WHAT DOES TOMORROW LOOK LIKE?

SMARTER NETWORKS CAN TRANSFORM

A STAFF ANALYSIS FROM THE INFRASTRUCTURE FORUM

POST-PANDEMIC: SMARTER UK NETWORKS

SMARTER COMMUNICATIONS
SMARTER ENERGY
SMARTER TRANSPORT
THE UK'S COMMUNICATIONS, POWER, AND TRANSPORT ARE CRITICAL TO THE BOUNCEBACK

THIS REPORT SHOWS HOW THEY CAN INTERCONNECT DIGITALLY TO MAKE THE REBUILD SMARTER FOR BUSINESS AND CONSUMERS

SECTIONS

SIR JOHN ARMITT CBE CHAIRMAN NATIONAL INFRASTRUCTURE COMMISSION

Driving integration and communication across the sectors is an extremely important task as our industries continue to become ever more interlinked. In its next National Infrastructure Assessment, now beginning, we at the NIC will look at society's future demand for services and connecting infrastructure. We will see a continuing need for new transport connections, particularly between and into our largest cities, alongside the revolutionary change in use of internet and telecommunications technology. The UK Regulators Network can play a key role in helping ensure that the sectors work constructively with each other, and an independent chair and data sharing function would further support this goal.

THE OPPORTUNITY

THE OPPORTUNITY AND POSSIBILITY OF MAJOR TRANSFORMATION

The post-Covid reset gives the UK the chance of a leap forward in developing its most important networks - for communications, energy and transport.

In preparing this report, The Infrastructure Forum has found a new momentum to develop these networks. Old plans have been resurrected and new ones brought forward. The scale of finance needed to handle Covid has brought the investment required into perspective. Building new networks for the future is now a no-brainer rather than a debatable option.

The new insight is that these networks interconnect across the sectors. Wireless, 5G, Satellites and the fibre backhaul, that will underpin data communication are critical to making possible next generation net zero energy, digital roads and railways and the operation of autonomous vehicles and freight- or people-carrying drones.

Smart energy networks, in turn, provide the clean power for electric cars, electric trains and eventually electric aircraft; and also for the massive consumption of electric power needed by tomorrow's data centres, supporting seamless cloud systems which, through the web, are transforming work-life balance for the better.

Rail networks need fibre, telecoms and 5G to give customers better quality travel and to interconnect more easily, for example with their 5G devices, connecting seamlessly to airport departure services as their train pulls into the station at Gatwick or Heathrow.

What are the prospects for this transformation, the opportunities around the corner, the best guesses at the future?

Where are the blockages in policy or regulation which need to be fixed?

This report seeks to provide some facts and put forward some ideas.

THE COVID RESET AND LIFESTYLE CHANGES

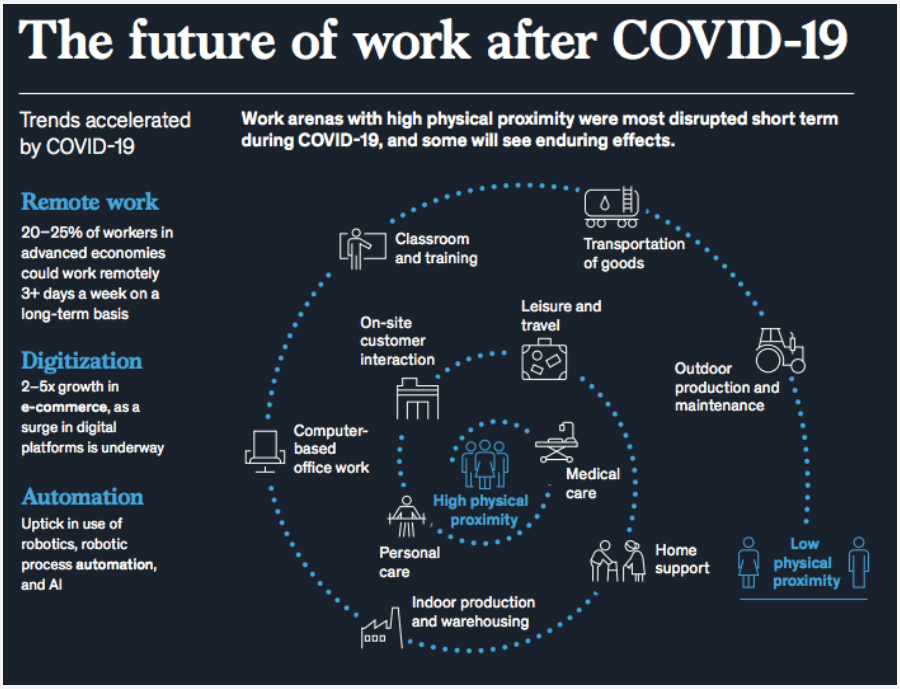
Analysis suggests that while more people will work from home and will need full-on wireless, 5G and broadband communications connectivity, others will need energy-efficient travel and transport to get to work and do business.

Work by McKinsey identifies three groups of trends accelerated by Covid-19 that may persist after the pandemic recedes (1):

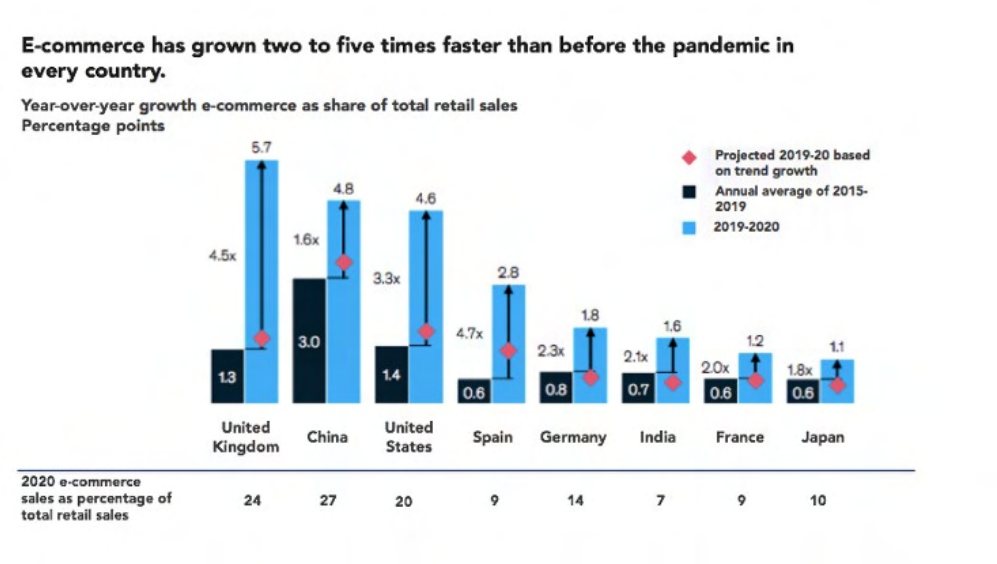
- The shift to remote work and virtual interactions
- The surge in use of e-commerce and other digital platforms
- The deployment of automation and AI

All these require word-class communications technology.

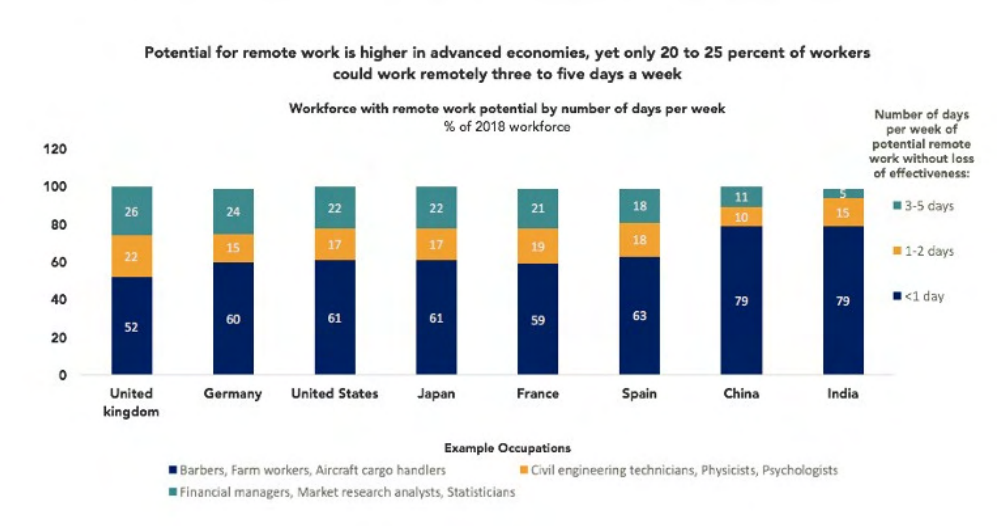
McKinsey say: *In each case the pandemic pushed companies and consumers to rapidly adopt new behaviours. We consequently see a sharp discontinuity between the level of adoption before and during the pandemic. The extent to which these trends persist after the pandemic remains to be seen, but there is growing evidence that many of the new behaviours will persist, even if at somewhat lower levels than during the peak.*



Source: McKinsey The future of Work after Covid February 2021

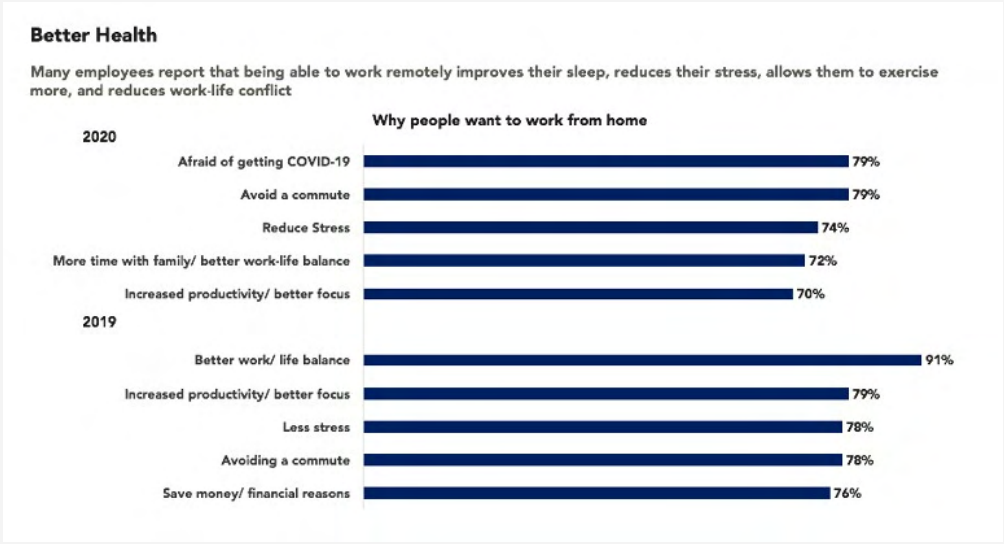


Source: McKinsey *The future of work after Covid-19,* February 2021



Source: McKinsey *The future of Work after Covid*, February 2021

A number of motivations led to working from home, but currently fear of Covid-19 tops the list for many. As and when the virus is controlled will affect the propensity to WfH, but it is unlikely that patterns will revert to the "status quo ante". Most likely a hybrid world will emerge. It could be that digital will dominate, given people's preferences revealed during the pandemic:



Source: Global Analytics

When the Financial Times analysed (2) trends between the start of the pandemic and January 2021 in a number of UK cities, the results were very similar and showed significant and consistent falls in the number of people travelling to places of work:

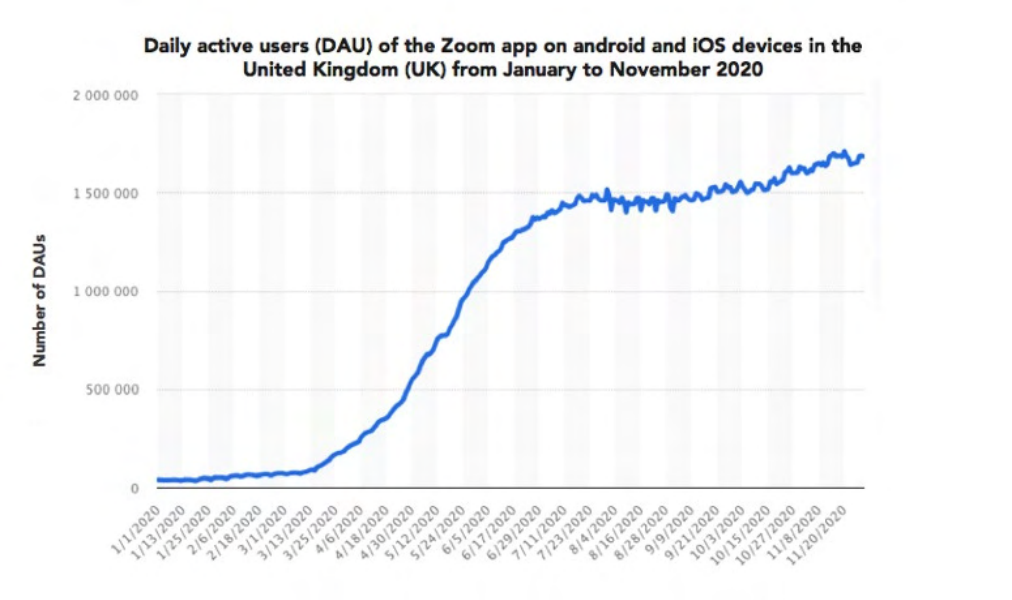
Source: FT, 2021

The takeup of Zoom shows how people have adjusted to working from home.

Zoom only started trading on the stock market in April 2019, but with lockdowns imposed globally, it quickly became the way people do just about everything.Globally, Zoom saw demand for its service rise rapidly when the first global lockdown was imposed, as exemplified by their usage statistics:

- In December 2019, the maximum number of daily meeting participants, both free and paid, conducted on Zoom was approximately 10 million
- In April 2020 Zoom reached more than 300 million daily meeting participants, both free and paid.

In the US, traffic to Zoom's website in December 2020 was nearly 30 times what it was at the beginning of the year. In the UK, daily active users (DAU) of the Zoom app on android and iOS devices alone reached over 1.6 million in November 2020 (3).



Source: Statistica, 2021

After the pandemic, the vast majority of office employers plan to use a hybrid work model, where some of the workforce will work remotely at least some of the time. Digital will likely play an increasing part in how we work in the years to come.

