**
2026-2030 **4,200**

West Midlands
2020-2025 **2,800**
2026-2030 **8,900**

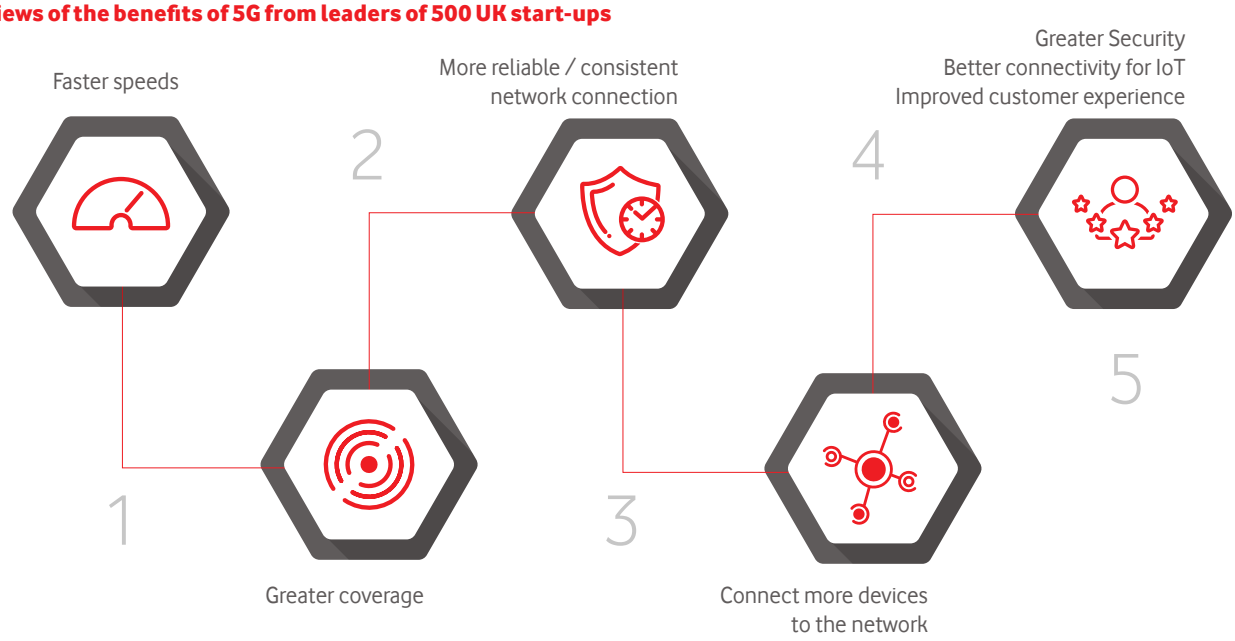
North West
2020-2025 **3,700**
2026-2030 **11,600**

Northern Ireland
2020-2025 **900**
2026-2030 **2,700**

Supporting Business Productivity

Not all of the benefits of 5G come from the introduction of new products, approaches and services. In fact, some of the core benefits come simply from the improved speed and capacity that 5G brings, which will be even more important as some businesses increase their employees' remote working. Again, the potential benefits are clear. For example, Vodafone's recent research with start-ups showed that the most commonly cited benefit of 5G was faster speeds, followed by greater coverage and more reliable connection.

Views of the benefits of 5G from leaders of 500 UK start-ups



As awareness and understanding of the potential of 5G grows amongst businesses, the wider benefits of 5G highlighted above are likely to far outweigh these. However, in each of these areas businesses are right to think that 5G has the potential to provide significant benefits over the traditional wired and wireless networks they use. Outside of the office, the practical applications include office wireless speeds on the go and improved reliability of connectivity, ensuring that remote working is opened up to more people.

