O2

A greener connected future

How connectivity can enable a resilient economy and a low carbon society

cenex

IC&CO

Contents

Foreword

Steve Martineau,
UNFCCC COP26 High Level Climate Action
Champions Lead – Mobile & ICT

There is no doubt that connectivity has helped us navigate the COVID-19 crisis, enabling us to work and socialise, deliver remote healthcare, and order food and supplies like never before.

This unplanned disruption has shown us that there are many things we can do, which were unthinkable just a few months ago.

And now, innovation must play a role in another, even greater threat: the climate crisis.

This year, the UN Climate Champions team launched the #RaceToZero campaign, setting out an ambitious plan to engage businesses, cities, regions and investors for a healthy, resilient, zero carbon recovery that prevents future threats, creates decent jobs, and unlocks inclusive, sustainable growth.

Businesses like O2 are mapping out a blueprint for change that starts with decarbonising their own operations, whilst importantly looking out to the wider industry and asking that all important question – how can we do even more? This report makes clear that connectivity has a major role to play in reducing carbon emissions and rebuilding Britain.

Looking ahead to COP26, I hope this report prompts important conversations across the telecoms industry, with other businesses, and with policymakers. Greener technology must be built into our recovery plans to deliver a stronger economy and a more resilient society as we accelerate on our path to Net Zero.

Steve

Introduction

Mark Evans,
CEO of O2

For nearly twenty years, O2 has proudly contributed to the very fabric of modern British life - connectivity.

Over the course of this year, that connectivity has proven to be more important than ever. As the nation faced an unprecedented crisis and grappled with the challenges of life in lockdown, mobile helped to keep families and friends in touch and allowed volunteers and neighbours to provide support to communities in need.

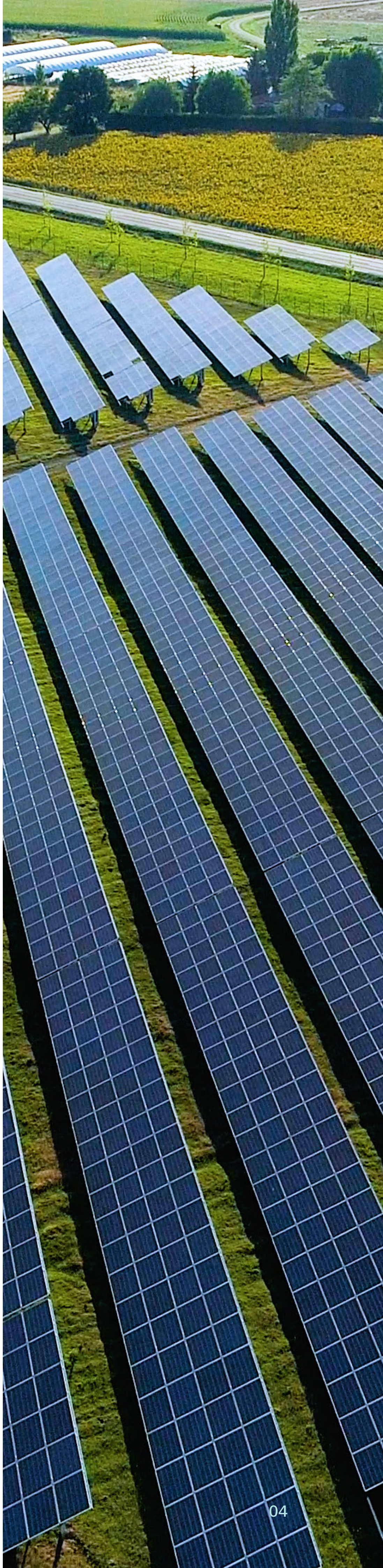
As we look to "build back better" following the devastating impact of COVID-19, now is the time to invest in the technologies that will lead to a greener, more connected, more sustainable future.

At O2, we believe we have a role to play in rebuilding Britain. We want to help the UK's businesses and economy thrive, and to help our customers get back on their feet. Our focus will be to accelerate our recovery, with renewed efforts on productivity and sustainability. That's why we announced our ambition to become the first UK mobile operator to reach Net Zero at the beginning of this year, aiming to eliminate as much carbon as possible from our operations by 2025.

If the UK is to reach Net Zero by 2050, we need to play an even greater role. This report sets out a vision for how connected solutions enabled by 4G and 5G will power a green revolution over the next decade and beyond. The use cases referenced paint an exciting picture of what a prosperous, sustainable Britain could look like if it embraces smart homes and cities, next-generation factories, and greener ways of living.

Collectively, we're still at the start of this journey. It's an important mission with exciting possibilities. If we invest now, there is a real opportunity for Britain to become a leading adopter of 5G and unleash the power of connected solutions to build a greener nation for generations to come. For our part, we are committed to getting our own house in order, rolling out 5G and committing to industry-leading trials that show the industry, and the country, what is possible through connectivity.

Mark



Executive summary

Connectivity is key to helping Britain build back better, and crucially greener, as part of its COVID-19 recovery.

As the UK heads towards its target of Net Zero by 2050, with Scotland looking to get there earlier, it will take an industry-wide effort to help the nation reach its goal. The telecoms industry will need to reduce its own carbon impact, but also has a critical role to play in supporting other businesses and industries reach their Net Zero ambitions.

We believe that key to this, is 5th generation mobile connectivity that is faster and will be more ubiquitous than 4G. 5G will revolutionise the economy and society by enabling our devices to connect – think smart fridges that tell you when they are empty and can move to an economy setting, or traffic lights that are designed to respond to traffic flows automatically.

O2's report, in partnership with IC&CO and Cenex, looks to define the role that mobile technology and innovative 5G solutions can play in reducing the carbon impact across four of the economy's largest sectors where there is a clear opportunity for connectivity to drive significant reduction in carbon - transport, utilities & home energy, Manufacturing, and Healthcare – to understand how the smart cities, homes, and industries of the future can be even greener.

While the scope of this report focused on key industry verticals, it would be reasonable to expect 5G-facilitated emissions savings in other sectors of the UK economy.

Our key findings:

- Through the application of 5G and connected solutions across these four industries, **up to 269 megatonnes of CO2 can be avoided by 2035** – which is almost the equivalent of England's total emissions for 2018, which came in at 280 megatonnes.[1]
- The greatest impact is seen in the **Utilities & home energy sector**. 5G will help green the national grid and power the smart home revolution, which combined, is set to **avoid up to 181 megatonnes of CO2**.
- As work from home habits look set to stay beyond the COVID-19 lockdown, **up to 43 megatonnes of carbon emissions could be avoided as people become less reliant on transport**, and as 5G-powered autonomous vehicles and more efficient systems make our transport system greener. 5G networks are poised to power the factories of the future, creating sweeping efficiencies in the manufacturing sector including automated production lines that could take **up to 40 megatonnes of carbon out of the economy by 2035**.
- New advancements in **e-Health, powered by connected IoT devices, are set to avoid up to 6 megatonnes of carbon emissions** and could have profound implications for improving patient outcomes.

Cumulative WTW savings 2020-35 (Mt CO2e)

Sector/scenario	Low	Medium	High
Transport	32	38	42
Utilities & home energy	151	169	181
Manufacturing	32	37	40
Healthcare	5	5	6
TOTAL	**220**	**249**	**269**

How 5G can help us get to Net Zero

This report explores some of the ambitious 5G trials taking place across the country, which show how connectivity is the key to our greener future. From the testing track putting the cars of the future through their paces, to the smart island of Orkney, and connected 5G factories – it is clear the UK is sitting at the forefront of cutting-edge innovation.

5G will facilitate the technologies that make many of these carbon savings possible. The calculations in this report have been made on the assumption that 5G will gradually gain share over Wi-Fi and 4G in the home broadband market, to the point where it is used by 50% of homes in the UK by 2035. This facilitates the major carbon savings of increased remote and flexible working, and smart heating systems – specifically heat pumps. 4G, 4GLTE or future generations of wireless will also help facilitate these savings.

The carbon cost of connectivity

Naturally, any investment in connectivity also comes at a carbon cost. To power this connected green vision, the telecoms industry will need to continue to invest in critical digital infrastructure over the next ten years to power 5G networks. Increased use of these networks could also lead to a significant escalation in data usage and energy consumption from consumers and businesses, making it vital that mobile operators and data centre operators mitigate this through improved energy performance and the use of renewable energy sources.

Any connectivity-powered path to Net Zero must start with reducing the carbon impact of the telecoms industry, which is why O2 has committed to reaching Net Zero by 2025. Working with partners like Ericsson, who are already implementing solutions to mitigate the impact of growing 5G infrastructure and demand for data, O2 is paving the way for an efficient and green future for telecoms.

The UK could be a world-leader in digital infrastructure and 5G adoption and is best placed to show how connectivity can help us build more efficient, greener solutions that will power the UK to reach its Net Zero ambitions.

To account for the uncertainty in possible 5G coverage/penetration in the next 15 years, three scenarios have been modelled. These scenarios are low, medium and high penetration, and are split by coverage in urban (cities and large towns) and rural areas (rural and motorway roads and railways). The penetration factor is assumed to be the % of total data transmitted using 5G networks and devices. For each of these scenarios we gave a % penetration factor shown in the methodology.