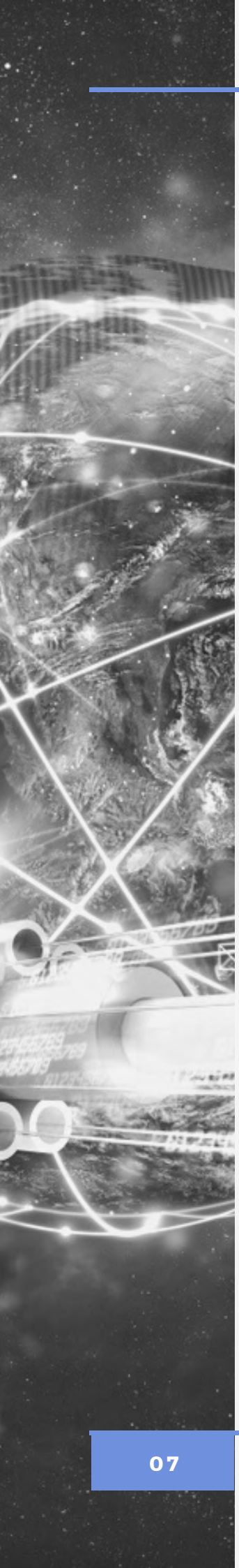
THE UK NEEDS MORE CONNECTED NETWORKS - FAST

The National Infrastructure Commission identified the need for new digital infrastructure in its National Infrastructure Assessment, published in 2018 (4). It describes how 'Digital connectivity is now an essential utility, as central to the UK's society and economy as electricity or water supply. Demand for data, and therefore the speed, reliability and capacity of broadband connections, is growing rapidly… Full fibre can provide this for the future.'

Full fibre technology uses fibre optic cables in the entire network, and has the following characteristics that make it capable of supporting the economy of the future:

- Gigabit download and upload speeds. This symmetric capability is essential for many industries and infrastructures to operate, including the other sectors outlined in this report such as creating a smart energy grid, enabling autonomous vehicles, and mass cloud computing.
- Reliability – lowest fault rate of broadband technologies. The ability for ultra-reliable connectivity is critical to enable other infrastructures to become smart, such as supporting the next-generation of mobile data transmission (5G).
- Low latency i.e. minimal delay to process data. This supports operations that require near real-time access to rapidly changing data.
- Energy efficient, many more times than existing broadband technologies. This has practical implications for running large networks and also changing society to become more environmentally friendly (by enabling behavioural changes such as where to live, work, and set up a business).

A report by Regeneris (5) for CityFibre in 2018 highlighted the economic benefits that can be enabled by full fibre, which go beyond residential use. It clearly shows that businesses, the public sector (for example, health and social care) and citizens benefit from improvements in productivity, innovation and the new technologies that are enabled, such as 5G, the Internet of Things and Industry 4.0, as well as other smart cities infrastructure.



The report said:

"While we have chosen not to provide one single economic impact figure, the FTTH Council (2014) does provide an early overarching estimate. Based on evidence from the US, it suggests that providing full fibre to just half of all premises could result in a 1.1% rise in annual GDP. If this growth rate is applied to our combined 100 city and town economies, it suggests a total economic impact of up to £85 billion associated with 50 towns and cities over 15 years and up to £120 billion for 100 towns and cities.

The speed of technology change in each of these areas means that predicting future uses, let alone the scale of associated economic benefit, is naturally difficult. Despite this, we have generated some broad, indicative and cautious estimates of economic and environmental impact over a 15-year period, drawing on headline forecasts and evidence of specific impacts generated to date. Throughout we have used lower end figures in the ranges presented in research."

Headline Impacts over 15 years

Impact Category		Impact Focus	50 Towns & Cities	100 Towns & Cities
Core Economic Impacts (Part 1)	Direct Employment	1. Network build	£1.4bn	£2.1bn
	Business Impacts	2. Productivity improvements	£1.5bn	£2.2bn
		3. Innovation	£1.6bn	£2.3bn
		4. Flexible working	£1.4bn	£1.9bn
		5. New business start-ups	£1.5bn	£2.3bn
	Private Benefits to Households	6. Housing wealth	£4bn	£7bn
Wider Impacts (Part 2)	5G	7. Total economic value	£20bn	£28bn
	Smart Cities Infrastructure	8. Energy use & congestion	£3.6bn	£5bn
	Industry 4.0/IoT	9. Manufacturing productivity	£7bn	£10bn
	Health Care	10. Cost savings	£0.7bn	£1.1bn
	Environmental Impacts	CO2 reductions	1.5Mt CO2	2.3Mt CO2
		Value applying Shadow Price of Carbon	£100mn	£160mn

Source: Regeneris Consulting

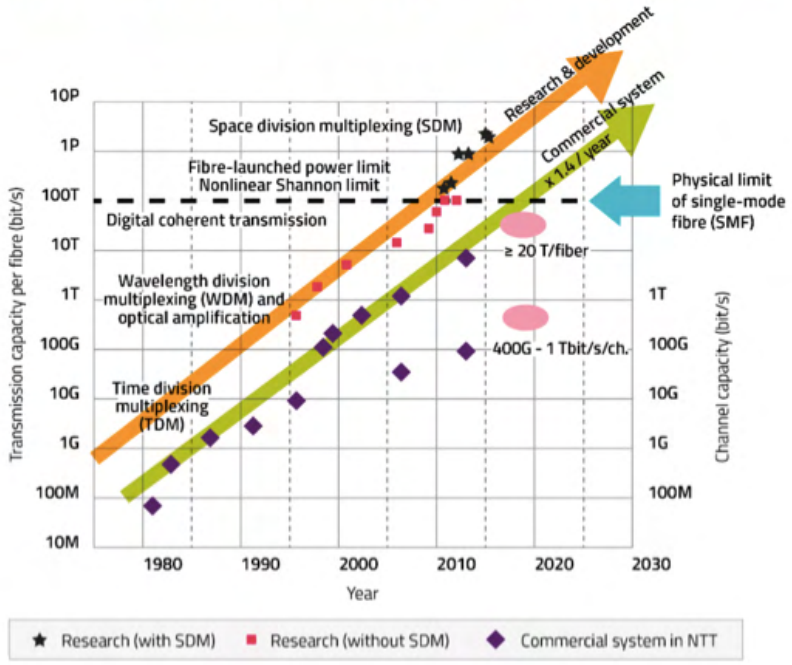
'Full Fibre will provide the core infrastructure required to kick start the next generation of digital technology and drive expansion of smart infrastructure in towns and cities where it is deployed. The result will be a modernised, more productive and innovative UK economy.'

The UK Government has made 'levelling up' a priority and it is clear that full fibre will be crucial to the economic growth necessary to achieve this, particularly in enabling areas that have previously been left-behind by infrastructure rollouts, such as rural areas, to bridge the digital divide.

This is now happening as full fibre infrastructure is being built in a competitive environment, with commercial incentives in place, backed by a strong regulatory framework.

Importantly, full fibre is a future-proof technology, with massive potential to carry the enormous quantities of data which the UK's future economy and society will need. Around the world fibre networks have grown exponentially, moving from Megabyte to Gigabyte to Terabyte power (a Terabyte representing a trillion bytes).

The evolution of high-capacity fibre networks over time, showing the consistently exponential growth over many decades and with successive technical improvements. Yellow line experiments, green line commercial systems.

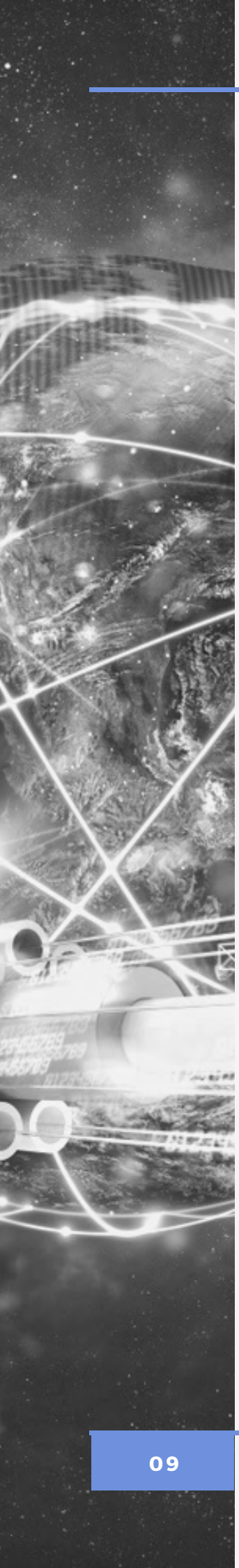


Source: Ofcom, Technology Futures, 2021

Full fibre is also key to aligning the digital transformation and net zero agendas.

Full fibre is the most reliable broadband technology currently available, with less service disruption, less failure and lower maintenance costs. Full fibre connections experience fewer operating faults than copper-based networks and are cheaper to maintain and operate. Full-fibre connections are also less likely to slow down when many people use the network.

Several studies which have compared the energy consumption and CO2 emissions of traditional copper or coaxial cable based



technologies with full fibre networks have been published. One of these by BREKO, the leading German broadband Association, showed that copper-based networks (“VDSL” vectoring, super vectoring) consume up to seventeen times more electricity than fibre networks.” (6)

A recent report “Building Back Faster” by LSE Consulting, for independent owners and operators of utility infrastructure, highlights the move to home working and the digital divide, in particular, the importance of a fibre connection. “Those able to live in a home of their own with a fibre connection would have an important advantage in work continuity over those in shared accommodation reliant on copper wires and mobile data. Spreading these benefits as quickly as possible and as efficiently as possible is central to the rise of independent connections.” (7)

This report is also an interesting example of how important coordination of access to different networks can be for new building developments and future consumers. Increasingly in the UK, independent providers are providing utility connections which may cover electricity, gas, water, fibre communications and waste water disposal, for new developments. "As barriers to competition have reduced, independent network providers have built a substantial market presence. In 2019 more than 300,000 gas and electricity connections were provided by independents. Set in context the additional 159,000 gas connections provided by independents was three times the size of the total growth in gas connections, and the 150,000 independent electricity connections was 130% of the year’s total increase in electricity connections. It is clear that independents competing with each other now dominate the markets for new network connections, including some of the UKs most iconic new developments such as Media City, Kings Cross, and Battersea Power Station."

To these opportunities must be added the Net Zero imperatives.

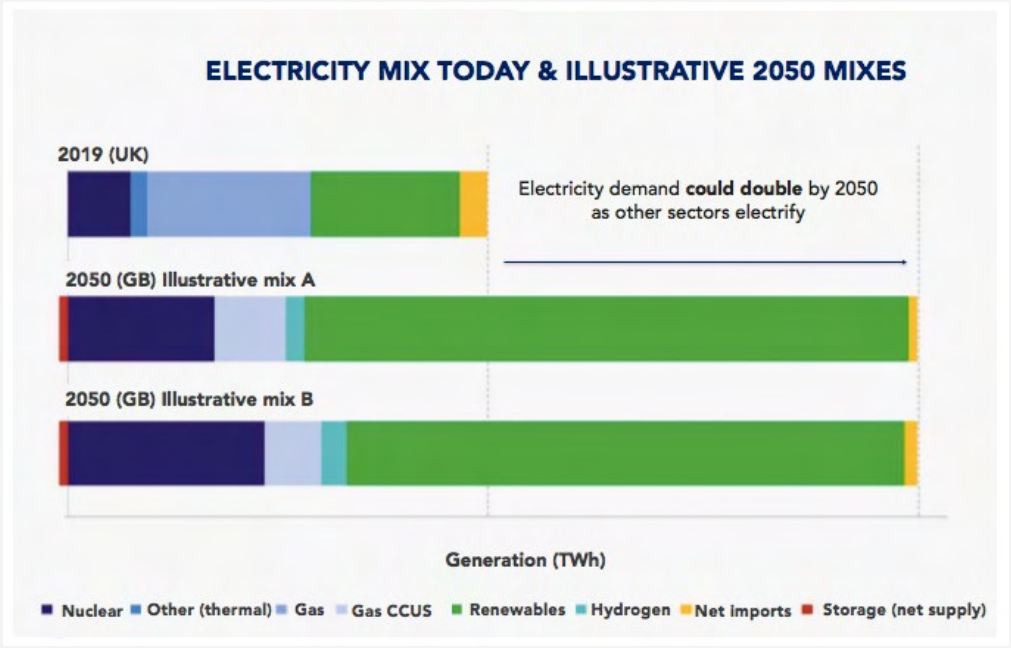
Following adoption of the legally binding "Net zero 2050" target by the UK in 2019, the government's Ten Point Plan for a green industrial revolution announced in November 2020 set even more ambitious greenhouse gas emission reduction targets. (8)

According to the Global Carbon Budget report (9), published on 11th December, 2020, global emissions fell around 7% last year as a result of pandemic-related lockdowns closing down many areas of the economy. The UK showed the second biggest fall in emissions globally, down 13% for the year compared with 2019, with surface transport particularly affected.

However, it is expected that emissions will rebound as economies open up, hence the continued need for ambitious targets to make a difference to climate change.

As the UK is hosting the COP-26 Conference in Glasgow in November 2021, this will provide a continued focus on climate action during recovery from Covid-19. The scale of the challenge is huge. In particular:

- Massive investment is required in renewable electricity
- There will be a doubling of electricity demand due to electrification of other sectors, such as transport and space heating, by 2050
- Government needs to transform to deliver effective cross-government working.



Source: Energy White Paper, December 2020

The UK's commitment to reach "net zero" greenhouse gas emissions by 2050 was examined in NAO's report "Achieving net zero" of 4th December, 2020 (10):

Its assessment is that upgrading energy networks will involve:

- changes to existing gas networks to make them hydrogen-ready, for hydrogen-based space heating
- connecting around 5 million homes to low-carbon heat networks (where a central low-carbon heat source provides heat to a number of homes)
- building 1,000 hydrogen refuelling stations
- installation of over 200,000 electric vehicle chargers and 1,000 depot-based chargers
- more than 50% of rail track to be electrified by 2040
- Ofgem, the economic regulator for energy, will need to ensure that electricity network companies are incentivised to transform and "support a low-cost, low-carbon energy system in the way that it sets rules for networks' allowed costs, targets and performance".