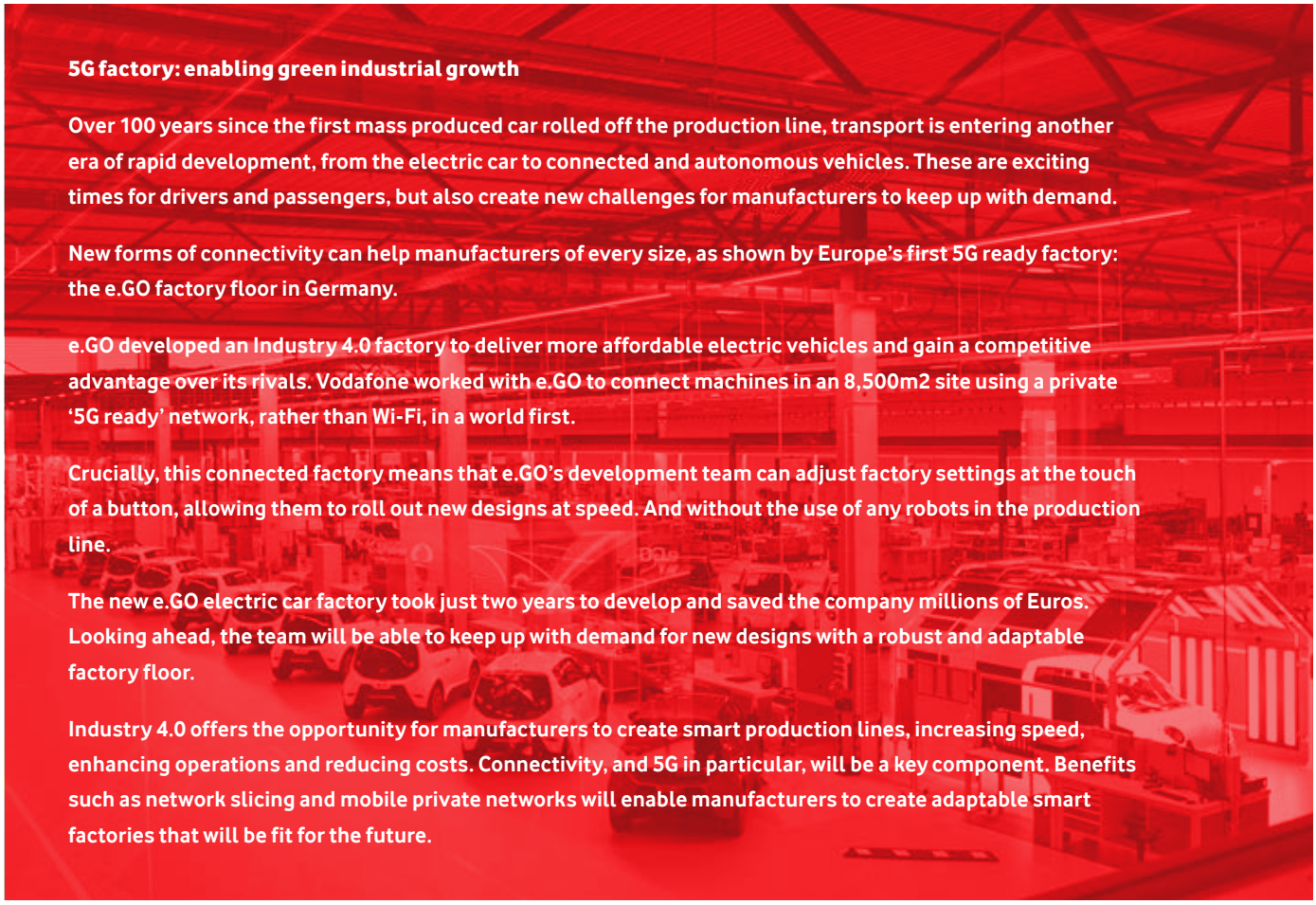
There are also potentially significant benefits within the workplace, with private 5G networks provided by mobile network operators offering an alternative to traditional wired local area networks (LAN). There are a range of potential advantages to this:

- As IoT becomes the norm and workplaces have more sensors and devices connected to each other, an ever-expanding web of wires will become near-impossible to set up and manage. Equally, connecting devices, or people who move around the office, factory or site can again be costly and impractical. A 5G private network, provided by a mobile network operator, removes the need for this.[xiv]
- Control and security are strong and can be tailored by the business, ensuring that sensitive, proprietary data remains local.[xv]
- As with other uses, a private 5G network boasts wireless speeds, network slicing to optimise performance and super-low latency; together providing advantages over both traditional wired LAN and existing private networks delivered through 4G.[xvi]

As already highlighted, with greater speeds and improved connectivity comes new technologies and ways of working.

The box below takes this a step further to show how 5G could radically change how whole production lines are operated, with seamless connectivity, sensors and data flow in industrial and business processes having the potential to be a significant boost to productivity and subsequently helping to rebuild local economies. There are also potentially significant safety benefits, for example, in remote inspections of power lines and gas pipelines and in controlling heavy machinery from a distance.