The scenarios are based on conversations with O2, where it became clear that 5G would be used first where it is immediately needed: in highly populated cities. It will then be rolled out in smaller cities and finally, in the road and rail networks borrowing features from 3G and 4G. This information is corroborated by a report published by Juniper Research on behalf of O2, which states that "the total number of 5G connections will reach 1.5 billion globally by 2025, rising from only 5 million in 2019" and that "the year 2025 is used based on the assumption that 5G penetration will be close to 100% in UK[1] cities".

Within each sector, it is important to understand the difference between projected direct effects of 5G and the projected indirect effects. As an example, in transport, direct effects come when 5G enables such innovations as "platooning" - where convoys of commercial vehicles can work in auto-pilot slipstreams, radically reducing fuel consumption.

Indirect effects come as 5G becomes the preferred network for increasing numbers of citizens and flexible workers, enabling reduced commuting and business travel.

> **"There is a big potential to save energy; the ICT industry is currently responsible for 1.4% of global CO2 emissions, but by greening the telecoms sector you can have a leveraging effect of reducing CO2 emissions in other sectors."**
>
> Patrick Blankers, Program Manager Sustainability for Ericsson

Utilities & home energy

Households have a big role to play in the UK's journey to Net Zero. Heating our houses and powering the myriad devices that keep Britain's families running has a significant energy cost.

5G could play a significant role in the energy infrastructure of the future, with its high-bandwidth and low-latency features beneficial for the smart grid and the smart charging of electric vehicles (EVs), while also enabling more intelligent energy management systems.

However, we found the **biggest single contribution of 5G technology to GHG savings from utilities and home energy in the years up to 2035 could be in the application of smart thermostats and heat pumps** to remove CO2 out of our home heating systems.

If, as some best-case scenario suggest, 50% of homes have 5G as their main data network, **smart thermostats and heat pumps have the potential to save, cumulatively, between 150 and 180 megatonnes of CO2** - the equivalent of the combined total GHG emissions (domestic, industrial, commercial and transport) from the North (East and West), the Midlands (East and West) and Yorkshire in 2017.

4.1 Smart heating

We have focussed on smart thermostats and heat pumps when investigating the carbon savings of 5G-enabled heating solutions.

According to simulation work by the Fraunhofer Institute, future smart thermostats featuring presence detection and weather forecasting could save between 14% and 26% of a household's heating energy. As such we have assumed an average value of 20% without any variation between 2020 and 2035.

The use of heat pumps combined with a smart distribution network can provide carbon savings of 9 g CO2e/kWh in 2030. This equates to 11% carbon savings in 2030, assuming 0% in 2020 and extrapolating to 17% in 2035. Therefore, the combined effect of smart thermostats and heat pumps yields CO2 savings from 20% in 2020 to 37% in 2035.

While the influence of 5G in these smart heating technologies is not fully known, O2 sees great potential. The speed of the network will allow for greater exchange of information and further increases in efficiency, making it easier than ever for individual households to control and reduce their energy usage and emissions.

Combined, the 5G penetration scenarios and the energy emissions baseline results in the WTW GHG saving of smart heating are shown on page 11.

4.2 Smart grids

A smart grid is the digital technology within the electrical grid that allows for two-way communication between the utility and its customers. These technologies work with the electrical grid to respond to quickly changing demand. A smart grid could provide a range of benefits and opportunities for consumers, businesses, network operators and the wider energy industry, both day-to-day and as part of the transition to a low carbon economy, including reduced costs to consumers through savings on network costs, increased energy security and integration of low carbon technologies.

A report from Imperial College London[2] states that smart grids and smart distribution networks can provide carbon savings by enabling several low carbon technologies: Electric Vehicle (EV) charging, heat pumps (HPs), industrial and commercial demand side response (DSR), and dynamic time-of-use (dToU) tariffs for residential customers. This section focuses on the latter two technologies.

We acknowledge that smart grids will be beneficial for both domestic and commercial/industrial users, but we consider the population percentage as a good enough representation of the amount of energy used in urban and rural areas.

O2 believes that the benefits here could be significant, and advocates for 5G to play a more substantial role in smart grid innovation through the rapid detection and response to spikes in demand and the provision of more dynamic energy pricing based on real-time demand. 5G connected smart grids could also enable two-way communication and allow citizens to choose where they buy their energy.

The WTW GHG saving results for the three 5G coverage scenarios are shown on page 11.

4.3 Smart meters

Smart meters help people understand their actual energy usage in much greater detail, closing the psychological gap between usage and expenditure.

This incentivises individuals to reduce energy costs by cutting down usage and therefore carbon emissions. This can lead to savings of as much as 7% in the first six months of usage but tends to stabilise at around 3% over longer-term use. For the purposes of our calculations, we used a value of 3.3%, an average across different data sources.[3,4,5]

The introduction of 5G should see smart meters become more efficient, prolonging battery life, and its shorter wavelength means smaller antennas can provide the same amount of precision and control as bulkier, more expensive units.

All the described factors were then combined with the same 5G coverage scenarios and baseline as in previous sections to produce the WTW GHG saving graphs on page 11.

4.4 EV Charging

One of the great benefits of 5G is how it will enable reliable and ultra-fast communication between machines, helping to power next-generation IoT devices. For energy providers, 5G has exciting applications that will enable sweeping efficiencies, including the automation of energy transfer from EVs straight to the grid.

Energy providers could develop the capability to influence consumer behaviour to use energy-consuming systems at off-peak times when the energy grid is greenest, such as charging your EV when there is excess wind or solar energy within the system.

> **"5G will be able to turn off inactive systems or optimise water consumption to provide a better balance of demand and supply. Today this simply is not possible without the investment and specialised networks that make wide scale use of the internet of things (IoT) affordable."**
>
> Professor Mark Skilton, Warwick Business School[6]

According to the simulation study from Imperial College London, an average of the pessimistic and optimistic 2030 scenarios yield an 8% saving from smart EV charging compared to non-smart charging. We used this figure to extrapolate from 0% in 2020 to 11% in 2035.

The ongoing SEEV4City project[7] (in which Cenex is a partner) has recently identified the UK upscaling potential in the following EV technologies during the next 5 to 10 years as low to very low:

- Vehicle to House: 0 to 5%
- Vehicle to Building: 5 to 10%
- Vehicle to Grid: 10 to 20%

The main barriers justifying this low projection are the reduced number of EV models available for bidirectional charging (a system that allows charging of EV batteries but can also take energy from car batteries and push it back to the power grid) and reduced number of bidirectional chargers in the market. The projection also accounts for the potential restrictions that the local distribution networks may place on the user to balance the grid, and the current lack of business case for these services.

Overall, the WTW GHG saving results for EV charging across the three 5G coverage scenarios are shown below.

4.5 Energy Summary

The table and graph below show the cumulative WTW GHG emission savings between 2020 and 2035.

Our initial review shows that these technologies are predicted to deliver substantial GHG savings. While the use cases and evidence are still building, 5G is already increasing the penetration, performance and efficiency of these technologies, demonstrating the potential for dramatic savings in GHG emissions.

Smart heating is the 5G-enabled area where GHG emissions can be reduced the most in the energy sector, with **76% of the 5G-enabled savings coming from it**. While 5G can avoid large amounts of carbon emissions in the energy sector, it will still facilitate a relatively minor role in the sector's overall path to Net Zero. Our estimates showing only a 4.6% to 5.5% reduction in the UK's energy emissions thanks to 5G-enabled technologies, leaving a large portion for the sector to tackle through other means.

The home automation market is still in its infancy, with a very fragmented marketplace with a number of point to point solutions and protocols that are not compatible with each other. 5G has a role to play in this, not only bringing together these competing protocols but also using its connectivity to process everything centrally, intelligently, and automatically in the cloud.

Cumulative WTW savings 2020-35 (kt CO2e)

5G coverage scenarios	Low	Medium	High
Smart grid	17,308	19,348	20,794
Smart heating	115,423	128,441	137,656
Smart meters	17,685	20,260	22,074
EV charging	438	482	512
TOTAL	**150,854**	**168,530**	**181,038**
% of energy baseline	**4.6%**	**5.1%**	**5.5%**

4.6
5G in action case study - smarter homes and smarter grids

4.6.1 Kenilworth

In a suburban home in Kenilworth, a remarkable experiment is going on.

Chris Rimmer drives home in his electric car and docks it. It has been a sunny and windy day so there is spare energy in the grid. Thanks to a smart tariff, his car automatically tops itself up for the week at the cheapest rate. Conversely in winter time when he gets home in the dark and everybody is cooking and heating their homes, smart tariffs and Vehicle to Grid (V2G) charging will allow Chris to sell back the excess energy in his car battery for a profit.

A European wide connected smart grid will allow this to happen automatically across the continent, with Chris in Kenilworth buying and selling his excess energy from Clemens in Koblenz.

This will probably be commonplace in 10 years' time, and almost certainly by 2035, when it will be illegal to buy a new car that isn't electric.