The same broad message in the government's 10-point plan to accelerate the drive to achieve net zero carbon emissions by 2050 also comes across in the National Infrastructure Strategy, published on 25th November 2020 (11) and the Energy White Paper "Powering our Net Zero Future" (published on 14th December 2020) (12)

SMART GRID WILL BE FUNDAMENTAL

It is clear that a smart electricity grid will be fundamental to the decarbonisation of the entire UK economy. This "once in a generation change" will be as significant for the electricity industry as the advent of fibre broadband is for communications:

- A smart energy grid will be needed to mitigate the intermittency of renewables, by improving connections between different regions
- Smart energy distribution networks at local level will also be required, to deliver the level of connectivity to the electricity network required for electric cars

- The government will support the rollout of charging and associated grid infrastructure along the strategic road network, to support the switch to EVs
- Under the government's 10-point plan, the sale of new petrol and diesel cars will be phased out by 2030
- Smart tariffs, based on the cost of electricity at different times of day, and load control tariffs, that can manage when appliances are used, will ensure consumers use the cheapest energy
- Prices could even go "negative" so that consumers can be paid to use energy at certain periods.

COLIN MATTHEWS CBE, CHAIRMAN, EDF ENERGY

In our increasingly digitised world, the interdependence of sectors including transport, telecommunications and energy, is increasing constantly.

The modernisation of airspace allows aircraft to arrive just in time and burn less fuel. There are some challenges, but it is happening.

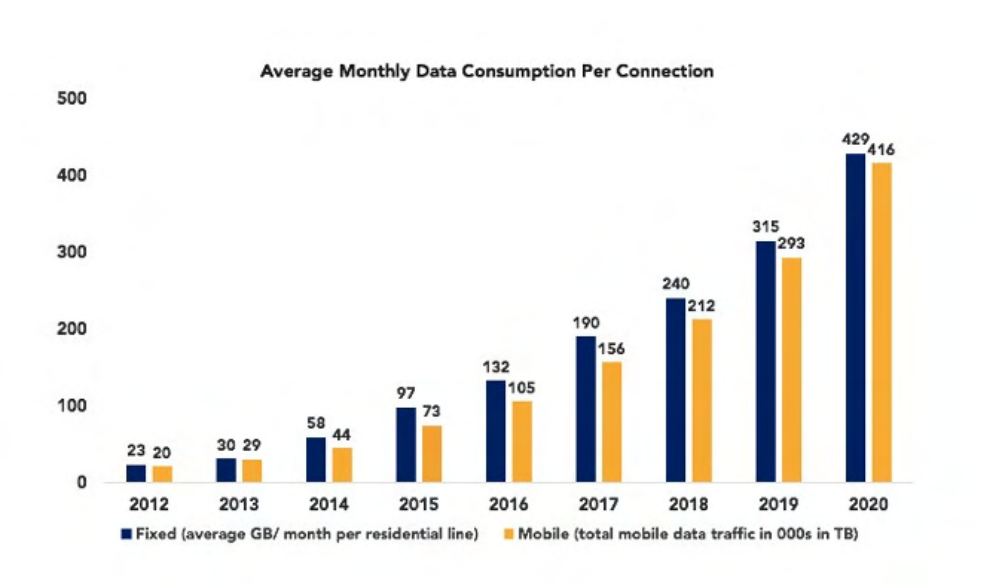
Real time quality information can transform customer experience on our highways, allowing users to adjust their journeys according to traffic flows. Again, this is happening.

Smart energy supply grids will be essential to shape the vast increase in demand as our economy decarbonises. It makes no sense to charge all electric vehicles at the same time. Equally important, we must get on with producing vastly more low carbon electricity. Wind will take us a long way, but not all the way. We need a mix of technologies - including nuclear - to ensure resilient networks.

MOVING TOWARDS THE NEW NORMAL

THIS SECTION SHOWS THE SCALE OF TRANSFORMATIVE CHANGE WHICH IS HAPPENING NOW

Looking first at **telecommunications**, UK customers have dramatically increased their use of comms data during the pandemic in both fixed and mobile applications:



Source: Ofcom, Connected Nations, December 2020

Broadband usage in the UK more than doubled in 2020, according to Openreach data (13). Home internet networks saw traffic vastly up over the course of the year, as people used their connections to work, study and live much of their lives from their home. Individual days also saw vastly increased internet usage, while the record for daily broadband use was broken 15 times through the year.

January and February 2020 saw data consumption at around 2,700PB per month - before the pandemic brought about a big increase, with most months at more than 4,000PB, for the rest of 2020. Overall Openreach's broadband network saw an increase to 50,000 petabytes over 2020, compared with 22,000 petabytes in 2019.

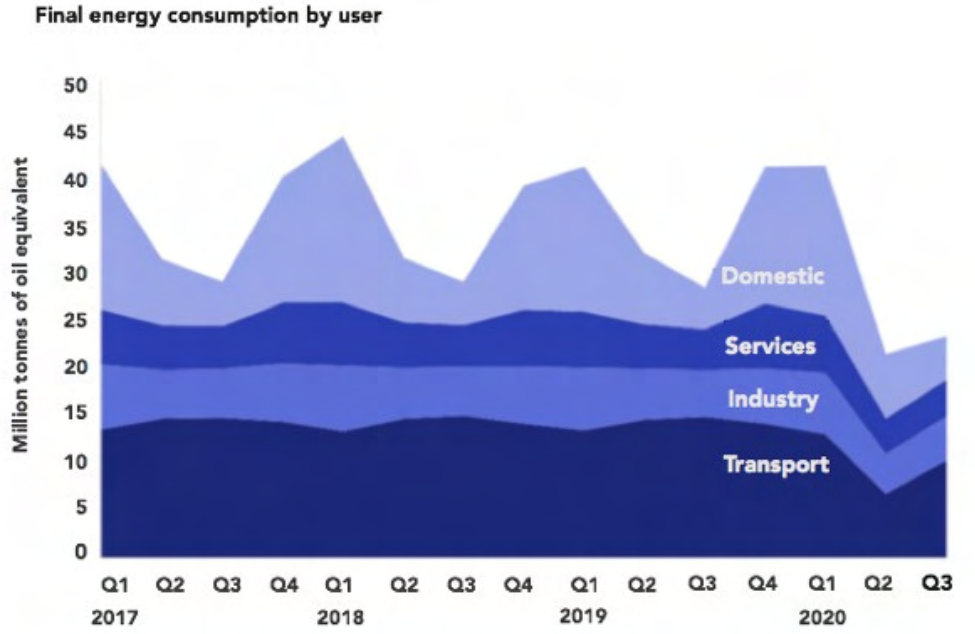
Meanwhile energy consumption between July and September 2020 fell as the effects of the pandemic led to a total fall in energy demand of 13%, led, in particular, by reduced manufacturing output and business use (14).

UK, July to September 2020

ktoe	Production	Imports	Exports	Demand
Total Energy	-9%	-19%	-9%	-13%
Coal	-39%	-1%	+108%	-10%
Primary Oil	-12%	-21%	-11%	-20%
Oil Products	-21%	-38%	-18%	-25%
Gas	-4%	+10%	+18%	+3%
Electricity	-13%	-27%	+54%	-13%

Source: BEIS, Energy Trends, September 2020

All users of energy displayed significantly reduced demand between the first and second quarters of 2020 with a very modest upturn in the third quarter.



Source:: BEIS, Energy Trends, September 2020

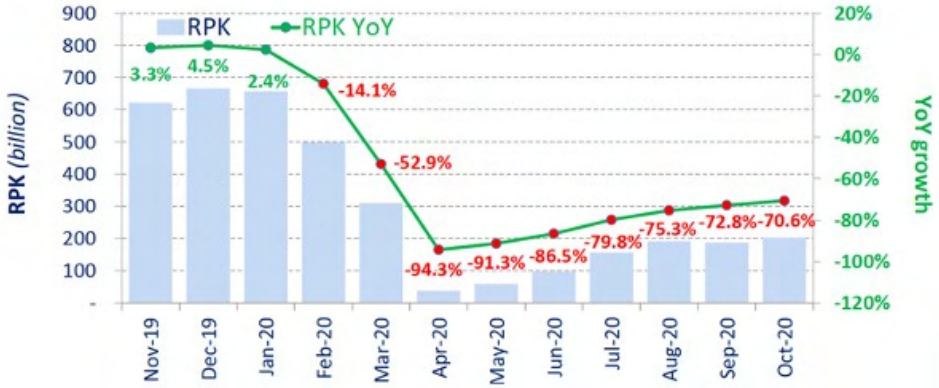
In **aviation**, internationally, passenger air traffic slumped, with more modest declines in freight volumes.

These tables show the year to October 2020 (15).

PASSENGER TRAFFIC

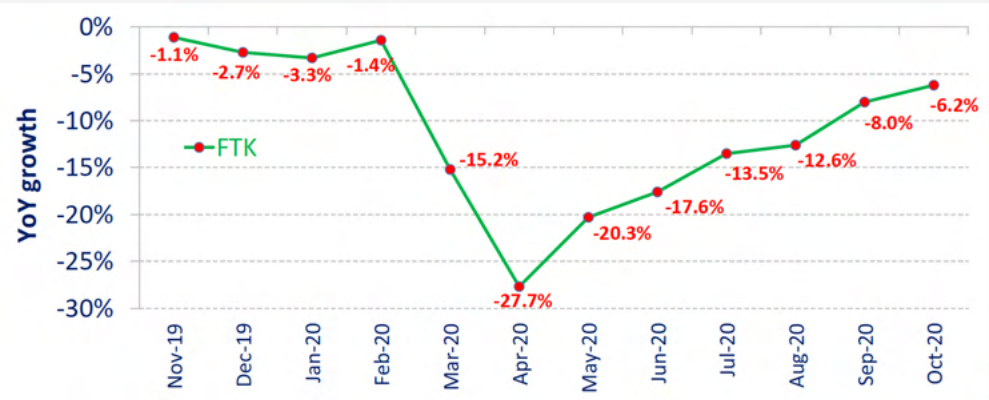
Revenue Passenger-Kilometres - RPK

World passenger traffic fell by -70.6% YoY in October 2020, +2.2 percentage points up from the decline in the previous month. The pace of recovery moderated further amid the resurgent epidemics and stricter containment measures. Europe was the main contributor to the moderation, being the only region with deteriorated traffic decline. On the contrary, Africa and Latin America/Caribbean have shown more resilience. Domestic travel in China demonstrated the best performance with traffic recovering to nearly pre-pandemic levels.



ICAO, Dec 2020: Air Transport Monthly Monitor, December 2020

In terms of world freight carried by aircraft, the fall was almost insignificant by comparison, showing a decline of only 6.2% by October 2020.



Source: ICAO, Dec 2020: Air Transport Monthly Monitor, December 2020

However, IATA predicts that there will be a recovery of passenger journeys in 2021 and 2022.

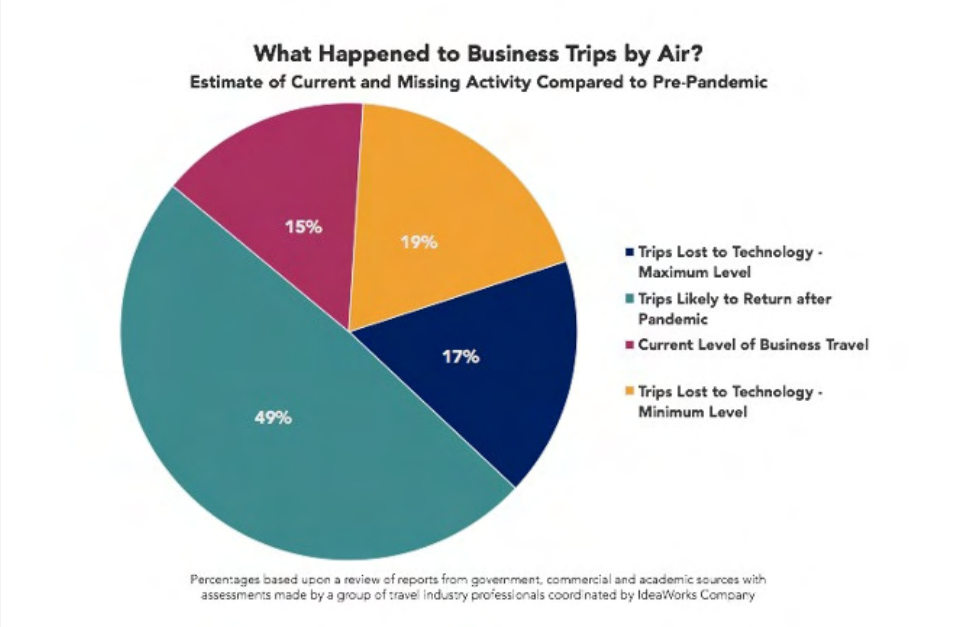
Industry experts expect pent-up demand to visit friends and relatives and leisure travel to bounce back quickly as soon as health conditions allow.

There is a consensus in the industry that overall demand will return to pre-pandemic levels by 2024, at which point the need for greater capacity in infrastructure investment in airports would once again show itself.

Business travel, however, especially long haul, will see a decline, with an expected move to new forms of digital connectivity.

Almost all commentators agree that there is likely to be a significant shift away from long haul business travel.

Research by IdeaWorks expects that up to 36% of business air travel could be "lost to technology" when a post pandemic normality resumes.



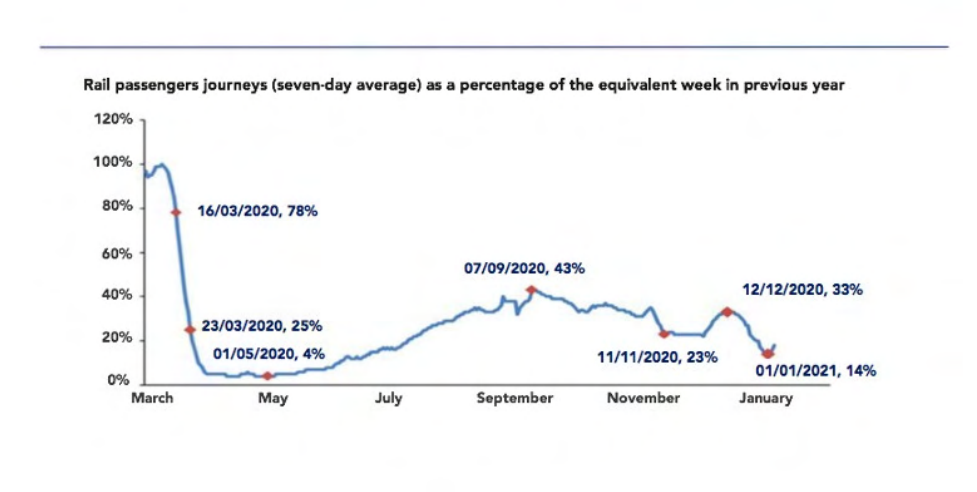
Source: Business Air Travel assessment from IdeaWorks, December 2020

Air freight is much more significant than many appreciate with Heathrow, Britain's largest "port" and many consumer goods arriving in the cargo holds of passenger airliners.