More broadly, technologies facilitated by the rollout of 5G could also provide significant savings from more efficient buildings. For instance, through smart buildings which optimise the use of heating, ventilation and air conditioning.



5G factory: enabling green industrial growth

Over 100 years since the first mass produced car rolled off the production line, transport is entering another era of rapid development, from the electric car to connected and autonomous vehicles. These are exciting times for drivers and passengers, but also create new challenges for manufacturers to keep up with demand.

New forms of connectivity can help manufacturers of every size, as shown by Europe's first 5G ready factory: the e.GO factory floor in Germany.

e.GO developed an Industry 4.0 factory to deliver more affordable electric vehicles and gain a competitive advantage over its rivals. Vodafone worked with e.GO to connect machines in an 8,500m2 site using a private '5G ready' network, rather than Wi-Fi, in a world first.

Crucially, this connected factory means that e.GO's development team can adjust factory settings at the touch of a button, allowing them to roll out new designs at speed. And without the use of any robots in the production line.

The new e.GO electric car factory took just two years to develop and saved the company millions of Euros. Looking ahead, the team will be able to keep up with demand for new designs with a robust and adaptable factory floor.

Industry 4.0 offers the opportunity for manufacturers to create smart production lines, increasing speed, enhancing operations and reducing costs. Connectivity, and 5G in particular, will be a key component. Benefits such as network slicing and mobile private networks will enable manufacturers to create adaptable smart factories that will be fit for the future.

Public Services And Infrastructure

The Government has already recognised - and taken action through the 5G Testbeds and Trials Programme to promote[xvii] - the vast potential that technology has both in driving innovative improvements to public services and helping more people to access those services. In many cases, 5G technology could also bring about significant fiscal savings.

Connecting the country

The Government's Rural Connected Communities programme is funding testbeds to explore how superfast 5G mobile connectivity could also help people living in the countryside.

Vodafone is excited to be working with Dorset Council on a £6.6m project, 5G RuralDorset, exploring how 5G could help with a wide range of activities. Four trials in the county look at innovative public, social and business uses of 5G technology. They will test whether this connectivity can be delivered cheaper and quicker using existing masts, buildings and fibre wherever possible to minimise visual and other impacts on communities. Use cases include crop and livestock monitoring using drones, improved coverage for locals and tourists at Lulworth Estate, public coastal safety and a new 5G Innovation Accelerator at Dorset Innovation Park.

The potential across the whole of the public sector is significant. Key examples are in health and social care, education and Smart Cities. It is already possible today for health professionals to provide virtual help in real time to colleagues based elsewhere. And the Covid-19 outbreak led to many GPs seeing patients virtually, teachers providing lessons to their pupils online and public sector employees across the country working remotely. But 5G will take this technology to the next level. In years to come, the world's best surgeons could operate on patients anywhere in the world and the speed, low latency and capacity that 5G provides will be central to ensuring that this is done safely and effectively. There are also exciting use cases being developed to support blind or visually impaired people. The box below highlights technology enabled by 5G that allows a blind Paralympic skier to ski solo and how this technology could be used in other settings.

5G Skiing: helping a blind athlete conquer the slopes

High up on the Riedberger Horn in the Bavarian Alps, 27-year-old Noemi Ristau stood on a snowy cliff. With freezing temperatures, bright sunshine and blue skies, the conditions are perfect for downhill skiing – but she saw nothing of it. Noemi, one of the most successful Paralympic ski riders in Germany, is blind.

With the help of 5G, Noemi was able to master her first solo descent down the slopes since she lost her sight 15 years ago. Up until this point, her guide Paula Brenzel had to accompany her down the slopes, talking her through the length of each turn. This time, the two were able to communicate from different parts of the mountain, connected only by a smartphone.

Using a local 5G wireless network, video and sound were transmitted from a smartphone camera attached to Noemi's helmet, allowing Paula to relay her instructions back to Noemi verbally. All in just under 10 milliseconds, as fast as the human nervous system.

The extremely high bandwidths and minimal response times of 5G technology mean that Noemi can now ski on her own, while still receiving support from her guide.

In the future 5G connectivity won't just benefit people like Noemi. Motorists, pedestrians and cyclists will be able to communicate with each other in real-time to improve road safety.