Right now, smart meters are still in their early stages. But they have some important beneficial effects - initially reducing energy consumption of a home by 7% and stabilising at 3% across gas and electricity.[8]

What will really shake things up is when the smart grid, smart meters, and electrical vehicles come on stream. Connected smart meters and vehicles have been shown to deliver a reduction in peak energy use by up to 20% in trials.

Using dynamic Time-of-Use tariffs, consumer behaviours can be influenced to use these energy-consuming systems at off-peak times when the energy grid is greenest, or for example charging your car when there is excess wind or solar energy.

4.6.2 Isle of Orkney

Six hundred miles north of Kenilworth is the Isle of Orkney, another unlikely spot for an experiment bringing to life the tech of the future. Here, the ambition is to make the Isle of Orkney a smart energy island.

One of the great advantages of 5G is that it can connect huge numbers of sensors in the real world to build a picture. Digital twinning, which creates a computer simulation of the real world using connected sensors, can be used to demonstrate certain energy scenarios and optimise the energy networks.

This is especially critical in the windswept Scottish Islands. On Orkney, one of the 5G testbeds has successfully modelled the complex balance of wind energy generation, energy storage and energy demand (especially EV charging demand).

Live monitoring of wind energy generation, coupled with smart meters, has also been used in a successful prototype on the Isle of Lewis. Smart tariffs have shown how every EV car battery, when coupled with a smart grid, could capture £110 of electricity annually that would otherwise be "spilt" (when electricity supply exceeds demands).

5G rollout will allow even more powerful IoT devices, with even better connectivity, which will facilitate machines to take decisions automatically, continually optimising and minimising our homes' energy usage.

Isle of Lewis

Transport

Before the COVID-19 lockdown confined many people to working from home and banished from the office, we were a nation constantly on the move. That reliance on public transport and our vehicles was always going to be a key challenge when moving the UK towards its Net Zero targets – how do we move towards a sustainable model for our transport system? Could a more connected society be one that travels less and is therefore more sustainable?

Our research shows that, between 2020 and 2035, the cumulative reduction in greenhouse gas emissions enabled by 5G networks across the UK's transport sector could be as much as 41 megatonnes of CO2 (equivalent to 2% of the baseline GHG emissions from road and rail).

The vast majority (85%-89%) of this reduction in CO2 is achieved through 5G enabling more people to work from home effectively, relegating the daily commute to a thing of the past.

This chapter analyses the possible role 5G could play in decarbonising transport in three areas: connected and autonomous vehicles (CAVs), smart rail systems, and remote working.

5.1 Connected and Autonomous Vehicles (CAVs)

CAVs have the potential of providing carbon savings due to several factors, including:[9]

- platooning (two vehicles following each other closely on the motorway to reduce aerodynamic drag, mainly applicable to HGVs)
- eco-driving
- reduced congestion
- reduced acceleration rates to improve passenger comfort
- lighter chassis due to the reduction in accidents
- increased vehicle utilisation via Mobility as a Service (MaaS)
- smaller vehicles due to reduced number of passengers

There are other factors that could also have the opposing effect of increasing emissions, such as the increased vehicle energy requirement to process and send the data generated by CAVs and to provide on-board entertainment. However, based on the current data and evidence, the efficiency improvements of CAVs are likely to outweigh the opposing factors to provide an overall CO2 saving of around 10% compared to non-autonomous vehicles.[4]

O2 provides the 5G connectivity that powers a number of the UK's leading CAV trials. 5G connectivity supports the levels of driving automation that do not require any interaction from the driver – the fully autonomous driving experience first dreamed up in science fiction (levels 4 or 5 autonomous vehicles requiring no human interaction).[10]

The total WTW GHG saving results for CAVs for the three penetration scenarios are shown on page 17.

5.2 Smart Rail Systems

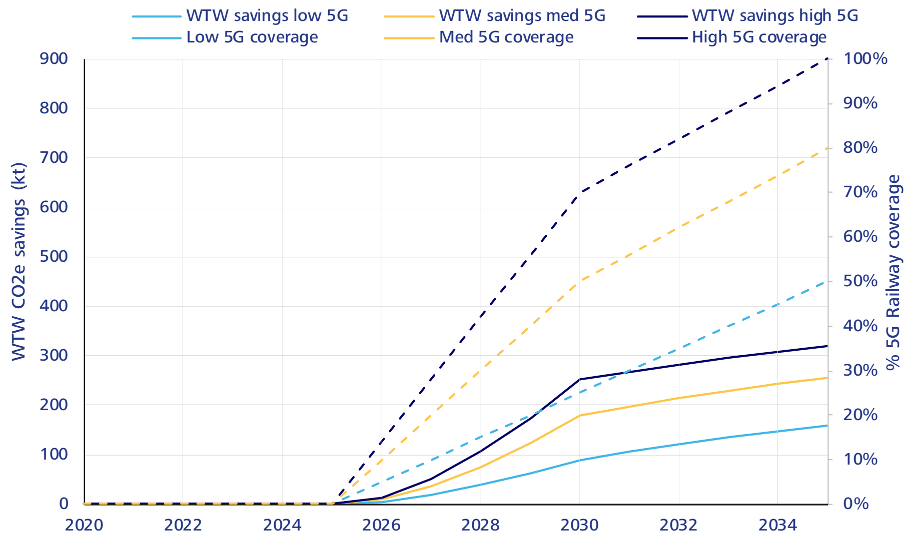
Smart rail systems are the digital technology within the rail network that allow for the automation of certain processes, such as rail analytics and capacity planning, allowing for the creation of a more efficient rail system.

Smart rail systems - such as standardised train-to-ground communications, adaptable communication systems, and advanced traffic management and control solutions - should be available by 2024 and **could provide energy savings of up to 45%** according to our research, via optimised speed profiles, predictive maintenance and increased railway utilisation.[11]

Though the influence of 5G in these systems may be limited, as its use in railways is likely to be some years away (2025), 4G LTE is able to deliver these core requirements for some time.[12] As such, we have assumed a linear increase in the penetration of 5G-enabled smart rail systems from 0% in 2025 to 50% in 2035.

The role of 5G in smart rail systems is forecasted to deliver WTW GHG savings as shown below.

Annual WTW GHG savings - Smart Rail Systems



5.3 Remote Working

5G can improve the remote office experience, powering meetings run through virtual reality and providing high-speed data processing capabilities. As the "commute" becomes the walk downstairs rather than a train or bus journey, there will also increasingly be less travel demand for work, both from commuting and business trips.

O2, IC&CO, and Cenex recently investigated the carbon savings available if UK workers had more flexible working policies enabling them to work from home and to reduce their business trips.[13] This research showed that, if the UK workers able to work from home (just under half of the workforce) did so for just 2 days per week, the annual WTW GHG savings could be 14.3 Mt CO2e, which is equivalent to Northern Ireland achieving Net Zero as early as 2024.

If the UK workforce reduced their domestic business trips (excluding air travel) by just 10%, emissions would be reduced by 1 Mt WTW CO2e every year – the equivalent of all home, business and surface transport emissions in the London Borough of Bromley.

The annual WTW GHG emission savings from 5G-enabled remote working in the future are shown below.

5.4 Transport summary - estimates of GHG savings

The table below shows the cumulative WTW GHG emission savings between 2020 and 2035.

Cumulative WTW savings 2020-35 (kt CO2e)

5G coverage scenarios	Low	Medium	High
CAVs (cars and vans)	1,795	2,340	2,732
CAVs (HGVs)	449	685	855
Smart Rail Systems	882	1565	2,072
Remote working	28,840	33,020	35,969
TOTAL	**31,966**	**37,610**	**41,627**
% of energy baseline	**1.5%**	**1.8%**	**2.0%**

The estimates shown above demonstrate that remote work is the area where 5G can have the biggest impact on GHG emissions from transport, delivering 85 to 89% of the estimated 5G-enabled GHG savings in the sector. However, while 5G can avoid large amounts of carbon emissions, it will not have a significant direct role in the path to Net Zero from a transport perspective, as the projected GHG savings above only account for 1.5 to 2% of total surface transport emissions.

5.5
5G in action case study - autonomous vehicle testing at Millbrook

Millbrook Proving Ground is an extraordinary place. Seven hundred acres of every road type, surface or incline you can imagine. It is where cars, trucks, e-bicycles go to prove themselves in every condition. And it is the obvious place to explore how auto--nomous and connected vehicles will behave.

Alongside other partners, O2 has built a private 5G network to enable demonstrations and testing of CAV capabilities, and has worked closely with the site since June 2019 to support on industry-leading innovations which could transform the way we experience travel.

A more sustainable future may well see more people on public transport. To encourage people to leave their cars at home, it is vital that our trains and buses can provide great connectivity on board.

"5G comes into its own when you need something ultra-reliable and ultra-fast. For example, everyone's now video-conferencing - but have you ever tried to do that on a train?"