Domestic flights as a share of total domestic travel have declined and airport operators tend to favour international rather than domestic flights because of pricing advantages.

In the second quarter of 2020 passenger rail journeys equated to just under 30% of those recorded in the same quarter in 2019.

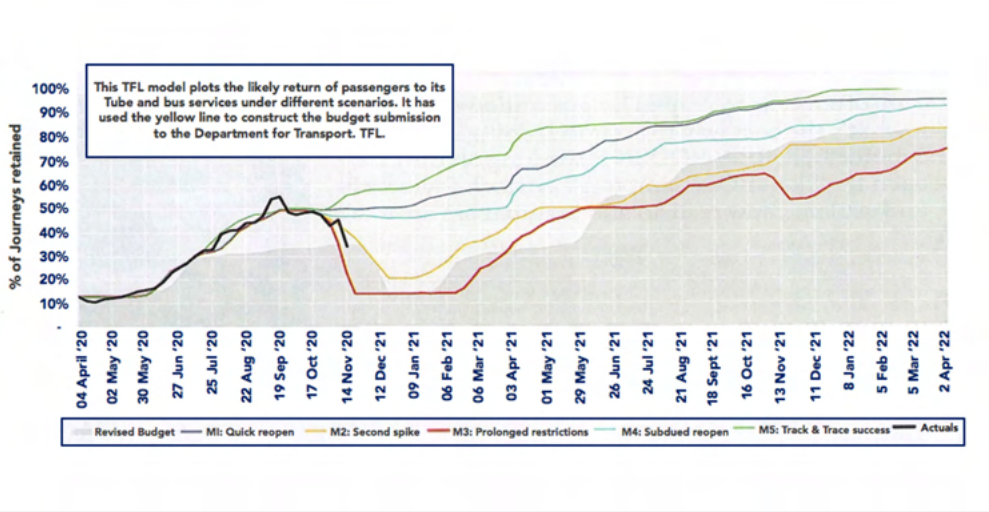
Passenger rail use has fluctuated dramatically, depending on government regulations and guidance on travelling to work and using public transport.



Source: ORR

Industry experts believe that there will be a permanent and significant reduction in commuter rail traffic beyond the pandemic, even if holiday and leisure travel recovers and if there is some net-Zero related shift from domestic air travel to rail; analysts note, however, that as well as being faster, domestic air travel is frequently cheaper than its rail equivalent.

An authoritative organisation like Transport for London expects a significant bounce back in the use of its networks. These scenarios are from its budget submission to the government.

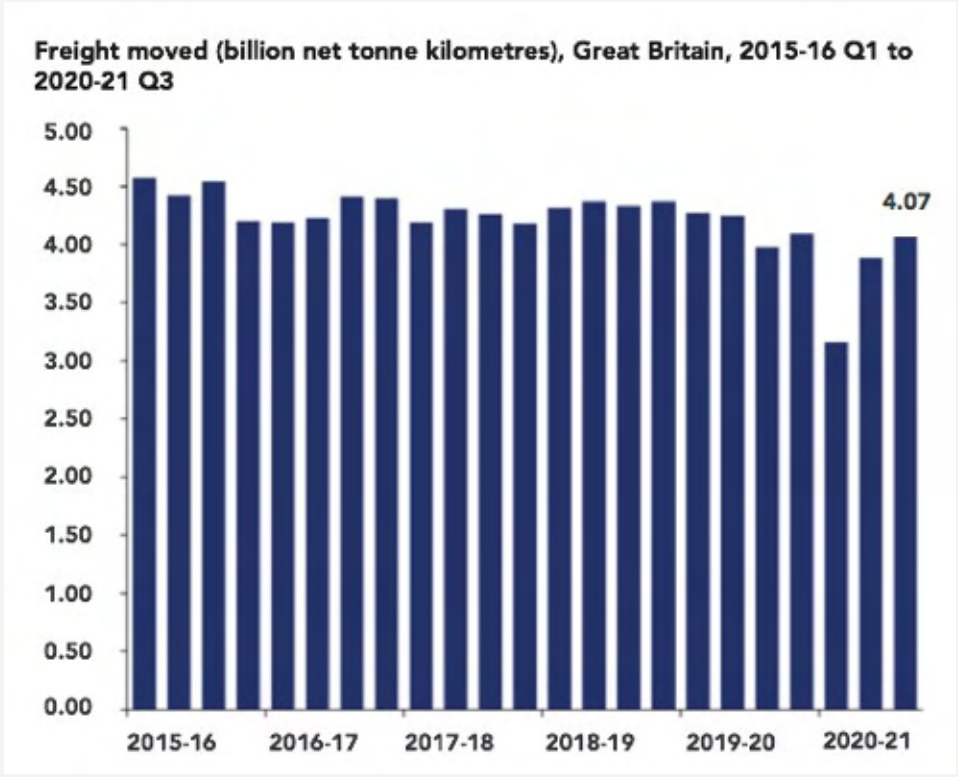


Source: RAIL, 27 January 2021

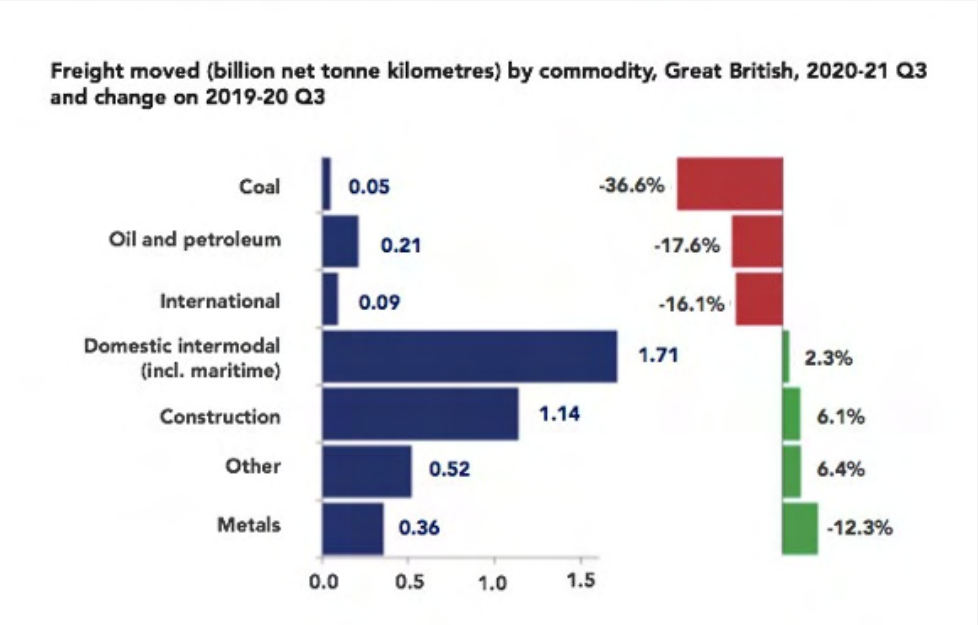
The volume of freight moved by rail was 4.07 billion net tonne kilometres in 2020-21 Q3. This was a 2.1% increase on the same quarter in the previous year. It indicates that freight volumes have recovered following the impact of Covid-19 on 2020-21 Q1 and Q2 (16).

Changes in rail freight volumes seem to match the trends identified in this report. Coal has seen the biggest percentage reduction in freight moved (down 36.6%) compared with the same quarter last year. This fall is consistent with the longer-term trend for coal volumes. Oil and petroleum saw the biggest decrease in market share compared with the same quarter last year, falling by 1.2 percentage points to 5%.

The construction sector, on the other hand, saw the largest increase, rising by 0.07 billion net tonne kilometres compared with the same quarter last year.



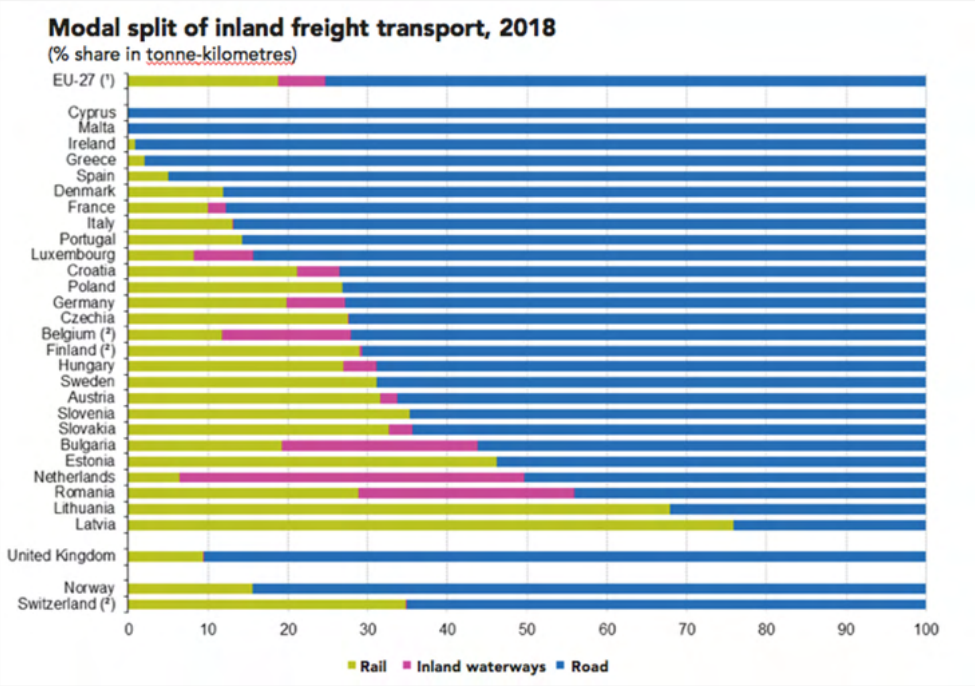
Source: ORR, Freight Rail Usage & Performance, March 2021



Source: ORR, Freight Rail Usage & Performance, March 2021

All the indications are that there is high potential for greater use of railfreight in the UK with potentially significant environmental and other benefits.

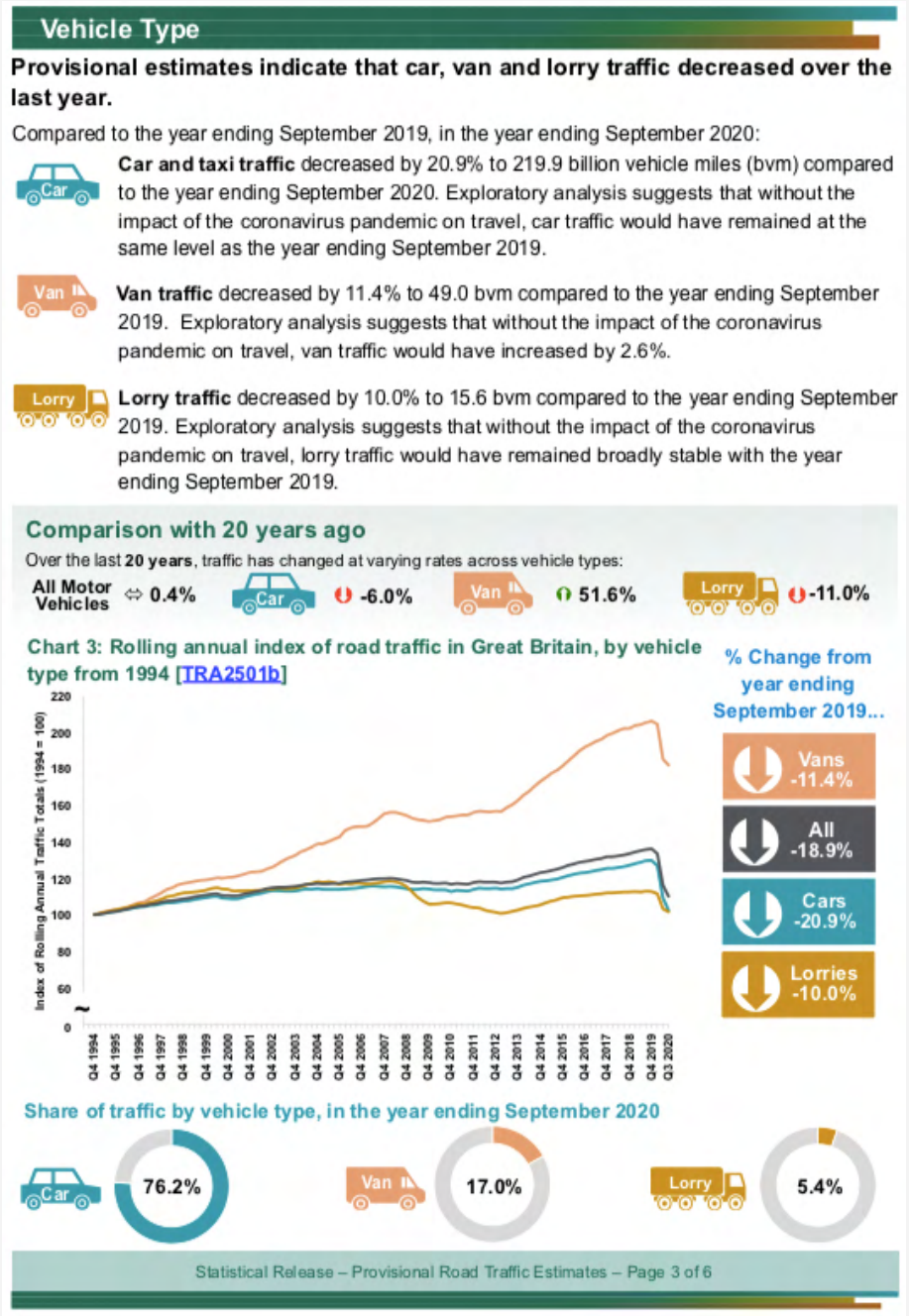
In recent years the percentage of freight shipped by rail in the UK has been significantly less than in other European economies (17). This chart shows the position in 2018 and the potential.