In schools, the use of virtual and augmented reality could mean that applications supported by 5G revolutionise how children are taught. For example, virtual reality could be used to give students interactive tours of the human body.[xviii] Teachers could also show children around the solar system or the ocean floor without leaving their seats. Equally, imagine the impact of lessons taught by international experts, leading entrepreneurs or world leaders - all enabled through holographic technology and supported by 5G. 5G technology has the power to enhance our already world-leading universities and education systems by creating an education powerhouse, providing first class resources to our schools, enabling the next generation of leaders educated across the whole of the UK.

Dialling into the future

In 2018, Vodafone achieved a significant milestone in UK communications by conducting the UK's first live holographic call using 5G technology.

The call from Vodafone's Manchester office featured England and Manchester City Women's Football Captain, Steph Houghton MBE. Using 5G technology, Steph appeared as a live 3D hologram on stage in front of an audience at Vodafone's UK tech centre in Newbury.

Steph's hologram gave footballing tips to 11-year-old Manchester City and Lionesses fan, Iris, in Newbury. Using the power of 5G Steph and Iris could chat and interact seamlessly as if they were in the same room – despite a massive 190-mile distance between them. The exchange demonstrated the exciting possibilities that 5G technology can bring to sport, including remote coaching and training, as well as the opportunity to bring sports fans closer to their idols.

More generally, research suggests that, by 2025, 5G enabled smart health devices and associated big data capabilities could lead to savings of £1.25 billion a year in UK public healthcare costs.[xix]

£1.25bn savings

5G's contribution to driving take-up of smart health devices and associated data capabilities could deliver £1.25 billion of savings per year to the NHS by 2025.

Source: WPI Economics, European Commission

A key example of where this could happen is in the Government's drive to tackle loneliness. Here, our recent report found that the health and wellbeing costs of loneliness in the over 50s were £3.9 billion a year, with a further £1.8 billion cost to the public sector and employers. The report demonstrated a range of ways in which technology could be used to tackle this issue (see box) and argued for the Government to ensure that digital is added to its social prescribing agenda, so that technology such as wearable devices and monitoring systems can be prescribed by GPs. 5G provides the opportunity to maximise the potential of these technologies and associated big data insights and innovate further to tackle what is a significant social issue in the UK.

Harnessing technology to tackle loneliness – Vodafone's V-SOS Band is designed specifically to support independent living, and, as a result, can play an important part in older people remaining in their homes and community for longer. Utilising the mobile network, rather than broadband, users can leave the home with the confidence that they can get help when they need it. The band comes with an SOS button and an easy-to-use app that means families can be directly alerted if the wearer needs help. It also uses fall detection technology so that families can be alerted automatically if the wearer falls either in the home or when they are out.

5G will also be central to the creation of Smart Cities right across the UK.[xx] Allowing so many more connected devices to work reliably, securely and uninterrupted in the same area could have profound impacts. For example, 5G technology could allow autonomous vehicles to connect in real time to each other, to signals, to pedestrians, to road infrastructure as well as to public telecom networks and resources in the cloud. This could help to avoid accidents and optimise traffic efficiency and therefore improve road safety, reduce traffic congestion, and lower greenhouse gas emissions. 5G could also offer connected and automated mobility services such as automated change of lanes ("lane merge") and trucks driving in platoons partly without need for drivers ("truck platooning"). Another example here could be Highways England and local road maintenance agencies deploying video cameras connected to local traffic lights to control the flow of traffic during roadworks to ease congestions and improve the environment. There are also opportunities to facilitate safer and quicker access to accident sites for emergency services.

Emergency services could also benefit in other ways. For example, emergency vehicles could become digital hubs for connected first responders. With more data, sent more quickly with low latency and for less money; police, paramedics and firefighters can use a common platform to assess emergency situations more quickly and communicate developments back to control rooms in real-time. With 5G, an ambulance can essentially be used as a connection hub for medical equipment and wearables that allows real-time streaming of patients' data to the emergency department in the hospital it is going to.

The box below provides an example of a 5G connected ambulance that has been used to improve both treatment prior to hospital admission and the admission process. Other examples include the use of drones, or connected cars, to monitor and report back on road conditions, in some cases even automatically repairing potholes.[xxi]

Connected ambulance – Vodafone worked with San Raffaele Hospital, the Lombardy Regional Emergency Service, Italian Red Cross and Altran to develop 5G enabled ambulances.