Peter Stoker, Chief Engineer at Millbrook

Peter and his team have just proved how this might be possible in the extreme, by driving a McLaren at 160mph around Millbrook while maintaining a 1 Gigabit video connection. Being able to maintain video connections on-the-go could also deliver real safety benefits: for example, it means train cameras can monitor the track conditions in real-time and feedback to the operators.

Back on the roads, anything that makes transport and logistics more efficient and less fuel-hungry has a potential environmental benefit.

5G could play a crucial role in reducing fuel consumption by freight. Autopilots on planes are similar to the idea of "platooning" where you have a convoy of trucks which are being driven by software, though you still have drivers on board. If they travel in close formation, there are big fuel savings to be made. But to do so safely and effectively, they have to be ultra-responsive to one another.

"5G is important there because the latency (delay) on a 4G signal is about 40 milliseconds - which equates to 4 feet on a vehicle going at 56 mph. The delay on 5G is 4 milliseconds -which is about 4 inches. That makes a big difference."

Peter Stoker, Chief Engineer at Millbrook

Another application of 5G will be remotely operated vehicles. To begin with, this will be used primarily in destinations like ports or transport depots, but is likely to expand over time to include deliveries to consumers' homes. These deliveries will use electrically powered vehicles, with their route planned and adjusted in real-time using 5G to make deliveries more efficient and replace the carbon impact of traditional delivery vehicles with a greener alternative.

Millbrook Proving Ground

Manufacturing

Globally, **5G could enable up to $740bn USD of benefits to the manufacturing industry by 2030.**[14] While 5G-enabled manufacturing is likely to provoke an increase in energy consumption in mobile networks, it could also lead to a reduction in resource usage as well as overall efficiency improvements.[15] 5G will therefore facilitate "higher flexibility, lower cost and shorter lead times for factory floor production reconfiguration, layout changes, and alteration."[16]

These efficiency improvements inevitably lead to carbon savings, as shown in several use cases in a study from the GSMA and the Carbon Trust,[17] where the **reported CO2 reduction from smart industries was between 8% and 21%**. This sits very much within the prediction of "up to 20% savings" from our interview with Eman Martin-Vignerte, Director at Bosch.

For the purposes of our calculations, we averaged these data sources to estimate a **16% GHG emission saving due to smart technology facilitating efficiency savings in manufacturing**. The influence of 5G in these smart industry technologies was assumed to increase linearly from 0% in 2020 to 50% in 2035, as other technologies like 4G or Wi-Fi networks could compete with 5G in warehouses and factories.

6.1
5G in action case study - the factory of the future at Worcester Bosch

The Worcester Bosch factory is situated on an unassuming industrial estate just outside Worcester city centre. But inside, something very novel is happening. The factory has its own dedicated 5G network, which it is using to bring to life cutting-edge innovation.

A modern manufacturing plant is a very complicated place. Thousands of components are assembled into dozens of different products - all part of a complex logistics system that sources parts from around the globe and then moves the products out again.

If you know more about precisely what's happening and where, you can orchestrate the whole system more efficiently. And by doing so you save energy – and reduce CO2.

Eman Martin-Vignerte, UK5G advisory board member and Bosch Director, is a Qatari-born, German-trained engineer. Living and working in the UK, she brings a unique perspective. Eman is also a self-confessed 'geek' and has been closely involved in Bosch's Factory of the Future programme.

"In a modern factory, there is a hugely intensive usage of data and data communication between the production line and between the technicians who are actually monitoring the production line - so 5G can empower a seamless communication between machine to machine, and machine to person."

Eman Martin-Vignerte, UK5G advisory board member and Bosch Director

The 5G setup also allows greater flexibility because the factory can be reconfigured to create and produce many different components at different times.

There is increased efficiency because you can predict downtime, it is easier to run remote maintenance, to test the incoming components, and track product quality and progress through the production line. In fact, you can evaluate the entire manufacturing chain from component up until the finished product is in the warehouse.

Not only does this provide greater flexibility and reliability for Bosch, but these efficiencies also directly impact the bottom-line, with energy consumption and bills falling by as much as 20%.

5G is firmly embedded in Bosch and other manufacturers roadmaps, and plays a vital role in driving quality, efficiency and productivity in the factories of the future.

Manufacturing in the UK is entering a fourth industrial revolution (sometimes called Industry 4.0 or 4IR). The goal of this next generation vision is to drive innovation and growth through more advanced use of digital data, connectivity and cyber systems – all of which are reliant on 5G. In return, these projects provide the high-value industrial applications that make 5G viable.

Bosch believes that Industry 4.0 will see a new spark of innovation in their digital transformation, not only in the way they design and run their factories in the future but also the full digitalization of the production line. Practitioners foresee concepts such as:

- The Connected Screwdriver which automates the maintenance and calibration of the 1000's of screwdrivers in a factory
- Augmented reality for troubleshooting to reduce production downtime
- An intelligent production line which self-optimises using AI to increase efficiency, reduce waste and improve safety in a 5G connected factory

"5G's security credentials are vital to give manufacturers the confidence to build their factory's digital infrastructure, which is something that Wi-Fi and 4G just can't deliver on."

Eman Martin-Vignerte, UK5G advisory board member and Bosch Director

Finally, there is little doubt that a 5G connected factory like the Bosch trial in Worcester would be better able to continue running in the face of a pandemic. With people able to connect remotely to control the factory, the production line is more resilient to unforeseen challenges.

The Worcester Bosch Factory

Healthcare

COVID-19 has reminded us how much we rely on the NHS to support the health and wellbeing of the nation - but also of the immense strain our healthcare system is under.

Technology has an incredibly important role to play in supporting the healthcare industry, delivered through solutions that make health professionals' jobs easier and improve patient outcomes. The following innovative technology solutions for improving healthcare will become increasingly feasible with 5G:

- Connected ambulances
- Virtual consultations
- Remote patient monitoring
- Augmented reality
- Advanced predictive maintenance of critical medical equipment
- Inventory management devices

Our research shows the cumulative decrease in GHGs from the above innovations is estimated to be between 3 and 5 megatonnes of CO2e - representing around 2% of the health sector's emissions.

Healthcare generally constitutes only 4% of total GHG emissions in developed countries.[18] The UK is one of the few countries that has a detailed methodology for modelling GHG emissions from the healthcare sector via the NHS.[19] We used this data as our GHG emissions baseline including the predictions from 2020 through to 2035.

The most significant impacts that could align with the benefits of 5G involve the concept of e-health. Telehealth can be similar to wearing a Fitbit or other wearable, with the device monitoring a patient's vital signs, facilitating a reduction in patient hospital and GP visits as in the Liverpool 5G testbed trials detailed below.

E-health can result in a 20% reduction in emergency hospital admissions, a 14% reduction in elective admissions and a 14% reduction in bed days.[20] For our calculations, we have assumed that the reduction in hospital admissions and bed days is approximately equivalent to the reduction in trips to hospitals and GPs, with a corresponding reduction in carbon emissions.

There is strong potential for further 5G-enabled savings in GHG emissions, in particular through connected ambulances and inventory management devices. These would work by optimising the storage and transport of supplies to reduce needless transportation, and by optimising ambulance travel patterns. However, would require more data and further research to fully quantify the impact.

O2 has been working closely with healthcare partners to **drive forward the testing of "Smart Ambulances"**, trialling the latest monitoring and remote consultation technology to enable paramedics to conduct on-board treatments through mobile expert consultation. It is hoped this work will demonstrate how "Smart Ambulances" can empower paramedics to treat more people at home and in communities than is currently possible, helping to ease the strain on hospital resources by reducing the number of patients taken to hospital.

7.1 5G in action case study - a 5G testbed for public services in Liverpool

The boroughs of Fairfield and Kensington sit just east of the city centre in Liverpool. When its citizens saw a series of antennae going up on their lampposts, they probably were not aware that an exciting new trial was happening in their midst.

The network has been used by Liverpool council to deliver high speed mobile internet to an area of relative deprivation. CGA Simulation, a Liverpool based gaming company were involved in the design and positioning of the BluWireless 5G stations. The intention was to run real life experiments to explore the potential of e-health.

The 5G network has revolutionised many aspects of e-health, including out-patient monitoring, the creation of social care networks, and remote pharmacies. These projects have delivered tangible benefits, such as reduced costs and the environmental benefits of avoided journeys. Most importantly, this has led to improved patient outcomes in deprived communities in Liverpool.

7.1.1 Medicine use and compliance

According to the Department of Health over £300 million a year is wasted on unused medicines across the UK - covering not only the cost of the wasted medicines but also the impact of missed doses or incorrectly taken medicines.[21]

In Liverpool, for example, the PaMan system uses an Alexa type connected device to enable pharmacists to call and consult patients over 5G video to ensure patients take their medicines on time and follow their prescriptions. This frees up vital social care resources to focus on other tasks, both cutting out unnecessary daily visits and also reducing the waste of medicines.

"We see a happier, healthier population who can get expert medical advice beamed directly to their homes in a cost-effective and timely manner which leads to better patient care and health outcomes."