Source: Eurostat, Freight Transport Statistics, September 2020

Although Department for Transport statisticians consider that in ordinary circumstances road traffic volumes for the year ending 2020 would have remained broadly stable with the previous year at some 3.75 billion vehicle miles, their provisional estimates are that the pandemic in fact reduced road traffic for the year ending September 2020 by 19.2% or 68.2 billion vehicle miles.

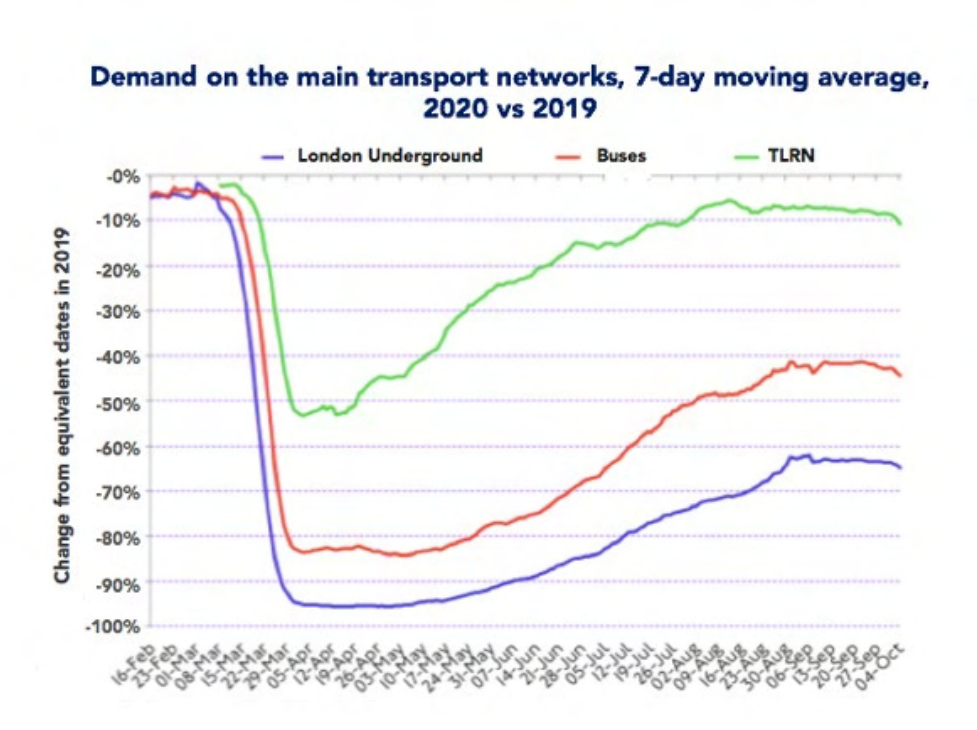
Car traffic was more affected than van and lorry levels and slightly larger falls occurred on motorways compared with other road types.



Source: Department for Transport, December 2020

In the week when England's stay at home rule was lifted on 29 March 2021, car use reached 78% of normal levels – its highest of the year so far.

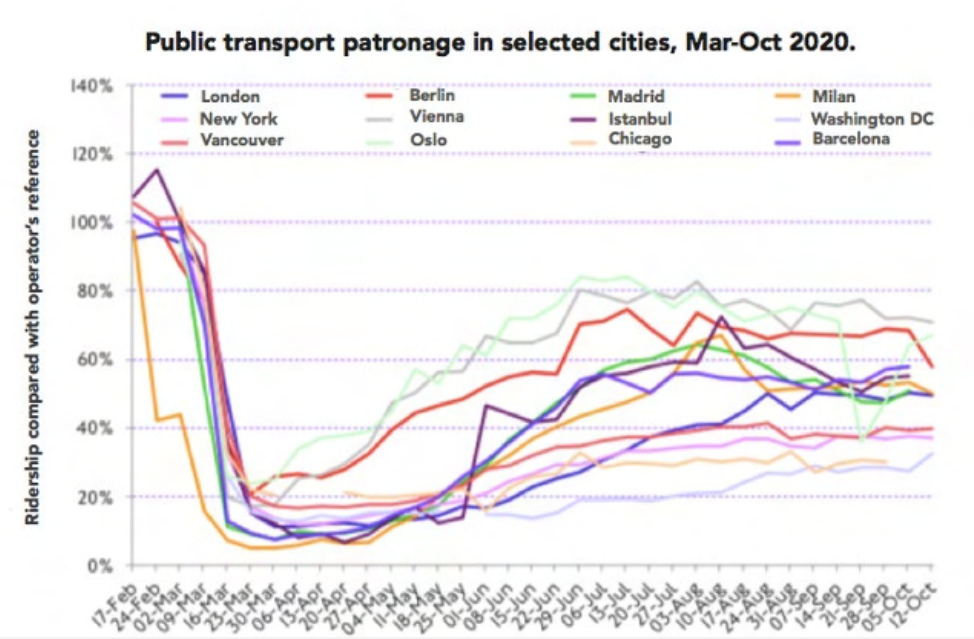
Finally, looking at **transport networks in London** (18):



Source: Transport for London, September 2020

The impact of the pandemic on roads and public transport has been different and so has the recovery trajectory after the initial shock.

- London Underground saw the biggest drop in demand, which at the lowest point in the following days reached 97% (ie only 3 per cent of normal patronage remained).
- Bus demand also fell significantly, reaching up to an 86% drop at the lowest point.
- The fall was smallest for motorised road traffic on the TLRN strategic road network, which at the lowest point only saw a maximum 65% reduction with respect to 2019 at the London-wide level.



Source: Transport for London, September 2020

The trend for overall mobility in London during 2020 was comparable to that seen in many other European and North American cities, although perhaps reduced to a greater extent and for longer than some. Modally, however, London saw a greater proportionate initial fall in public transport demand than was typical. In turn, although patronage recovery in London over the summer was steady and at a rate comparable to other cities, London's public transport return remained at a lower level (October 2020) than for many comparable cities.

SMARTENING THE BOUNCE BACK

The COVID-19 pandemic has highlighted to millions of people in the UK the importance of digital connectivity, with home school and working from home becoming ubiquitous as identified by the OECD "from education to health… teleworking, distance learning and e-commerce, have surged, as has uptake of digital tools for business." This means there is a need for high-quality connectivity to meet the demands of bandwidth-intensive activities. The UK needs to plan and invest.
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- Because fibre underpins other networks, investment in the deployment of fibre into fixed networks will also drive a substantial increase in speeds and capacity across all next-generation technologies, including 5G.
- Gigabit networks and 5G in turn will enable the Internet of Things (IoT) and Artificial Intelligence.

As the OECD notes, resilience and reliability will be ever-more important as core activities go digital: "The use of connected devices in critical contexts including in health, energy or in transport sectors, may require time-sensitive upload or download of data. This underscores the need for ultra-reliable, low latency networks." (19)

The story is reinforced by MPs in the House of Commons Digital, Media and Sport Committee, report of December 2020 (20):

- The pandemic and national lockdown makes "access to quick, reliable and affordable internet connections more important than ever, highlighting the gulf between those with good digital connectivity and those without".
- ·"The potential economic dividend from 5G in terms of jobs, productivity and capital is considerable, particularly in the light of new work patterns and behaviours adopted as a result of the pandemic."
- "Fibre will be a significant component of other gigabit-capable technologies such as 5G".

Rollout of fibre is progressing well, with currently 18% of premises in the UK now able to access a full fibre connection (21). This is in direct contrast with the UK market back in 2016, which was languishing bottom amongst OECD nations (22). The main reasons for this change are new entrants into the market, with network competition reinforced with pro-competition regulation. Over £7.6 billion of investment has been committed by the independent sector, driving rapid rollout. According to the Independent Networks Association INCA: 'This level of investment is really healthy for the industry and reflects how important the challenger networks are in keeping Britain connected.' (23)

GREG MESCH, FOUNDER AND CEO, CITYFIBRE

Digital connectivity is the foundation of a modern global economy, especially for a service-based economy like the UK. But a step change in our underlying digital infrastructure is required to ensure we maximise the benefits of the technological revolution that is now taking place.

This is why CityFibre is proud to be building world-class digital infrastructure for the UK. Our £4 billion Full Fibre investment programme is bringing future-proof digital connectivity to a third of the UK by 2025. This will connect 8 million homes, as well as underpin the needs of the public and private sectors in nearly 300 cities, towns, and villages across the country.

Full Fibre connectivity is a generational shift which not only delivers better home and business broadband, but enables new and emerging technologies, such as 5G, autonomous vehicles, and the smart energy grid to become a reality. As other networks harness technology to become smarter and greener, the interactions between the digital, transport, and energy sectors are more important than ever.

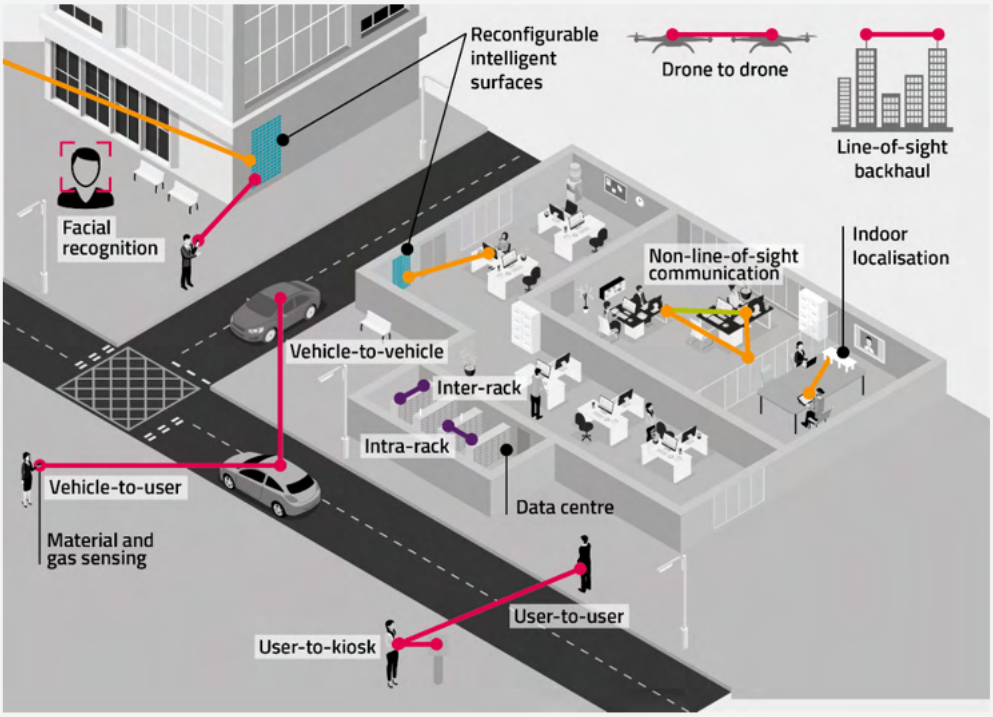
The promise is of a future with a net zero economy, with near instantaneous digital connectivity a ubiquitous reality, powering economic development and future success.

Work at Ofcom shows how digital communications technologies are not only interconnected among themselves, but are essential to facilitating the other smart networks which will power recovery from the pandemic, often in new and better forms.

Ofcom says that instead of mainly providing phone calls and internet access, new use cases have emerged including the trend to connect things (such as sensors and actuators) and to use wireless networks for control rather than communication.

This means that technologies like 5G have started to be used to provide connectivity solutions for vertical sectors including logistics, manufacturing, transportation, automotive and utilities.

Examples of applications for THZ communications and sensing



Source: Ofcom, Technology Futures, 2021

"Constellations of telecommunications satellites deployed in Medium Earth Orbit and Low Earth Orbit have the potential to increase overall satellite broadband capacity and offer reduced latency services – meaning a more reliable, instant connection," says Ofcom (33).

The regulator says that the interaction of these technologies and networks will create opportunities for new hybrid architectures to support connectivity especially helpful for consumers in remote locations.

Critical underpinning for many of these technologies comes from the "backhaul" provided by fibre networks.

ASSAD EBRAHIM, SENIOR MANAGER, UK & EU TRANSPORTATION OPERATIONS, AMAZON

When a customer buys a product from Amazon.co.uk and is notified of the speed at which they will receive their order, we always treat this as an ironclad promise.

To help us meet this promise, our transportation infrastructure relies on algorithms which optimise our deliveries. We look at where the product can be sourced, which source has the shortest transit time, and the possibility for consolidation with other deliveries. Our aim is to deliver the best possible customer experience, reducing friction in the system. The smarter the UK's communications and transport networks the better we can achieve these results.

We've invested a total of £23bn in our operations in the UK since 2010. We are very focused on ensuring our transport operations are sustainable as a key part of our plan to meet net zero carbon by 2040. We are working to maximise the efficiency of our current vehicles and electrify our fleet, as well as looking at alternative delivery methods such as e-cargo bikes and forms of micro-mobility. We don't see limits, only opportunities and are excited about what the future holds.

As Ofcom has reported,

"Fibre-Optic technology is the mainstay wired backhaul in Mobile Network Operators' networks and second overall although microwave backhaul is the most used technology due to a combination of its capability and relative ease of
.

deployment (i.e. no need for trenches/ducting) making it a low-cost option that can be deployed in a matter of days.) The demand for Fibre to the Tower (FTTT) has required Mobile Network Operators (MNOs) to upgrade many aspects of their backhaul networks to fibre-based Carrier Ethernet.

An example of this can be seen in the partnership between CityFibre and Three, with CityFibre full fibre being used to provide backhaul to Three's mobile masts. This is particularly critical for 5G, which relies on full fibre connections to small cell access points.

Dynamic businesses like Amazon are building their own fibre networks and new private capital investment means that a range of recent market entrants are rapidly growing the UK's fibre connectivity.

NICK SMALLWOOD, CHIEF EXECUTIVE, INFRASTRUCTURE AND PROJECTS AUTHORITY

Too many people still think of 5G as faster phones, when really, it is a completely game changing capability that is going to supersede Wi-Fi. 5G will allow massive data and energy transfer, allowing more remote activities and facilitating more use of robotics in industry as well as the use of drone technology.

We need to focus on networks and their resilience, on data security, a new normal in working practices and on the opportunities to lead in areas like hydrogen power and sustainable aviation fuels.