5G technology enables ambulances to be in constant contact with the emergency control centre and hospital through high-resolution video calls. This allows doctors to monitor a patient's condition and gather crucial information before the patient arrives at the hospital.

5G connectivity also allows emergency services to carry out non-standard procedures remotely using augmented reality. And to share biomedical data and the results of diagnostic tests using imaging equipment in real time. 5G technology thereby allows treatment to be delivered in the shortest time possible.

There are also a range of potential efficiencies and cost savings that could be delivered through 5G, facilitating the introduction of technology more broadly in public services, and supporting our towns and cities across the whole of the UK. Examples include:

- Smart buildings reducing the costs of running the public sector estate, for example reducing energy use by introducing smart lighting and by optimising the use of heating, ventilation and air conditioning.
- Smart bins that monitor waste levels and link to connected collection vehicles so that collection routes can be optimised in real time, thereby making collection services more efficient.[xxii]

To some extent, this is already happening, with HMRC recently signing a charter with construction and maintenance companies involved in the development of 13 new locations in the UK. The charter commits to "maximising the use of data and implementing the latest digital technology, including smart technology where systems interact with each other" and is central to achieving £300 million of savings by 2025.[xxiii] However, there is clearly a long way to go and the potential to retrofit the existing buildings comes with incredibly large potential cost savings.

World's first haptic rugby tackle

In July 2019, Vodafone demonstrated the power of 5G to transmit touch using haptic technology. Two players from Wasps rugby team were able to run a training session despite being more than 100 miles apart. The impact of a rugby tackle made by Will Rowlands at the Ricoh stadium in Coventry was transferred via 5G to teammate Juan de Jongh in London. Juan, in a specially developed haptic Teslasuit, was able to feel the force of the tackle in real-time thanks to Vodafone's high speed and super low latency 5G.

Connecting the smallest football league in the world

The world's smallest football league kicked off the 2019 season in style with a new piece of tech, and help from Vodafone.

The two-team football league on the Isles of Scilly, off the coast of Cornwall, used a well-known Video-Assistant Referee (VAR) system – with a twist. Thanks to Vodafone's 5G network, the first game of the season was introduced to FAR: Fan-Assistant Refereeing, a world first.

Showcasing the benefits of Vodafone 5G, the FAR system put supporters across the island at the heart of the game. Equipped with Samsung S10 5G handsets, fans were able to review incidents just after they happened. And instead of catching up on the ref's decisions after the game, supporters on the main island of St Mary's were able to have their own say on several fouls, a disputed goal, and two contested penalties as the game was being played.

Following a quick online vote, fans' decisions were relayed to the match official at pitchside. The Woolpack Wanderers won the match 4 – 3, with only minutes to spare.

Opening Up New UK Business And Societal Opportunities

Across a range of sectors, 5G has the potential to drive ground-breaking advances. This will come from innovation and development of new technologies, products and services that 5G enables. For example, the UK Government already has ambitions to put the UK at the forefront of the AI and data revolution.[xxiv] More broadly, the UK's digital technology sector is innovating in areas from advanced robotics to autonomous vehicles, the use of drones and virtual / mixed reality.

Whilst work in all of these areas in already underway, 5G has the potential to mark a step-change in the opportunities available and the extent to which ideas can become a reality. For example, 5G's ultra-low latency and ability to use network slicing means that autonomous vehicles will be able to receive vehicle-to-vehicle or vehicle-to-infrastructure data from sensors almost instantaneously. This will be important as autonomous vehicles are used in greater numbers, allowing them to react quickly to changing conditions or unexpected events.

Opening up applications like the development of autonomous vehicles means that 5G provides huge opportunities for UK businesses in every UK region and nation looking to develop new technologies and put the UK at the forefront of the Fourth Industrial Revolution. An example is Conigital, who are already innovating in this area.

Along with the connected devices, services and data analytics associated with IoT, the sections above have already demonstrated areas of innovation in healthcare, education and the delivery of infrastructure, which UK businesses can commercialise and use to access a global market worth trillions of pounds. 5G provides opportunities for businesses of all shapes and sizes and across all sectors to grow and to work in every area of the country. The reliability of the connectivity will allow businesses to stay in place, and to grow in the areas that people grew up in and love with greater flexibility for their workforces, levelling up every region and nation of the country.