Rosemary Kay, Managing Director of eHealthcare for the local authority

7.1.2 Vital signs from home

Sensor City, based out of the Royal Liverpool Hospital, have developed a small, easy to use piece of equipment that will revolutionise out-patient visits. No longer will patients have to visit the hospital to measure their vital signs - now a simple connected box can take blood pressure, pulse, body weight, and oxygen levels at home.

This can happen daily, which dramatically increases the amount of monitoring and allows problems to be picked up more quickly. These systems have helped patients be more informed about their health conditions, allowing them to leave hospital earlier after a procedure and also reducing the need for emergency visits. In some cases, patients who previously visited the hospital six times a year now only visit annually.

Other lifesaving projects include digital logging of social care visits, a video support network for isolated people and carers, and IoT sensors in safe houses to monitor noise, damp, and building access to ensure the safeguarding of clients.

One beneficiary of this is Peggy. Peggy is 74 years old and has diabetes. Health and care staff who administered her medication and injections were often delayed, so her medication was late, and she frequently suffered from hypoglycaemic episodes, where the level of sugar (glucose) in the blood drops too low. As a result she experienced several falls. She lacked confidence taking medication and checking her blood sugar level. With support from the PaMan device and team, Peggy now self-administers her insulin, and takes her medicine as prescribed – the right dose, at the right time – which means she is less likely to spend time in hospital. She no longer needs a district nurse and a "time-critical" carer visit. Peggy has more freedom to leave the house, has more independence, and better quality of life.

"I feel confident using PaMan because the pharmacists that call me are always polite and explain everything really well. I don't forget to take my medications anymore and I don't feel like it's a chore."[22]

Peggy

MP Margot James with participants in the social care testbed

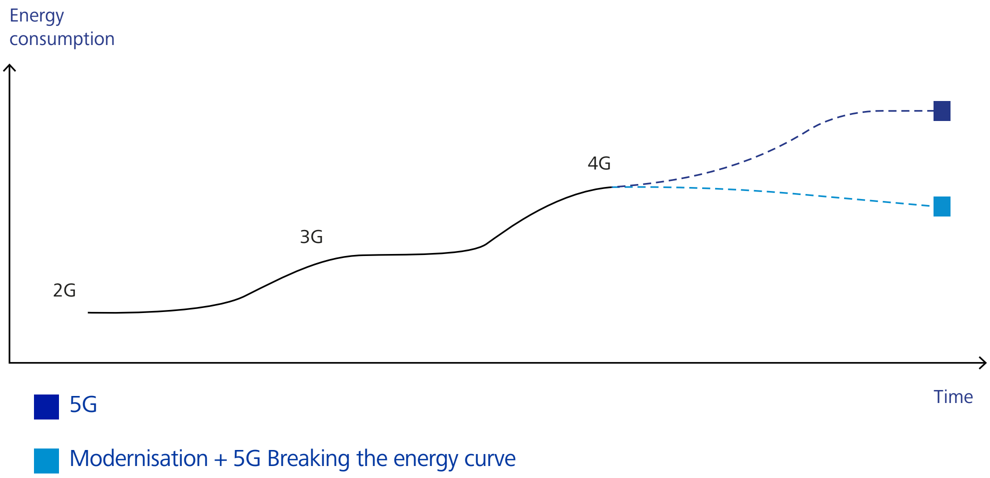
The carbon costs of 5G and their mitigation

With the number of telecommunications masts predicted to increase by a factor of twenty as 5G is rolled out, it is important that mobile operators and their suppliers increase efficiency, share infrastructure as has been done with the UK's Shared Rural Network, and power masts through renewable energy.[23] This will be essential to keep the telecommunications industry carbon footprint on track with the UK's Net Zero ambition.

Within the telecoms and the telecoms infrastructure industry, there are concerns that 5G will have detrimental effects on the environment and carbon emissions.[24] There is also some concern that the ambition to have billions of connected IoT devices will substantially increase the demand for energy.[25] Coupled with the potential extra load on data centres from consumers taking advantage of 5G's 100-fold increase in download speeds, this means that the entertainment sector's carbon footprint has the potential to increase overall data consumption, which will cause an uptick in energy usage.

The challenge facing the telecoms sector is to follow the example of the UK's power generation industry, which has successfully decoupled its growth from its carbon emissions.

This is exactly what O2's infrastructure partner, Ericsson, is on track to deliver. Ericsson has embarked on a programme called "Breaking the Energy Curve" to ensure that 5G is 10 times more efficient for energy usage than 4G.[26]



Ericsson suggests a four-step approach to prepare the network, through:

1. Modernising hardware
2. Activating energy-saving software
3. Building 5G with precision by using network hardware to deliver 4G and 5G
4. Operating site infrastructure intelligently using AI

This has already led to a five-fold increase in efficiency over 4G. Ericsson is fully on track to deliver their goal of a full 10 times increase in efficiency over 4G by 2023.[27]

As the world connects more and more online, and more energy is needed to power the machines that enable that connectivity, we know it's more important than ever that we work together to set goals to improve the sustainability of those energy sources.

O2's commitment to power masts that it owns with renewable power and to require third-party landlords to do the same is vital for the telecoms industry to stay on track with the UK's Net Zero ambitions through decoupling emissions from growth.

Methodology

This document has been prepared by IC&CO and Cenex. It is designed to contribute to an evidence base for how 5G could enable a high efficiency economy and lower carbon society.

The evidence in this document can be used to highlight:

1. The role of 5G in decarbonising (reducing the carbon footprint) of key sectors of the economy
2. The role of emissions created by 5G networks and data centres - and how these are being addressed by better energy "performance"

10.1 Methodology

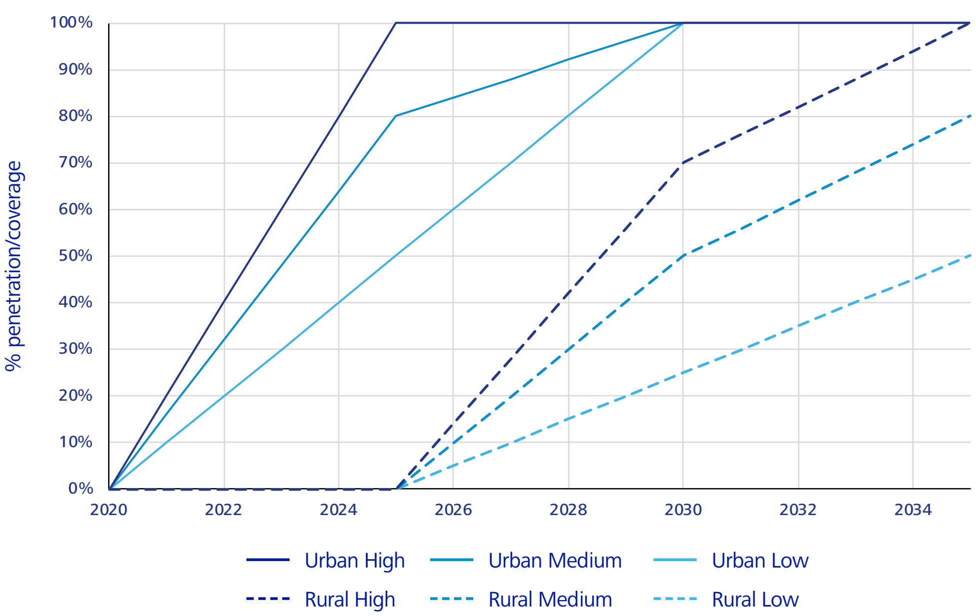
All references to CO2 also include emissions of other greenhouse gases on a CO2 equivalence (CO2e) basis.

10.1.1 Estimates of GHG savings

To account for the uncertainty in possible 5G coverage/penetration in the next 15 years, three scenarios have been modelled. These scenarios are low, medium, and high penetration, and are split by coverage in urban (cities and large towns) and rural areas (rural and motorway roads and railways). The penetration factor is assumed to be the % of total data transmitted using 5G networks and devices. For each of these scenarios we gave a % penetration factor shown in the graphs below.

The scenarios are based on conversations with O2, where it became clear that 5G would be used first where it is immediately needed: in highly populated cities. It will then be rolled out in smaller cities and finally, in the road and rail networks borrowing features from 3G and 4G. This information is corroborated by a report published by Juniper Research on behalf of O2, which states that "the total number of 5G connections will reach 1.5 billion globally by 2025, rising from only 5 million in 2019" and that "the year 2025 is used based on the assumption that 5G penetration will be close to 100% in UK cities."[28]

5G penetration scenarios in urban roads, cities and large towns



Within each sector, it is important to understand the difference between projected direct effects of 5G and the projected indirect effects. As an example, in transport, direct effects come when 5G enables such innovations as "platooning" - where convoys of commercial vehicles can work in auto-pilot slipstreams, radically reducing fuel consumption. Indirect effects come as 5G becomes the preferred network for increasing numbers of citizens and flexible workers, enabling reduced commuting and business travel.