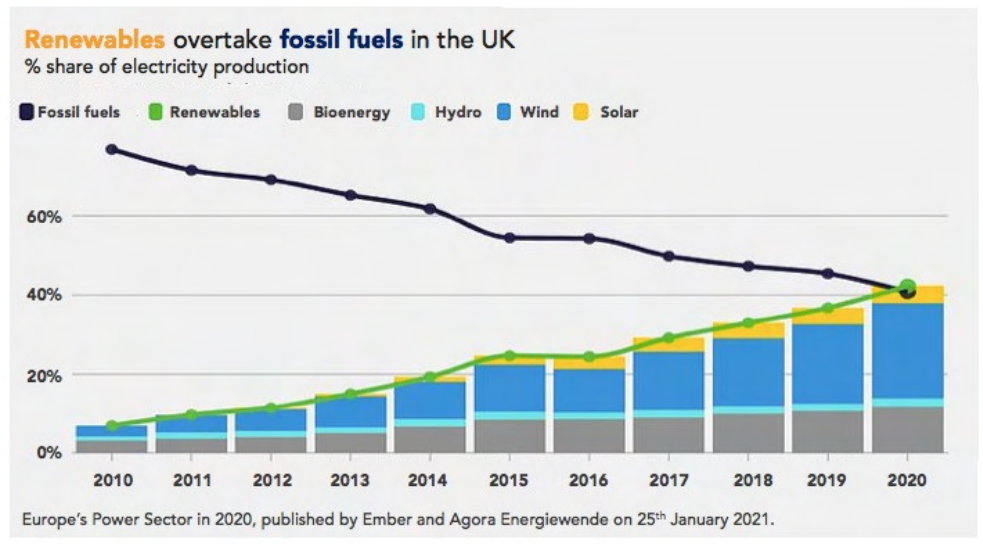
In planning ahead, we need to understand that rapid transport systems must be built into the development of new communities. Linking road, rail and airport nodes in these communities is essential.

ENERGY NETWORKS POWERING CONNECTIVITY

NET ZERO IMPACTS ON CONNECTIVITY

One of the very few positive spin-offs from the devastating Covid-19 pandemic was that in the UK and elsewhere, it provided a glimpse of a "greener" future, which will have profound implications for our energy networks over the next 20 years.

According to a study by the think tank Ember, for the first time in 2020, renewable generation outpaced fossil fuel generation and could remain the largest source of electricity going forward. (24)



Source: EMBER, January 2021

In its 10-point plan of 17th November, 2020, the government committed to accelerate the transition to electric vehicles, including ending sales of new petrol and diesel cars and vans by 2030, and transforming the national infrastructure to better support electric vehicles.

It also committed to pioneering hydrogen heating trials, starting with Hydrogen Neighbourhood and scaling up to a potential Hydrogen Town before the end of this decade.

To achieve the net-zero target, more than 28 million households will need rapidly to adopt new low-carbon heat solutions. According to the Energy Technologies Institute, this could mean that between 2025 and 2050, around 20,000 households would have to be transitioned to low-carbon solutions every week.

The question of whether or not the gas grid can be successfully converted to hydrogen, will therefore impact hugely on the amount of renewable electricity grid capacity which will be required for space heating and heat pumps.

This 'electrification pathway' is also a potential route to decarbonise heat for the achievement of net zero, by widespread deployment of heat pumps across the UK, which, when combined with the roll-out of electric vehicles, could lead to more than a doubling of total UK electricity demand by 2050.

If the government is to pursue the electrification pathway it will need to do more to ensure there is enough new low-carbon electricity generation capacity that is flexible enough to deal with potentially higher and more variable demand and supply. These changes will facilitate decarbonisation and a shift to cleaner electric power in households, businesses and transport and will also require demand management in the form of large-scale investment in energy efficiency and smart electricity grids.

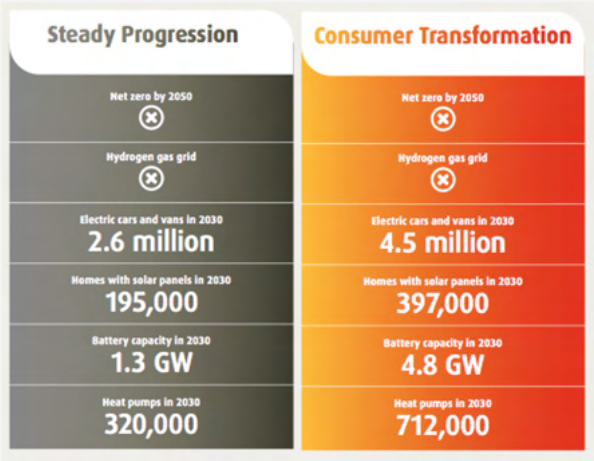
How quickly can the UK's networks be developed to meet these new demands and provide secure always-on power for electric vehicles and rail networks, power-hungry data centres underpinning the digital world of business, entertainment and consumption? One key variable will be the speed and nature of the recovery from the Covid-19 pandemic, which provided a glimpse of what the energy industry might look like in the future.

FOUR NETWORK SCENARIOS

UK Power Networks, which serves 19 million customers in Eastern England, London and the South East, has been leading the way in decarbonisation by playing a dual role - by connecting significant volumes of low-carbon generation at unprecedented pace, while other sectors such as transport and heating are decarbonising through electrification.

The company has pointed out that speed of decarbonisation varies on a regional basis due to different local policies and approaches. It recognises that regional planning authorities have a key role in delivering net zero for their area, a point also recognised by the Climate Change Committee. To capture these views it has engaged extensively with these stakeholders to get their feedback on its Distribution Future Energy Scenarios.

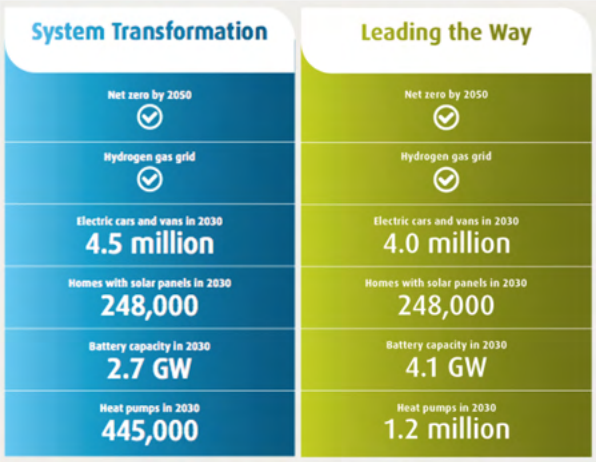
These feature four different models of recovery from the pandemic, ranging from a cautious steady progression regime through developing more imaginative ways of engaging consumers through to System Transformation and a more radical Leading the Way plan initiative.



Under Steady Progression, recovery from the pandemic is slow, with less investment in green recovery, so that the 2050 carbon target is not reached.

Consumer Transformation sees the economy recover fully from Covid-19 in the long-term, with consumers willing to change their behaviour and engage with new technologies such as EVs.

Electricity is the fuel of choice for heating, supported by a nationwide programme for energy efficiency of buildings. As the amount of grid-scale generation grows, so does the amount of both grid-scale and domestic storage, providing high levels of grid flexibility. These efforts still fall short of the Net Zero by 2050 target, however.



With System Transformation, heat and heavy transport are converted to hydrogen. Despite a heavy hit from Covid-19, the UK meets its net-zero target.

Under the Leading the Way scenario, the net zero target is met before 2050, This is as a result of a post-pandemic green recovery, with a fast roll-out of decarbonisation methods including hydrogen, electrification, and energy efficiency improvements.

BASIL SCARSELLA, CEO, UK POWER NETWORKS

Our business, together with the wider energy system and society at large will be undergoing significant changes over this decade if we are to decarbonise the economy and achieve Net Zero carbon emissions by 2050 as a country.

Through 2020, energy demand was dramatically affected by the COVID-19 pandemic, creating much uncertainty. As the economy recovers, one thing is clear. In the future, the decarbonisation challenge will create many opportunities and increased demand for clean electricity, on which other networks, including those for communications and transport, will depend.

UKPN has been leading the way by playing a dual role – by connecting significant volumes of low-carbon generation at unprecedented pace and facilitating other sectors such as transport and heating to decarbonise through electrification. A smart electricity grid is key to facilitating Net Zero at lowest cost. We have invested heavily in digital capabilities to make our networks smarter; in December 2020 UKPN was ranked number one in the world in the annual Smart Grid Index, based on a study of 85 utilities across 37 countries."

This next decade of decarbonisation will be local and much more impactful on our day-to-day lives. That's why we are working closely with our regional stakeholders, such as local authorities, to develop distribution energy scenarios which will reflect the many local factors that may influence the take-up of key low-carbon technologies.

THE WORLD'S FIRST PILOT OF 5G CONNECTED SMART SUBSTATION OPERATION

This UKPN project (26) will see computers installed in a series of substations, optimising utilisation of the substations to free up capacity and help facilitate the rise in renewable energy generation. The volume of distributed generation - energy which is no longer connected to the national transmission system but to regional distribution networks - is forecast to grow from 26GW today to 65GW in 2050.

The project will allow UKPN to safely release more capacity and enable more renewable energy to connect at lower cost, saving customers money and helping the environment at the same time. It marks a transformation in the way electricity networks operate. It will enable local substations to analyse millions of data points on how the network is running, meaning the network can reconfigure itself to safely enable higher volumes of electricity to flow. It will also provide a foundation for many other smart solutions.

The solution pioneered by UK Power Networks hopes to release 1.4GW of capacity (enough to power more than 700,000 homes) and save consumers more than £750 million by 2050 if the project proves a success and is rolled out nationwide. It is also forecast to save more than 19 tonnes of harmful CO2 emissions by 2050.

NETWORK INTERCONNECTORS ARE CRITICAL TO ENERGY RESILIENCE

The UK is a net importer of energy. The EU currently provides some 5-10% of the UK's electricity supply, and 12 % of its gas needs.

Electricity critical to the UK's security of supply and resilience comes from it and from Norway, as shown below.
There will be an increase in interconnector capacity by 2030, and this increased interconnection capacity can help reduce curtailment of renewable electricity, by facilitating the spread of excess renewable generation across interconnected countries.

Under the EU-UK Trade and Co-operation Agreement, the UK will no longer participate in the internal energy market of the EU. However, the possibility of developing separate arrangements for trade over interconnectors, similar to those existing at present, is foreseen.

Name	Countries	Capacity (MW)	Cap & Floor	Exemption	Date
IFA	France-GB	2,000	No	No	1986
Moyle	Ireland-GB	500	No	No	2002
BritNed	Netherlands-GB	1,000	No	Yes (Second Package	2011
EWIC	Ireland-GB	500	No	No	2012
NEMO	Belgium-GB	1,000	Yes	No	2019
IFA2	France-GB	1,000	Yes	No	2020
North Sea Link	Norway-GB	1,400	Yes	No	2021
FAB Link	France-GB	1,400	Yes	No	2022
ElecLink	France-GB	1,000	No	Yes (Third Package)	2022
Greenlink	Ireland-GB	500	Yes	No	2023
Viking	Denmark-GB	1,400	Yes	No	2023
Celtic Interconnector	Ireland-France	700	No	No	2025

Source: Cornwall Insight, September 2020

SMARTER TRANSPORT NETWORKS

DIPESH SHAH OBE, CHAIRMAN, HIGHWAYS ENGLAND

At Highways England, we are making giant strides in future-proofing the strategic road network for our customers and for the nation. The nature and advent of technologies are crucial to how we think of the arterial road network developing into the future.

Our vision for digital roads can be broken down into three subsections. Digital design & construction, digital operations, and digital for customers.

To improve our design processes, we are working on automation platforms and digital twins, which will help us to design in an accelerated time frame.

In construction, we are exploring the use of modern construction methods including modular and standardised, meaning much of our construction will be done offsite.

Advancements to our daily operations will be facilitated by a data-rich automated traffic-management system, one of which has just been set up in the North East. We will soon roll these out across the seven regions of the country.

In addition, many of our maintenance needs will be identified by drones, and we will use sensors to ensure that we are proactive, rather than reactive, in our approach.

This will greatly benefit our customers and help limit delays to their journeys. To further benefit our customers, we want to create a road network that is more interactive, where roads and vehicles are in direct communication with each other. Our roads are already amongst the safest in the world, but this will further enhance safety, as well as improve traffic management, and reduce journey times. Not only do we want to improve the in-journey experience, we are also working hard to improve pre-journey information, mapping out to customers exactly how things are on the roads. We at Highways England hope to make progress across all of these areas over the current 5-year period and beyond. However, a strong backbone of fibre and 5G will be critical if we are to succeed fully.'

ROADS

SMART ROADS AND CONNECTED VEHICLES

The UK needs to move from digital signalling and traffic monitoring to complete intercommunication for road vehicles including the autonomous vehicles of the future.

On a 2.5-mile road in the city of Wuxi in China, a self-driving bus travels back and forth, making stops, based on information it constantly receives from its surroundings. Embedded in the road, traffic lights, street signs and other infrastructure are sensors, cameras and radars that talk with the vehicle. The site, used by Huawei, was part of China's first national project for intelligent and connected vehicles.

The bus is linked to a transportation-control network that sees and decides everything that happens on the test road. The communication is two-way: the bus constantly sends information to the network and can make requests such as favourable traffic lights to help it stay on schedule.

In Finland, 15 futuristic poles – doubling as street lights - line a 1km route from Nokia's head office to the train station at Kera, each fitted with an array of sensors and antenna, which together create a 5G network that allow the bus to drive autonomously. In addition to the smart poles, the pilot network also has two smart and safe bus stops and a separate city information display, showcasing how different sensors can be integrated into the elements found in the urban infrastructure.

A wider use for the poles, in more isolated rural areas, will utilise their in-built cameras to survey the environment and give a heads-up warning to cars of possible collisions with animals.

Finland already has an operating smart road - the Aurora public tests ecosystem - which was established in 2017 when a 10km stretch of road in the north of the country was equipped with sensors. The smart road has helped drivers to tackle issues including freezing fog and extreme temperatures.

In the future smart roads across the world could allow transport bodies to manage road networks in real time, controlling traffic lights, traffic flow and congestion through automated machine-learning and artificial intelligence programmes.

There could be significant improvements in transit-route planning and road safety, through the increased capture and transmission of real-time information. Alongside weather warnings and traffic updates, 5G also means receiving alerts from other smart road users. With 5G, the data will be reliable enough for vehicles to receive details of upcoming speed restrictions and actually adapt their speed accordingly. Smart connectivity will eventually mean better use of road space, reductions in congestion and improvements in vehicle energy consumption. Network connectivity in the future will depend on reliable coverage that won't drop out, a crucial factor when it comes to the future development of autonomous vehicles.