Conigital is using artificial intelligence to develop connected and autonomous vehicles for ground fleets. From its base in Birmingham, Conigital provides both on-vehicle automation and off-vehicle operations, to support both partly and fully automated fleets of vehicles in airport environments like Manchester Airport. Conigital is benefitting from the slicing capacity of 5G, which enables operators like Vodafone to provide portions of the network for specific use cases like driverless cars, to deliver the extremely reliable connectivity needed for the technology.

Another example is the team behind XR1, a mixed reality technology that is being developed and could signal ground-breaking advances in remote working across a range of fields. Including from how businesses communicate and collaborate remotely, to how new products are developed, repaired and maintained. Again, the improved speed, reduced latency and increased capacity of 5G are at the centre of allowing this remote working revolution to happen.

Xpllore: XR1

The XR1 is a virtual reality streaming hub. It is 5G compatible and much smaller than previous VR hardware, allowing it to be carried on the user's back where a VR headset can be attached. 5G allows users to access a vast amount of content from a cloud-based platform, instead of having to be physically connected to a stationary console. This allows users to move around freely whilst using the technology.

XR1 creator Chris Guerin, who is based at Vodafone's Tech Innovation Hub in Salford, highlights the enormous potential in XR technology. These include simulating training scenarios for engineers to learn how to conduct potentially dangerous repairs in the safety of a virtual environment. Haptic sensors – where wearable devices can convincingly mimic the sensations you would feel when handling real machinery – greatly enhance the experience. 5G facilitates this technology through its ability to connect many devices at the same time. A similar use could apply in medical and military educational settings, among others.

Another key area of potential is in facilitating international business meetings where meeting rooms, people and products are simulated in one virtual place. This new technology will enable international knowledge sharing at the highest level, without the need for travel. But this is not simply an improvement on videoconferencing. For example, if aeroplane engine designers in one country need to discuss their products with the airframe designers in another, the VR experience which XR1 and 5G could enable, would be so precise and effective that the engine would not need to be shipped abroad. And the airframe designers would not need to travel to the engine production site. Instead, a virtual space could be created where both groups of engineers could 'meet' in the same 'room' and see and discuss the product as though in person. As well as saving on travel costs, this could make business processes more efficient, facilitate knowledge sharing and improve productivity.

Rejuvenating UK Retail, Levelling Up The Local High Street

The Covid-19 outbreak has significantly impacted the retail sector, with many businesses facing difficult times. However, retailers are among those who are likely to gain first from innovation and new products and services driven by 5G. Technology and, in particular, the internet have historically presented a threat to the high street. However, a wave of innovation on the high street, supported and enhanced by 5G connectivity, could provide the vital boost and support that the high street and our local economies need. As well as making shopping more rewarding and exciting for consumers 5G could provide the opportunity for retailers to improve brand loyalty and achieve tangible results for the business.

We have already started to see the first signs of the shopping experience being improved through the use of personalised digital signs, digital fitting rooms and "magic mirrors" that recognise the clothes that the customer is trying on and make suggestions for accessories. More broadly, the use of big data analytics is helping retailers to both understand shopping trends and tailor services. Whilst retailers can already adopt many of these technologies, 5G could supercharge the potential of these approaches, whilst driving further innovation and take-up.

Mango is one retailer already making use of this existing technology, with a small number of digitally fitted dressing rooms in selected stores. With the onset of 5G, the company will have access to the bandwidth, low latency and capacity needed to make huge strides forwards.

Digitally fitted dressing rooms in high street shops blend the online and real-world shopping experiences for shoppers. Vodafone and global high street fashion retailer Mango paired up on a programme to roll out digital fittings rooms worldwide to offer customers a new in-store experience. The new Internet of Things digital mirror designed by Mango, and developed by Vodafone in collaboration with Jogotech, allows the shopper to scan clothes tags in the fitting room and to contact shop floor staff directly from the mirror, through a digital watch, to request different sizes or colours.

The mirror also suggests accessories or clothes to complement the shopper's original choice.

For customers without the time or inclination to step into a dressing room, 'quick try' Augmented Reality (AR) tools could be the answer and have already been piloted by in-store clothes retailing. With AR, customers will also be able to walk into a store and be guided to the exact location of the items they are looking for. And when it comes to paying, the evolution of the digital wallet should mean that consumers will be able to leave a store without reaching for their wallet as payment information is integrated into the retailer's system.

Beyond the high street, 5G will help retailers and consumers by allowing a virtual 'try before you buy' experience. The technology is also set to transform warehouse management through the use of the smart shelves and inventory management. More broadly technologies facilitated by the rollout of 5G could also provide significant savings from improved use of buildings.