10.1.2 Case studies

We feature a series of qualitative case studies - current trials that indicate the potential role and impact of 5G in our lives and the UK economy. We interviewed key personnel and linked their cases to other trials and trends:

Transport - the Milbrook Proving Ground

Utilities - the home smart grid experiment by Cenex

Manufacturing - the Worcester Bosch 5G experiment

Healthcare - the Liverpool 5G test bed

10.1.3 Expert commentary

We solicited expert commentary from two notable experts:

Eman Martin-Vignerte
Board Director, Bosch UK & Board of 5GUK

Professor Rahim Tafazolli
Regius Professor of Electronic Engineering and Professor of Mobile and Satellite Communications at the University of Surrey.

10.2 Detailed methodology and workings by sector

4.1 Smart heating

According to simulation work by the Fraunhofer Institute, future smart thermostats featuring presence detection and weather forecasting could save between 14% and 26% of a household's heating energy.[29] As such we have assumed an average value of 20% without any variation between 2020 and 2035.

Using the Imperial College study again,[21] the use of heat pumps combined with a smart distribution network can provide carbon savings of 9g CO2e/kWh in 2030 (average of Slow Progression and Green World scenarios). Using the same method as in section 3.1, this equates to 11% carbon savings in 2030, assuming 0% in 2020 and extrapolating to 17% in 2035. Therefore, **the combined effect of smart thermostats and heat pumps yields CO2 savings from 20% in 2020 to 37% in 2035**.

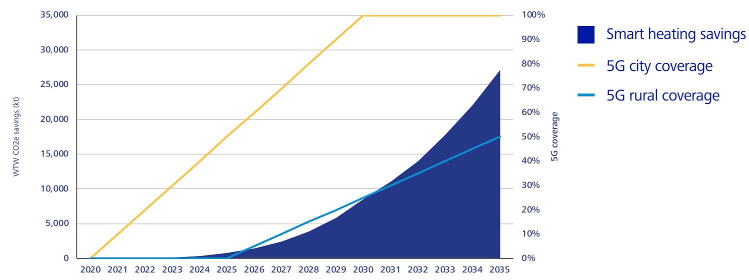
Heat pumps currently represent 2% of installed UK heating capacity.[30] Market forecasts for heat pumps predicts strong growth in annual sales from 30,000 in 2020 to 45,000 in 2025.[31] Using UK government's population predictions,[32,33] there is likely to be a simultaneous increase in the number of households in the UK from the current 28m to 30.8m in 2035.

The market forecast was then translated to a projection of the number of houses with heat pumps from 2% in 2020 to just 4.4% in 2035. This small increase is due to the fact that heat pumps are mostly installed on new builds with existing builds relying on gas boilers, which typically last for 15 years.[34] A similar exercise was done with smart thermostats, taking account of their stronger future market prospects with the proportion of households using them predicted to rise from 5% in 2020 to 84% in 2035.[35,36]

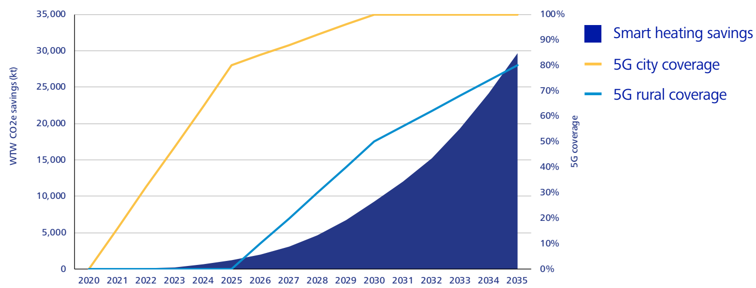
As an assumption, a value of 0% for the installed base of 5G powered home broadband was used in 2020, which increases linearly to 50% in 2035.

All the factors described were then combined with the 5G penetration scenarios and the energy emissions baseline in the same way as in previous sections to calculate the WTW GHG emission savings from smart heating as shown in the following graphs:

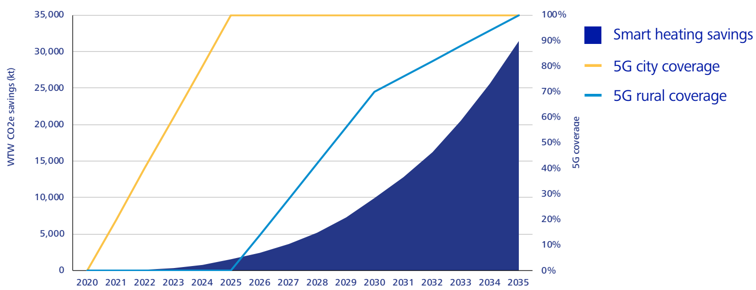
Annual WTW GHG savings from smart heating - Low 5G uptake



Annual WTW GHG savings from smart heating - Med 5G uptake



Annual WTW GHG savings from smart heating -High 5G uptake



4.2 Smart grids

The Imperial report simulated two carbon saving scenarios for 2030: Slow Progression (pessimistic) and Green World (optimistic). We averaged the predictions from both scenarios to calculate a reduction in 6.5 g CO_2e per kWh of energy demand via DSR and dToU. According to the latest energy and emissions projections by the UK Government,[37] the grid will have a carbon intensity of 80 g CO_2e/kWh by 2030, thus giving a GHG emission reduction via DSR and dToU of 8% in 2030.

We then assumed a linear increase for the savings from 0% in 2020 to 8% in 2030, which was extrapolated to 12% in 2035. This figure is corroborated by O2 who, using data from Juniper Research, quoted a **12% energy consumption saving to be provided by 5G-connected smart grids.**

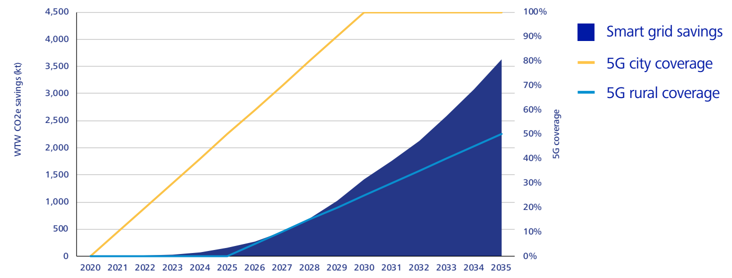
However, we need to address the question of how much of these savings will actually be enabled by 5G. The global market penetration of DSR was forecast by the International Energy Agency at 18% of the energy demand share in 2020 increasing to 24% in 2035.[38] A report by Guidehouse[39] predicted an approximate 25% increase in the neural grid ecosystem revenue by considering the opportunities that 5G represents for the smart and (future) neural grids. This figure seems to be backed up by another study from Hui et al,[40] which balances out the strengths of 5G for smart grids against potential challenges that it may face in the future.

The baseline for "business as usual" (i.e. no uptake of 5G and smart grids) was taken from the latest energy and emissions projections by the UK Government[1] summing the emissions from the business, energy supply, public and residential categories in the "Reference Scenario."

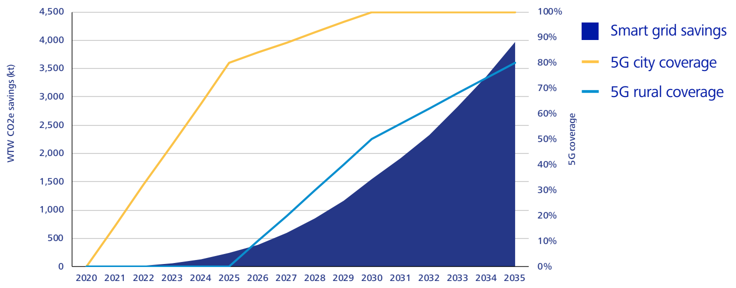
Finally, we applied the 5G penetration scenarios for urban and rural areas factoring in the 72% population living in cities and large towns.

The WTW GHG saving results for the three 5G coverage scenarios are shown below:

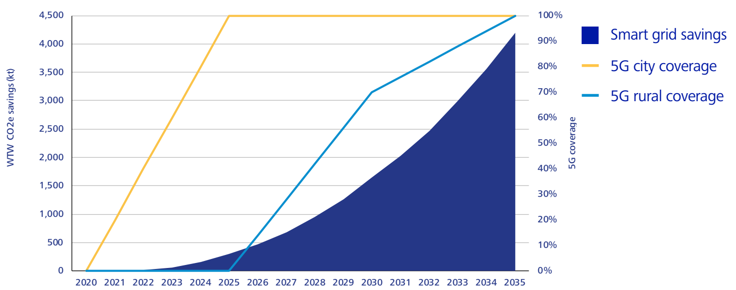
Annual WTW GHG savings from smart grids - Low 5G uptake



Annual WTW GHG savings from smart grids - Med 5G uptake



Annual WTW GHG savings from smart grid - Low 5G uptake



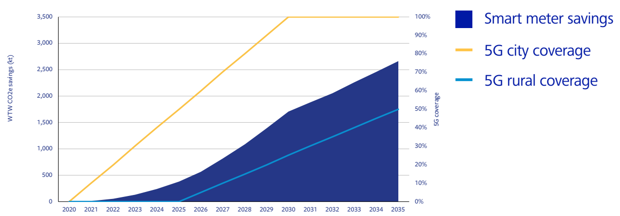
4.3 Smart meters

Our projection of future smart meter installations was obtained from government sources,[41] which predict a strong uptake from the current 58% coverage of both domestic and non-domestic electricity and gas installations, to 92% in 2025. The increase thereafter is less pronounced, but still achieves 98% coverage by 2035.