ELECTRIC VEHICLE CHARGING

The Committee on Climate Change's "Reducing UK emissions – Progress Report to Parliament"(27) recommended in June 2020 that EV users would welcome government collaboration with regulators, local authorities and industries to ensure a "universal service expectation" from charging infrastructure.

Charge points should be harmonised so that drivers are able to use any charge point conveniently. This is not currently the case, for example, drivers have to register separately with each charging service provider.

Vehicles will also need to travel across borders, so drivers require international coordination to ensure journeys abroad in EVs are not stalled by incompatible charging infrastructure

At present targets for rolling out EV charging do not seem to reflect the accelerated time-scale of the government's 10-point Plan for switching to EVs. As responsibility for EV charging roll-out is currently split between DTp and BEIS, with a jointly staffed Office for Zero Emission Vehicles, it would seem timely to spearhead a new initiative to take this forward.

The smart electricity grid infrastructure which EVs and the electrification of other sectors will require, will be very significant. For multiple mega-hubs it would have to be bigger than anything currently existing in the UK and will require improved management of data, including from other sectors such as transport, heat and buildings, to optimise use of physical networks and energy storage. Whether control and management is based locally or in the Cloud, this will require cyber-secure and resilient digital communications infrastructure to be integrated into the energy system.

PROFESSOR STEPHEN GLAISTER CBE, FORMER CHAIRMAN, OFFICE OF RAIL & ROAD

We must do our best to understand passenger demand and factor this carefully into future plans for rail. We need to improve the ticketing system to make it fit for the future. There is a clear area of good practice in London, and there is scope for a similar electronic pay-as-you-go style ticketing system to be used across the UK. Rail connectivity to ports needs a careful new look especially for Felixstowe and Harwich. Our roads can also use new technologies and it is time that we begin to make full use of real time information systems to manage our roads more intelligently. We could use the change in fiscal revenue which will be the inevitable consequence of the arrival of electric vehicles to devolve more transport policy decisions and boost local investment.

NEW MULTIMODAL NETWORKS

Before Brexit the UK was part of the EU Trans European Transport Network, TEN-T. These projects had a very low profile by comparison with the prominence given to the networks in Continental Europe, where they were seen as a part of modernising connectivity, facilitating the Single Market and removing borders.

Brexit means that the UK will no longer form part of these networks but there is an opportunity to create a successor UK integrated transport network, and Sir Peter Hendy's Union Connectivity Review has suggested that this would be worthwhile.

Establishing a National Strategic Transport Network would have a number of potential benefits for the UK:

- The promotion of efficient and safe infrastructure
- A stronger focus on multimodal transport
- A strategic approach to transport decarbonisation and digitalisation.

The UK has suffered from policies developed in isolation failing to take advantage of opportunities to promote multimodal approaches. This has included short-term decision taking with start-stop consequences for infrastructure, in particular delaying the opportunities for shifts to optimal rail electrification; inadequate attention to the opportunities to move freight from road to rail; and inadequate focus on multimodal approaches, especially in terms of road and rail connectivity to ports, not excluding slow progress in improving surface access to London Heathrow Airport.

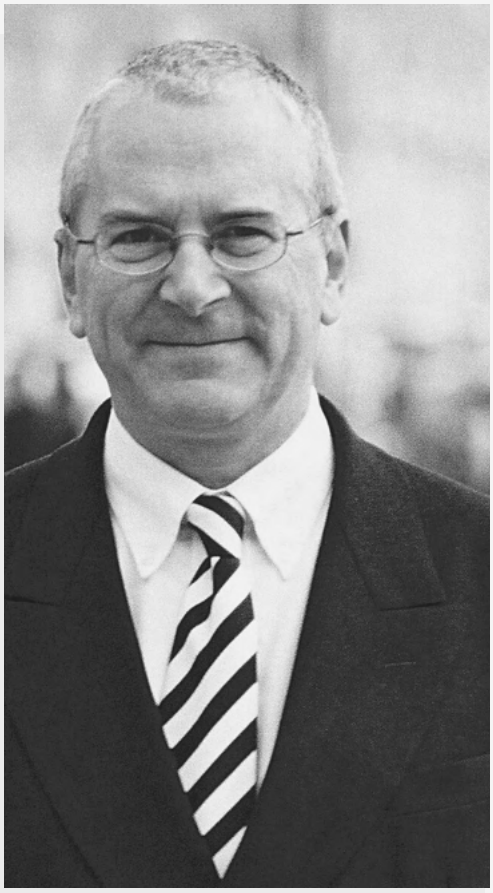
The TEN-T network shows that a strategic approach can promote the construction of fast roads bringing more motorway mileage and shorter travel times. The TEN-T network has also shown the importance of a streamlined approach, now known as Smart TEN-T, to speed up network completion, reduce delays, facilitate the involvement of private investors and clarify rules for public consultations. All these would be desirable in the UK system.

European Parliament research notes that the measures "target the permitting procedure, deadlines, designation of a single competent authority as a point of contact for investors, a joint authority for cross border projects, as well as EU financial and technical assistance." All these lessons are worth building into the UK National Strategic Transport Network.

It is important that consideration should be given to maintaining effective links with the EU; the UK is defined as a "neighbouring country" under Article 3(b) in the TEN-T Regulations. Close contact should be maintained with the European Commission to mitigate the impact of Brexit on formerly seamless and frictionless transport links and in particular with the Irish Republic. The latest post-Brexit position is shown below:

North Sea travel corridors between Britain and the EU after Brexit

SIR PETER HENDY CBE, CHAIRMAN, NETWORK RAIL & CHAIRMAN, UNION CONNECTIVITY REVIEW



A UK network of routes and nodes could increase connectivity across the union, bringing all four nations closer together, furthering economic growth, creating jobs and increasing social coherence. Although it is difficult to predict post-Covid demand a long-term plan for rail is needed, with an especial focus on the opportunities for freight, logistics and connections to ports. It should feature a careful examination of power sources, including a path to further electrification, and the use of hydrogen, battery and ammonia power sources. Digitalisation is a high priority and Network Rail's Project Reach holds out the prospect of maximising the use of trackside telecoms capacity.

The creation of such a network would need to be multi-modal; to focus on surface access to ports and airports, and adequately financed.

A specific authority should be responsible for the operation of the new National Strategic Transport Network, ideally under the authority of the National Infrastructure Commission and with the emerging National Rail Body, Highways England and the Civil Aviation Authority as important partners and deliverers of the network. Ideally the authority should be UK-wide on terms agreed with the devolved administrations. Local transport authorities should play a significant part in its work with a developed systematic participation in its deliberations.

SMARTER RAIL MEANS MORE ELECTRIFICATION

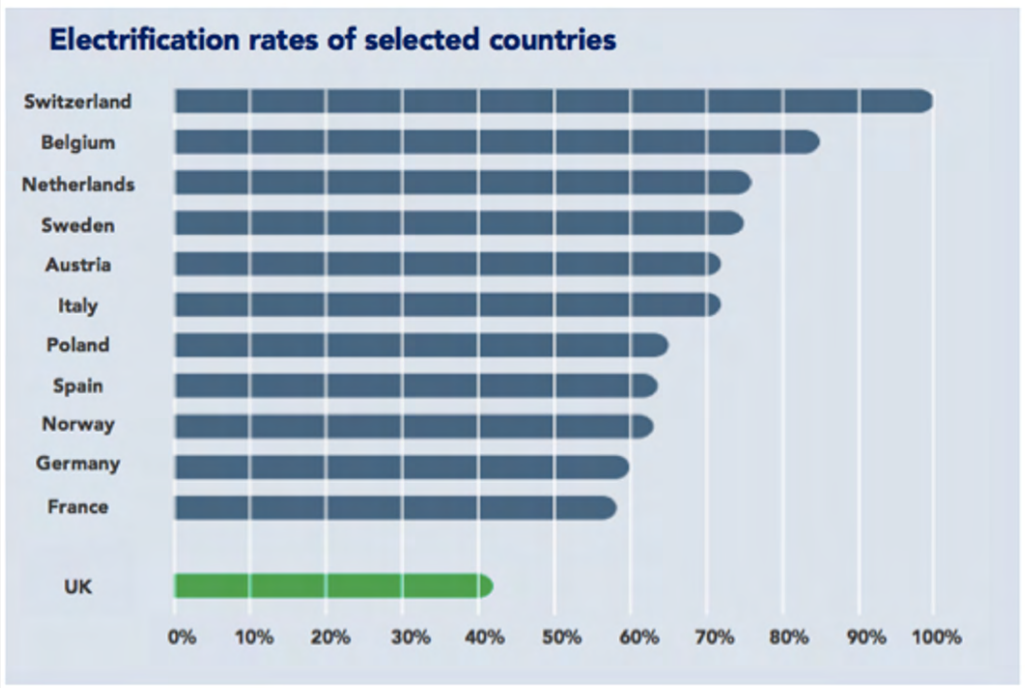
Publication of the Government's White paper following the Keith Williams Rail Review holds out the prospect of a joined-up rail system with a guiding mind, overcoming the fragmentation and complexity of the post-privatisation rail model.

It makes possible a Whole Industry Strategic Plan with a 30 year vision for the UK rail network, a development which is hugely to be welcomed.

What should be the key elements of this Plan? The agenda is huge but many aspects have long been obvious.

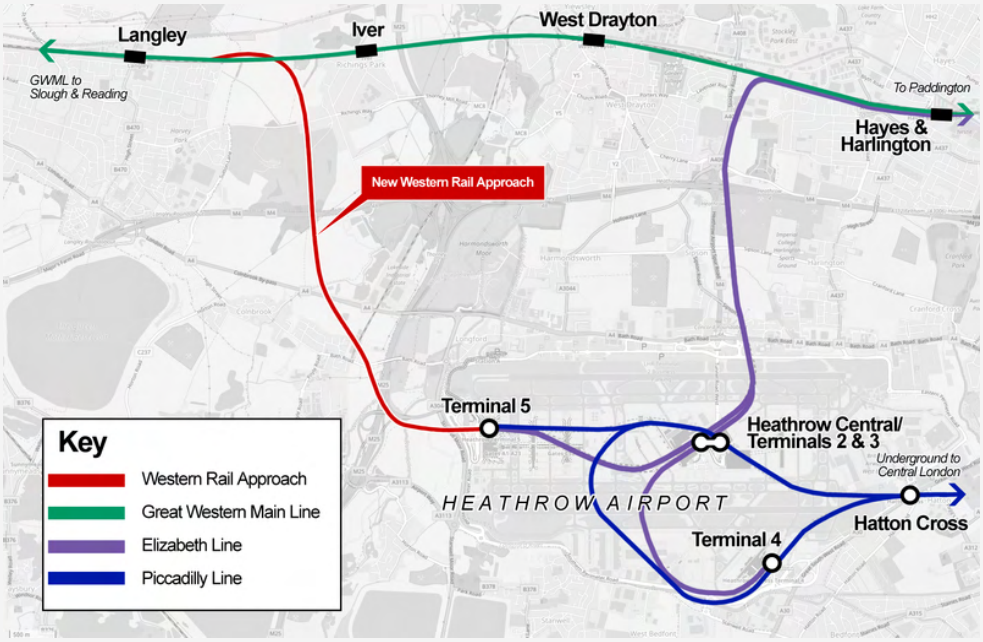
In the context of net zero targets the UK needs to return to the rail electrification agenda which was sabotaged by the poor delivery and cost overruns of the aborted electrification of GWR lines to the West, and the consequential abandonment of other projects.

The various expensive and climate unfriendly interim measures including the use of bi- and tri-mode locomotives are only temporary fixes. A comparison with other countries shows that the UK needs to catch up with rail electrification and prioritise key projects including: the Trans-Pennine: Manchester Piccadilly and Victoria via Stalybridge to Huddersfield, Leeds and York and Midland Main Line, ensuring the Completion of Midland Line electrification as originally authorised.



Source: Alstom, The UK's New Green Age, 2021

Another long-overdue priority is to improve surface access to major UK airports. Heathrow needs its Western Link to the main Western Region line urgently but regulatory interactions over funding have slowed progress once again. These need urgently to be overcome.



Source: Network Rail

NETWORK RAIL HAS GIVEN THIS DECEMBER 2020 UPDATE

The proposals for this scheme are well advanced and reflect the extensive feedback we have received from passengers, communities, businesses and stakeholders. However, the scheme is subject to a satisfactory business case and agreement of acceptable terms with the Heathrow aviation industry, so can only progress to DCO submission when funding has been agreed, including an appropriate financial contribution from Heathrow Airport Limited (HAL); this requires endorsement by the Civil Aviation Authority (CAA) as the relevant regulator.

The government has been working closely with HAL, but the Coronavirus pandemic has had a significant impact on the aviation and rail industries. This in turn has affected Heathrow Airport's ability to commit to a financial contribution to the scheme at this time. The government will continue to work closely with HAL to agree funding arrangements that offer value for money for the taxpayer and for the users of the airport. The DfT has therefore asked Network Rail to change the planned submission of the DCO application from winter 2021 to a potential winter 2022 submission; this remains subject to a satisfactory business case and funding agreement.

Network Rail Board minutes from January 2021 state that the project is now being brought to a controlled pause, to a point where it could be picked up again at some future point. People working on the project were being reallocated to other projects and DfT would periodically update its business case for WRLtH, reflecting any significant changes to both the aviation and rail sectors as a result of the Covid-19 pandemic.

What are the benefits?

The proposed rail link would:

- Reduce rail journey times between Reading and Heathrow by delivering a new, faster, frequent, more reliable direct train service to Heathrow with four trains per hour in each direction. All trains would call at Reading and Slough and alternate trains at Twyford and Maidenhead. Journey times could be as short as 26 minutes from Reading and 6 to 7 minutes from Slough.
- Significantly improve rail connectivity to Heathrow from the Thames Valley, South Coast, South West, South Wales and West Midlands.
- Provide an alternative form of transport for passengers and the large number of people who work at the airport who are currently travelling by road.
- Ease congestion on some of the UK's busiest roads, the M4, M3 and M25 resulting in lower CO2 emissions equivalent to approximately 30 million road miles per year, helping to deliver the UK's climate change and carbon reduction targets.
- Generate economic growth and new jobs across the Thames Valley and surrounding areas.
- Reduce passenger congestion at London Paddington.