Unleashing The Technology Revolution

This report has demonstrated the significant potential benefits that the rollout of 5G can have for UK businesses, families, communities and society across the whole of the UK. From a revolution in healthcare delivery and outcomes, revitalising retail and improving public sector and business efficiency and remote working, to opening up opportunities for autonomous vehicles and UK businesses to lead the way in AI, big data analytics and Augmented/ Virtual Reality. 5G can be a key tool in levelling up the country across sectors and geographies and play a significant role in the economic recovery from Covid-19. However, these benefits are not guaranteed. A number of studies have already highlighted challenges to the rollout and optimisation of the use of 5G.[xxv]

The current Government ambitions both for the UK to be a global 5G leader and for 5G to reach the majority of the country by 2027 demonstrate the importance of 5G to UK business and consumers. Government support and investment, including in 5G testbeds, has also been welcome. However, if the UK is truly going to be a leader in 5G and make the most of the opportunities provided by the Fourth Industrial Revolution, there is work still to be done. Some of the solutions will be technical, others will require Government and providers to work together to spread understanding and confidence in 5G, others will simply require investment.

This includes Government leading the way by committing to a 'smart by default' procurement strategy and removing barriers to 5G rollout in order to create the right investment climate. The Government has previously committed to rolling out nationwide gigabit capable broadband coverage across the UK as soon as possible and for the majority of the population to be covered by a 5G signal by 2027. The Government should go further and adapt its current 5G strategy to create the conditions and support that could enable the rollout of 5G to the majority of the population by 2025.

Doing so will provide the industry with the confidence that our politicians are serious about making the most of 5G and act as a spur to action across Government. In order to deliver on these ambitions, the Government should refresh the current 5G strategy including the following six recommendations:

1. **Smart by default:** The Government has the power to help create and expand markets, which in turn gives businesses the confidence to invest and innovate. The Government should help lead the market through its own 5G and IoT procurement, particularly in areas such as healthcare, borders, justice and local government. The Government should commit to a 'smart by default' procurement strategy. Within the balanced scorecard approach to procurement, this would place extra weight on solutions and products that used smart technologies and IoT. Given the Government's significant buying power, this would provide investment certainty, and would ensure that the public sector is at the forefront of medical, environmental and safety advances that stand to benefit the whole of the UK population. This approach already has precedent in the Government's presumption in favour of off-site construction.

2. **Stronger Towns Fund:** The Government should ensure that its Stronger Towns Fund sets criteria which allows the 100 towns eligible to bid to invest in high quality infrastructure, therefore creating the foundations of conditions for a digital super town in the future.

3. **Supporting the investment and regulatory environment:** To accelerate investment in 5G infrastructure, the Government should commit to removing barriers to 5G rollout in order to create the right investment climate as it has promised for gigabit-capable broadband and provided for superfast copper based broadband rollout via public investment programmes. This should include full access to dark fibre, business rates relief and the removal of planning obstacles for local authorities supportive of 5G rollout in their local areas and access to public sector sites. Government investment in full fibre broadband should include investment in full fibre for 5G. Government should invest in 5G in its Gigabit Broadband programme. If public money is used to invest in fibre or other gigabit capable fixed networks, access to dark fibre for 5G should be built into the procurement process.

4. **Digital transformation:** Government should consider whether incentives via vouchers or tax credits are necessary to nudge business, which are adversely affected by COVID-19 to adopt technology to facilitate home and remote working. In the recovery from COVID-19, Government focus should be on efficiencies and resilience that 5G can add in healthcare, manufacturing and retail. Government should work with mobile operators to encourage the uptake of 5G, private networks and IoT in these sectors.

5. **A diverse and resilient supply chain:** Government and industry should work together to increase R&D spending and support for Open-RAN deployment in the UK to diversify and create a more resilient supply chain.

6. **Shared Rural Network:** The Shared Rural Network will help solve rural network coverage issues – extending 4G coverage to 95% of the UK landmass, which will create the mobile network infrastructure on which 5G could be built in the future. The Government should give its continued full support, including funding, for the planned Shared Rural Network.

By taking these proposals forward, the Government could make its 5G ambitions a reality and support the technological revolution and the levelling up agenda which stand to drive significant economic and social benefits in every town, region and nation of the UK.