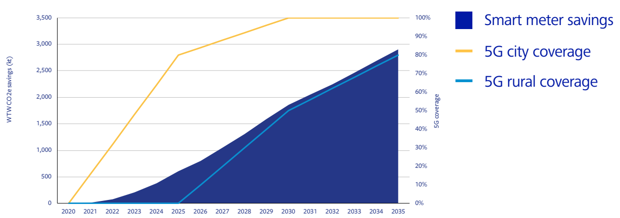
It is difficult to tell how many of these installations will require 5G. 5G will progressively replace 3 and 4G smart meters in new installations in the following years at a slow rate. In order to quantify this statement, we took the conservative assumption of a linear increase from 0% in 2020 to 50% in 2035. This yields a 5G smart meter uptake of 17% of the 92% of assets that have smart meters in 2025, and 50% of the 98% of assets in 2035.

All the described factors were then combined with the same 5G coverage scenarios and baseline as in previous sections to produce the WTW GHG saving graphs below.

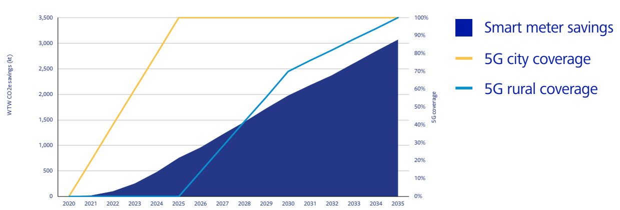
Annual WTW GHG savings from smart meters - Low 5G uptake



Annual WTW GHG savings from smart meters - Med 5G uptake



Annual WTW GHG savings from smart meters - High 5G uptake

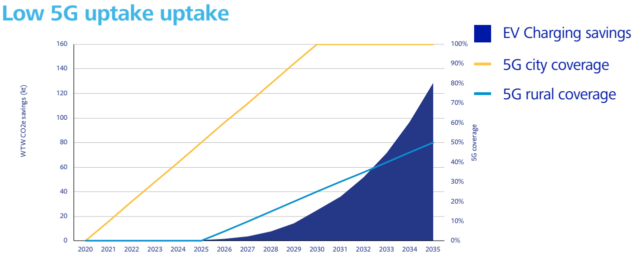


4.4 EV Charging

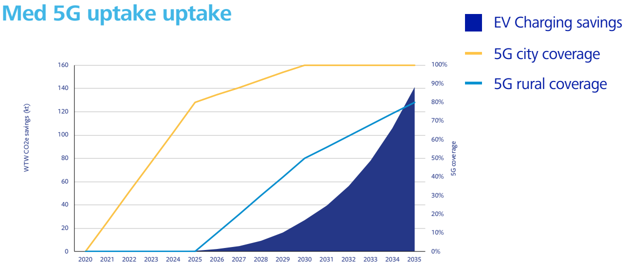
As for the impact that 5G may have on these services, this is again difficult to quantify and we could not find any reliable sources of information. As a conservative assumption, a value of 0% was used in 2020, which increases linearly to 50% in 2035.

The baseline emissions calculation used was different to previous sections because of the need to restrict the baseline to future WTW GHG emissions exclusively from EVs. The method followed to calculate this baseline is the same as in the Transport section of the report, where we use data from DfT and the Net Zero report.[5,6,7] Applying the assumptions for the 5G coverage scenarios produces the WTW GHG savings graphs below.

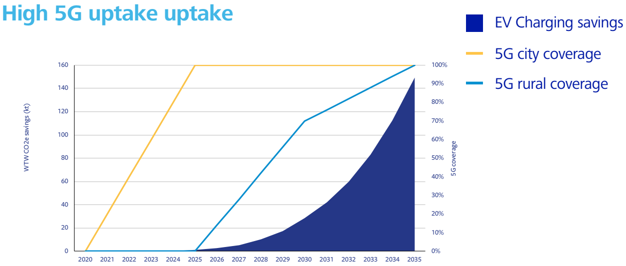
Annual WTW GHG savings from smart EV charging - Low 5G uptake uptake



Annual WTW GHG savings from smart EV charging - Med 5G uptake uptake



Annual WTW GHG savings from smart EV charging - High 5G uptake uptake

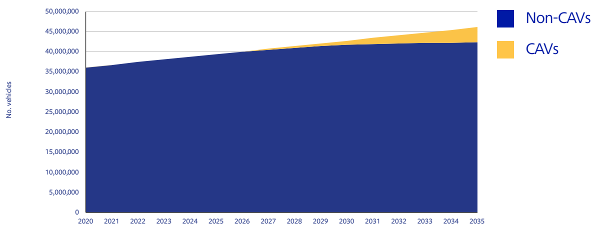


5.0 Transport

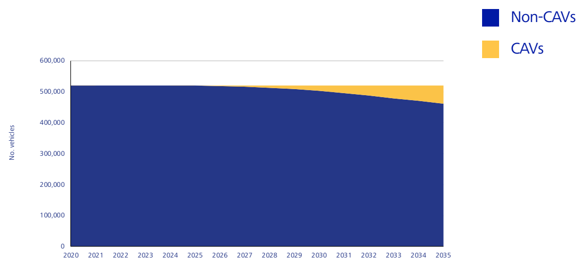
5.1 Connected and Autonomous Vehicles (CAVs)

Based on this information and the CAV market penetration forecast by the Transport Systems Catapul,[42] we estimated the level L4-5 CAV vehicle volume (or "parc") in the next 15 years as shown in the graphs below. The total vehicle parc was calculated using the latest available DfT data,[43] including vehicle age.

Total parc cars and vans: share of L4-5 CAVs



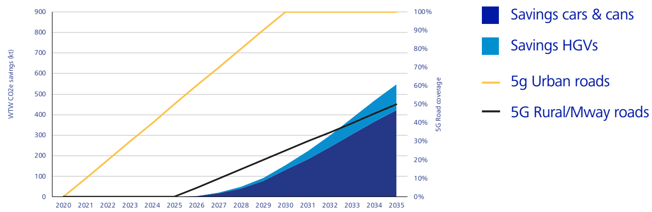
Total parc HGVs: share of L4-5 CAVs



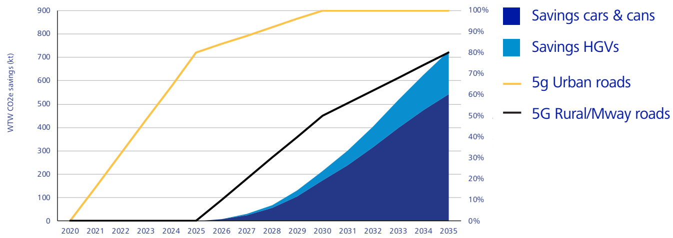
Finally, we require a solid baseline to represent "business as usual" (i.e. the carbon forecast from road transport if 5G and L4-5 CAVs did not happen in the next 15 years). This was calculated by assuming the targets set by Net Zero[44] to achieve carbon neutrality by 2050, with the additional assumption that the UK will ban sales of non-plug-in vehicles by 2032.[45] We used the latest data on the share of vehicle types (petrol, diesel, hybrid, electric), bodies (cars, vans, HGVs) and emissions per mile from the DfT5 to calculate the baseline CO2 emissions from 2020 to 2035. We then introduced the 5G penetration scenarios for urban and rural areas (assuming motorways have the same coverage as rural areas) and combined them with the average UK distances per vehicle and road type.[46]

The well-to-wheel (WTW, fuel life cycle emissions) GHG emission results are shown in the graphs below for the three 5G penetration scenarios, with the same scale on the vertical axis to aid comparison.

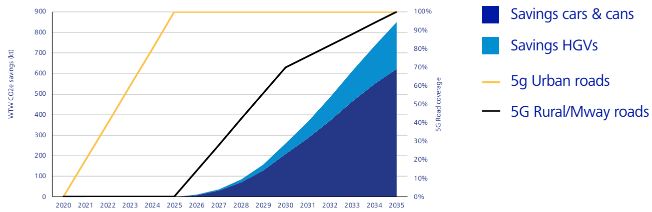
Annual WTW GHG savings CAVs - Low 5G uptake



Annual WTW GHG savings CAVs - Med 5G uptake



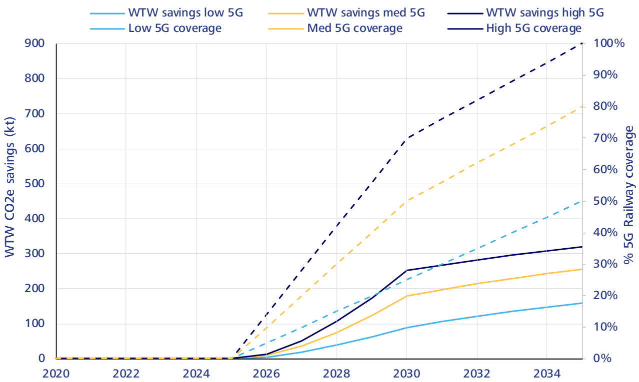
Annual WTW GHG savings CAVs - High 5G uptake



5.2 Smart Rail Systems

The "business as usual" future carbon baseline was estimated using data from ORR for the 2020 emissions and the target set for 2030 and 2050 by Net Zero; the values for the rest of the years were then extrapolated[47]. The WTW GHG emissions were then calculated applying the up to 45% emission reduction stated above and assuming the same 5G penetration in the railway network as in rural areas. We have kept the same scale in the vertical axis to aid comparison with the previous charts in this section.