Endnotes

i See here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863632/DCMS_Sectors_Economic_Estimates_GVA_2018.pdf Accessed 28/04/2020.

ii See here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/811903/DCMS_Sectors_Economic_Estimates_2018_Employment_report.pdf Accessed 28/04/2020.

iii See https://technation.io/news/uk-tech-leads-european-success-in-2018/ Accessed 27/07/19.

iv See here: https://mediacentre.vodafone.co.uk/news/digital-super-towns/ Accessed 27/07/19.

v See https://www.ofcom.org.uk/__data/assets/pdf_file/0030/113898/pricing-report-2018.pdf Accessed 13/08/19.

vi Vodafone: 5G Explained Pocket Guide – available here: https://www.vodafone.com/business/media/document/1508881116678/vodafone-5g-explained-pocket-guide.pdf Accessed 13/08/19.

vii See https://mediacentre.vodafone.co.uk/5g/5g-explainer/ & https://www2.deloitte.com/au/en/pages/economics/articles/5g-mobile.html Accessed 27/07/19.

viii Hall, W., & Presenti J., (2018). Growing the artificial intelligence industry in the UK. Available here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/652097/Growing_the_artificial_intelligence_industry_in_the_UK.pdf Accessed 14/07/19.

ix See https://www.mckinsey.com/mgi/overview/in-the-news/by-2025-internet-of-things-applications-could-have-11-trillion-impact Accessed 28/07/19.

x https://www.businessinsider.com/internet-of-things-report?r=US&IR=T Accessed 14/04/19.

xi HIS Markit (2017), The 5G economy: how 5G technology will contribute to the global economy. Available here: https://www.qualcomm.com/media/documents/files/ihs-5g-economic-impact-study.pdf Accessed 14/07/19. And Deloitte, (2018). The impacts of mobile broadband and 5G: a literature review for DCMS. Available here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/714112/The_impacts_of_mobile_broadband_and_5G.pdf Accessed 14/07/19. Notes: conversion to GDP from USD undertaken on 14/17/19.

xii Where results are not available in 2025, they are created using assumptions that underpin the analysis. For example, if a 2023 estimate is based on a 0.07% increase in GDP, this same GDP increase is applied to projections of GDP for 2025. All results are in 2017 prices.

xiii 2025 and 2030 figures are estimated using a weighted average of the estimates from a range of 10 studies, that have been standardised to provide estimates in those years. Estimates of intermediate years are then created using a logistic function.

xiv See https://5g.co.uk/guides/what-is-a-private-5g-network/ Accessed 28/07/19.

xv See https://www.networkworld.com/article/3319176/private-5g-networks-are-coming.html Accessed 28/07/19.

xvi See https://5g.co.uk/guides/what-is-a-private-5g-network/ Accessed 28/07/19.

xvii See https://www.gov.uk/government/collections/5g-testbeds-and-trials-programme Accessed 13/08/19.

xviii See https://community.jisc.ac.uk/sites/default/files/Education-VM_Extended.pdf Accessed 27/07/19.

xix WPI Economics analysis, using spending projections from the OBR and research here: https://connectcentre.ie/wp-content/uploads/2016/10/EC-Study_5G-in-Europe.pdf Accessed 28/07/19.

xx See https://www.raconteur.net/technology/4g-vs-5g-mobile-technology Accessed 27/07/19.

xxi See http://www.smf.co.uk/publications/tech-in-the-town/ Accessed 27/07/19.

xxii See https://www.openaccessgovernment.org/transform-public-services/63846/ Accessed 27/07/19.

xxiii https://www.civilserviceworld.com/articles/news/hmrc-hubs-be-%E2%80%98most-digitally-advanced-buildings-government%E2%80%99 Accessed 14/07/19.

xxiv See https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/industrial-strategy-the-grand-challenges Accessed 27/07/19.

xxv For example, see: http://researchbriefings.files.parliament.uk/documents/CBP-7883/CBP-7883.pdf ; https://www.londonfirst.co.uk/sites/default/files/documents/2018-09/RoadmapTo5G.pdf ; Accessed 28/07/19.

WPI Economics Limited

11 Tufton Street
London
SW1P 3QB

@WPI_Economics

wpieconomics.com

WPI Economics Limited, registered address 28 Church Road, Stanmore, Middlesex, England, HA7 4XR, is a registered as a limited company in England and Wales under company number 10086986.

June 2020