Annual WTW GHG savings - Smart Rail Systems



5.3 Remote Working

We have used the findings from this research for 2020 alongside the baselines for road and rail emissions in the next 15 years (see sections 3.1 and 3.2) in our calculations here.

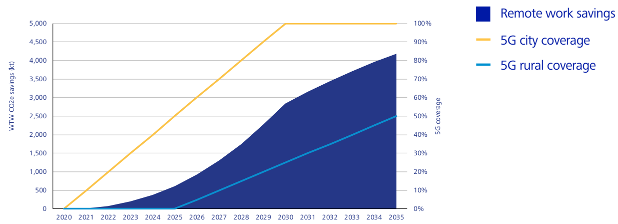
We then applied a "remote work" factor to account for the more flexible nature of business in the future, rising linearly between 2020 and 2035 from a 1 day per week reduction in commuting to 2 days, and from a 10% domestic business trip reduction in 2020 to twice as much in 2035. These assumptions are informed by a report from Verizon Media[48] stating that, before the COVID-19 crisis, only 6% of UK employees were permanent remote workers but, during the crisis, 46% of UK employees were working from home full-time (equivalent to 2.3 days/week).

We then assessed the influence of 5G on remote working capabilities. It seems that 5G coverage indoors will be challenging for some time due to high frequencies and thus the difficulty in penetrating walls and windows, with 4G having the similar challenges in comparable situations.[49,50]

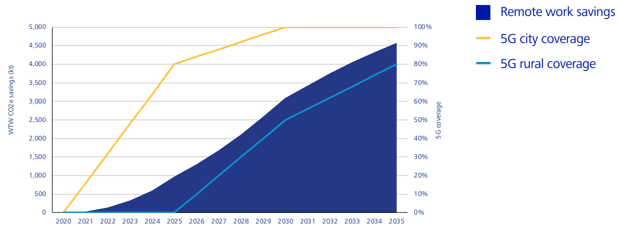
Wi-Fi will still be the preferred choice by domestic and business consumers for indoor networks in the next few years, with Wi-Fi data currently accounting for over 50% of total IP traffic.[51] And a new and faster generation of Wi-Fi 6 becoming available.[52] This is supported by the market value for Wi-Fi, which is expected to grow from USD 5.96 Billion in 2017 to USD 15.60 Billion by 2022, at a Compound Annual Growth Rate (CAGR) of 21.2% during the forecast period.[53] All this information is reflected in a factor representing the impact of 5G in the reduction of work-related travel, which increases linearly from 0% in 2020 to 50% in 2035.

Finally, the 5G urban and rural coverage scenarios were factored in with the split of the UK population living in cities/large towns versus rural areas, which is 72% and 28% respectively and is expected to stay roughly the same in the next 15 years.[54] All the factors above were combined to calculate.

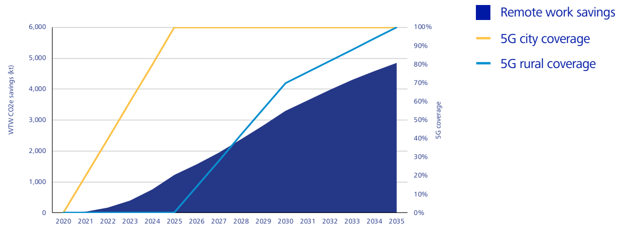
Annual WTW GHG savings from remote work - Low 5G uptake



Annual WTW GHG savings from remote work - Med 5G uptake



Annual WTW GHG savings from remote work - High 5G uptake



6.0 Manufacturing

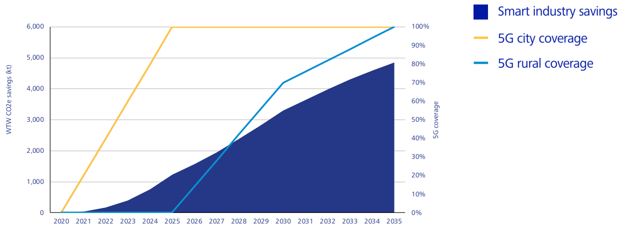
The cumulative reduction in GHG emissions over the next 15 years from 5G-enabled smart industries are 31,586, 36,615 and 40,148 kt CO2e in the low, medium, and high 5G coverage scenarios.

The carbon baseline was obtained from CCC's Net Zero report,[55] which gives a current UK value for the industrial sector of 105 Mt CO2e and an ambitious target for 2050 of 9.7 Mt CO2e, where we interpolated the intermediate values between 2020 and 2035. All the described factors were then combined with the 5G coverage scenarios factoring in the % population living in cities and rural areas (assuming that this is a reasonable approximation of the location of factories).

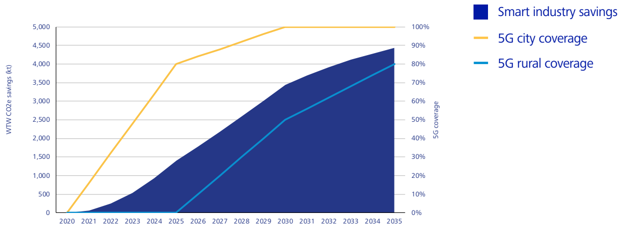
The graphs below show the estimated GHG emission savings from 5G-enabled smart industries.

Even though the GHG savings obtained via 5G-enabled smart industries/manufacturing are significant, they still only represent 2.4 to 3.1% of the baseline industrial emissions.

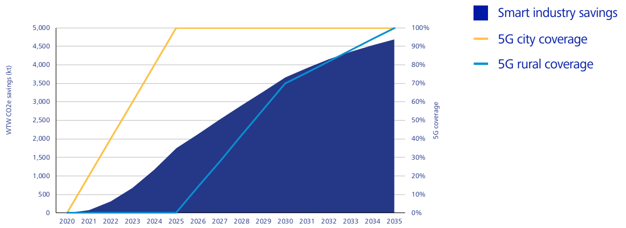
Annual WTW GHG savings from smart industry - Low 5G uptake



Annual WTW GHG savings from smart industry - Med 5G uptake



Annual WTW GHG savings from smart industry - High 5G uptake

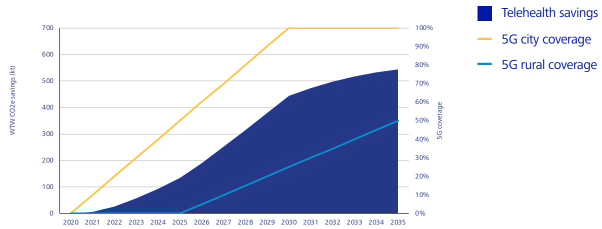


7.0 Healthcare

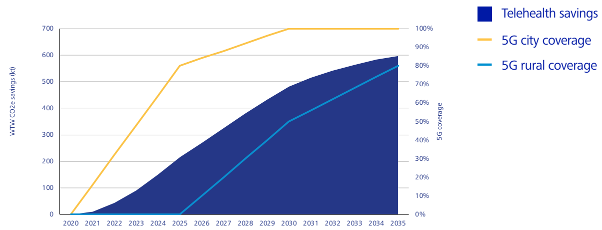
We could not find a solid source of data to quantify the level of 5G required for e-health, although there is some evidence to suggest that 5G is required.[56] We have therefore assumed a value of 0% in 5G influence in 2020, which increases linearly to 50% in 2035.

Applying the combination of these factors to the baseline and the 5G coverage scenarios (assuming the split of hospitals in urban vs rural areas mirrors the rural-urban split in the population at large20), we obtain the following WTW GHG emission saving graphs.

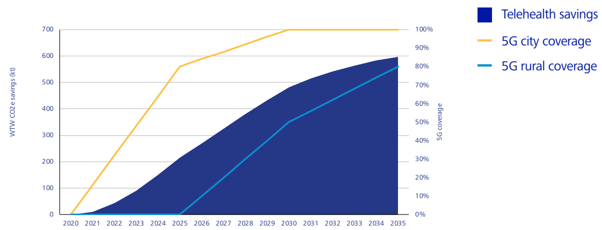
Annual WTW GHG savings from telehealth - Low 5G uptake



Annual WTW GHG savings from telehealth - Med 5G uptake



Annual WTW GHG savings from telehealth - High 5G uptake



The cumulative savings in GHG emissions in the next 15 years from 5G-enabled telehealth are 4,462, 5,200 and 5,718 kt CO2e in the low, medium and high 5G coverage scenarios. This represents 1.9% to 2.4% of baseline healthcare emissions.

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