There is an even lower cost opportunity to establish a Southern connection to Heathrow:

The proposed HSR will connect Old Oak Common with Woking, Guildford, Basingstoke and other towns via Heathrow, unlocking massive interchange benefits for Surrey and Hampshire with the Midlands and the North. HSR will also provide an alternative route to London from Surrey and Hampshire with trains able to arrive at Paddington, whilst southwest London will at last have direct rail access to Heathrow via Staines. The scheme is designed to use private finance (28).

There are major opportunities in rail to use technology more extensively to bring the efficiency of rapid digital deployment of data.

The industry expert Clive Kessell says (29):

"On a railway which has 60% higher track utilisation than most of Europe, a move towards intelligent infrastructure is long overdue. As one track engineer remarked: 'Data, data everywhere, but not a drop to use.'

Whilst some of the benefits of a move to risk-based maintenance are being realised, infrastructure faults still cause massive delay. Using data streams for intelligent decision making, coupled with aerial (drone-based) surveys, could make a big difference.

Is the rail industry successful in introducing new technology? In general, the answer is NO. Many legacy data systems exist, for example TOPS and TRUST, but they have no clear owner, which prevents them being updated and acts as a deterrent to the adoption of more modern data formats.

Is there insufficient industry leadership, the so-called directing minds? An all-industry approach is required to specify what is needed. Technology must be kept up to date, with better use of the engineering elements, for instance using the signalling system to show how the track asset is conditioned. Maybe artificial intelligence (AI) will help, but data silos remain a big risk."

And the Office of Rail & Road (30) says:

"ERTMS is a traffic management system which is specified by Europe to provide a unified signalling and control system throughout the European area. A key component of ERTMS is the on-board signalling equipment (referred to as the European Train Control System or ETCS).

So as to ensure compatibility between differing suppliers, the Command, Control and Signalling Technical Specification for Interoperability (TSI) has specified the key interfaces needed between equipment on the train and equipment fitted to the infrastructure.

The implementation plan for ERTMS within Great Britain will take over 30 years, targeting equipment that is life expired. Accelerating the plan would incur significant additional cost which is unlikely to be acceptable in most places."

The Railway Industry Association in a submission to the House of Commons Transport Select Committee in July 2020 (31) said:

"Greater political ambition for digital rail, including digital signalling and smart ticketing would accelerate the pace of benefits delivery. Both these digital solutions are proven and transforming rail journeys across the globe. The issue is not technological. A stronger top-down approach is required, with the appropriate legislation and regulatory power to ensure operators adopt existing digital solutions to improve passengers' journeys, across different modes of transport.

The Digital Railway Pillar of the Rail Sector Deal is an excellent example of government and industry working together to address shared challenges, in this case how to affordably address the backlog of signalling renewals. In 2019 Network Rail developed a long term plan and in 2020 industry responded with a strategy and plan to achieve European benchmark costs or better. The opportunity now is for the government to ensure the necessary pilot projects are in place to support the industry to build up its capability and demonstrate its efficiency."

NEW COMMUNICATIONS TECHNOLOGY CAN IMPROVE RAIL JOURNEYS

5G RailNext has been chosen to test how 5G can provide uninterrupted 'infotainment' services across the Seoul Metro system. The project will deliver Augmented Reality (AR) and Mixed Reality (MR) content - including travel information, video streaming and gaming - through wearable devices such as headsets.

A follow-up demonstrator in the UK will take place on the Glasgow subway, with the 5G RailNext consortium outlining plans to explore future use on the London Underground and New York Metro.

MARK THURSTON, CHIEF EXECUTIVE, HS2

At High Speed 2, the success of our ambitious project is clearly reliant on the successful interplay between the railway network and other key networks.

The passenger experience is at the fore or our thinking in our increasing digitised world and our passengers will benefit from the most up-to-date train technology.

We are building the most digitally advanced railway in the country and using a high-tech digital signalling system, we will be able to facilitate faster and much more frequent services.

We want to be part of a strong multi modal transport network for passengers across the UK. At Euston, HS2 will connect with Crossrail II, it will improve connections to Birmingham and Manchester Airports, crossover with various other rail routes, and link with bus and tram stations right across the UK.

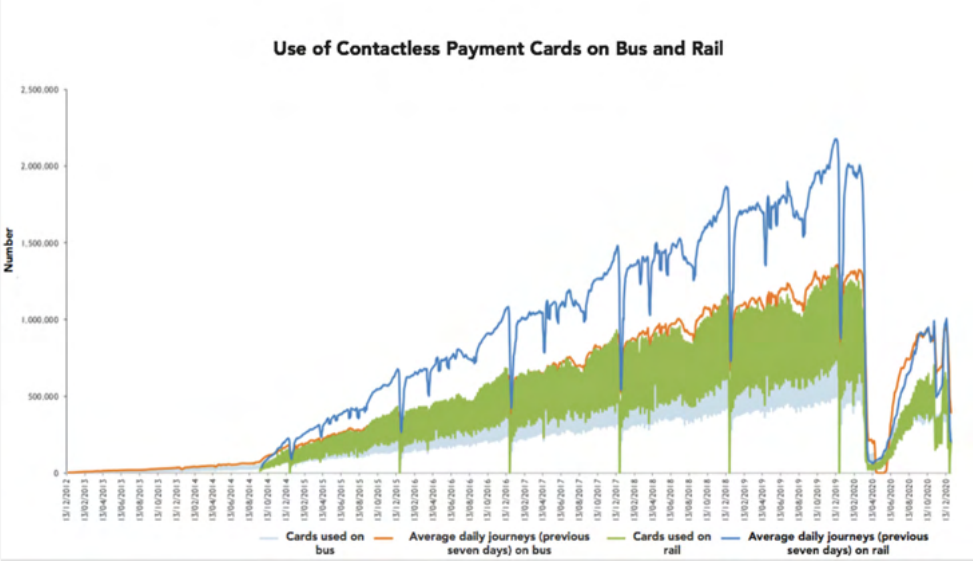
Clearly HS2 will have a major power supply network that will interface with the grid, and it is important for us that this is a sustainable source of energy. Train travel already generates seven times less carbon emissions than cars and seventeen times less than equivalent flights and soon enough, our trains will be powered by a grid providing 100% of its energy from zero carbon sources.

Whilst COVID-19 has reduced passenger demand on our railways for now, it will return. HS2 will be a leader, not a follower. We will be innovators in engineering and set the bar with our customer offering. We want HS2 to be a clear model of innovation, efficiency and sustainability, that everyone else can follow.

SMART ELECTRONIC TICKETING

Plans to introduce PAYG electronic ticketing systems across the network should be multi-modal and multi-operator, allowing customers to use one form of payment across the entire UK public transport network, including buses, trams and rail. Customers would be able to simply turn up and present their contactless card or phone in order to tap in and out, with a guarantee that they will get the right fare for their journey, dependent on its length, and the date and time.

Multi-operator models can be successful, as has been exemplified by the Reading to Paddington route which is served by The Elizabeth Line, along with GWR. Passengers are able to use the same tickets on non-stop or stopping services across both operators.



Source: Transport for London, 2020

There are a number of international examples that suggest an electronic ticketing system could go even further with technological enhancements.

BEIJING

Beijing Capital International Airport has partnered with tech company SITA to automate the entire passenger journey using biometric technologies. From the airport check-in and bag drop to security clearance and final boarding, passengers can just walk through the designated lanes equipped with facial recognition systems.

It might soon be possible that such a system could be used on railway networks with biometric technologies used to track passenger journeys, automatically taking payment from a passenger's account when they leave a station.

HONG KONG'S OCTOPUS CARD

A key payment method for transportation in Hong Kong is its Octopus card. This has been highly successful and has extended beyond use for public transportation, now being used to pay for a whole range of services, including car parks, fast food outlets, convenience stores, supermarkets, and more. It has also been introduced successfully in non-payment uses such as access control.

If the UK was to extend its use of Oyster or adopt another smart card option, a similar system could be explored, extending its use beyond transportation and consolidating a range of functions onto one card.

TICKETS VIA GPS LOCATION

Going further than having to tap into and out of stations, another option could be to use a smart phone's GPS facility to track a user's movement on the rail network, which would activate when entering stations and end journeys when exiting. However, there would be complexities with this system, as there would be privacy issues, people would have to ensure they had location services switched on, and people do not always have their phones switched on or with them at all.

The UK needs to overcome three main barriers if a new electronic ticketing system is to encourage flexible working in the new normal, according to proposals put forward by Henry Metcalf, of Stantec in a submission to the National Infrastructure Commission (32).

He suggests that:

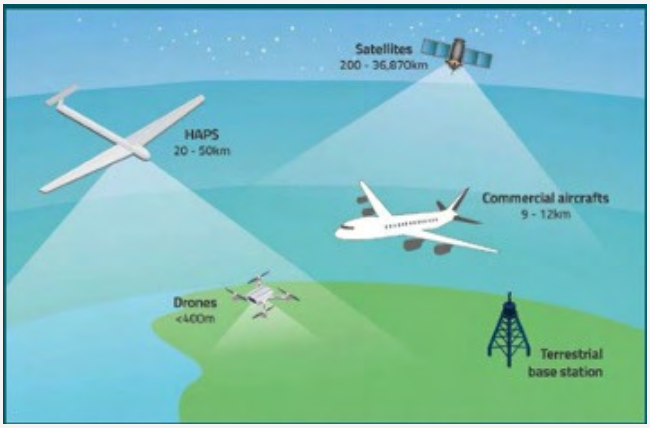
- Rail operators should offer 3-day and 4-day season tickets, for peak or off-peak travel without having to name the days of travel.
- There should be a fully digital ticketing system across the UK with 'simple' ticketing that is easy to understand and access.
- This would include 'tap-in/tap-out' ticketing that automatically delivers 3-day or 4-day season tickets prices.
- Rail users should be able to track their travel through one app showing their journeys made and providing recommendations on how to make cheaper travel in the future
- This app could be provided either via the public sector or via improvements to existing apps such as Trainline or loco2.
- Flexible working 'on the go' should be encouraged by providing trains with high-quality Wi-Fi that does not require users to sign-in.
- The current lack of mobile connectivity on UK rail featured in the NIC's "Connected Future" (2016) report and the continued lack of progress on this was highlighted in its recent "Connected Future: Getting Back on Track" (2020) report.

AVIATION

SIR DAVID HIGGINS, CHAIRMAN, GATWICK AIRPORT

Government and the aviation industry is working to modernise the UK'S air traffic control system in line with technological developments. Our airplanes should be landing on a digital track, without the need to slow down or circle. Updates to the technology will not only improve passenger safety, it will allow us to reduce our carbon emissions, helping the entire aviation industry on its way to meeting the decarbonisation target

Ofcom's recent innovative Technology Futures report (33) shows how the future of civil aviation is closely linked to wireless communications technology which has the potential to create a new mesh architecture, advancing the reach of communication and the safety of travel:



Source: Ofcom Technology Futures 2021

As Ofcom reports:

"Networks architectures are changing and will increasingly need to take into account vertical as well as horizontal deployments. This is both to increase the reach of networks but also to safely track, monitor and communicate with the growing number of (connected) air and space users across a range of altitudes. In connectivity terms, altitude allows for a wider footprint but this comes at the expense of increased latency and a higher contention ratio.

Satellites can also help track aircraft and ships from space. LEO satellites can detect 'Automatic Dependent Surveillance-Broadcast' (ADS-B) signals transmitted from aircraft which are designed to tell other aircraft their position, altitude, velocity and heading. This normally helps aircraft avoid collisions but now allows satellites to track aircraft anywhere in the world – even when travelling over oceans far out of range of air traffic control radars. Similarly, satellites can now track Automatic Identification System (AIS) signals on ships which can help maritime authorities monitor (illegal) activity on our rivers, seas and oceans.

High altitude platforms stations (HAPS) have been proposed as a halfway house between aircraft and satellite. The ITU defines a HAPS as a platform operating at between 20-50 km altitude and able to persist for several weeks or months. HAPS can be used as an Earth observation platform or provide local mobile and broadband connectivity. HAPS can use terrestrial links or satellite links to provide backhaul.

Ongoing work at 3rdGeneration Partnership Project (3GPP) to develop standards for satellite and non-terrestrial networks in 5G should help satellite and airborne services such as HAPS integrate more easily with terrestrial networks. It is expected that this work will start to bear fruit in the Release 17 of the standard, which is expected to be published in September 2021.

For short-haul aircraft travelling over land, connectivity is provided via terrestrial base stations, pointed at the sky. Passenger connectivity is provided via an 'air-to-ground' (ATG) network. In Europe, the European Aviation Networks provides a 4G-like service with speeds of up to 100 Mbps per aircraft. Satellite connectivity is used for aircraft travelling across oceans, typically on long haul flights. Satellite-delivered services can provide 50-200 Mbps per aircraft, depending on the operator. This will rise to 400 Mbps as new satellites come online. The airline market would like to move to a pay-per-use model providing free connectivity to their passengers, but this will require much higher throughput rates to keep pace with passenger expectations. Aviation is therefore seen to be a growth market for the satellite industry".

Using this technology, both satellite navigation and improved data connectivity by wireless and fibre between airports, airlines and air traffic control, there is a huge opportunity for airspace modernisation with energy, noise, environmental and passenger benefits, as explained by the Department for Transport (34):

'Outbound flights follow airport-designated departure routes from the runway until they reach a new, NATS-designed airspace network at 9,000ft. These lower level routes will be determined through the CAA's airspace change process. From then, they will follow these routes until leaving controlled airspace, descending to land, or leaving UK airspace. This should, in the long term, reduce the amount of tactical management required by air traffic controllers, as aircraft can be sent into different routes depending on their specifications and performance. This proposal is intended to allow aircraft to climb (and descend) continuously, getting into higher airspace more quickly, reducing fuel burn and noise at lower levels.

Inbound flights follow Performance-Based Navigation routes until the point of descent, when they will use satellite, rather than ground-based, navigation to move into position for landing. Increased capacity and better data sharing will allow air traffic controllers to slow down the flight of inbound aircraft that may be subject to delays before they arrive in UK airspace, rather than putting them into holding stacks over UK population centres'.

Our Open Skies, an industry group, says:

'It would be as if our road network hadn't changed that much since the 1950s. Without modernising airspace, the delays faced by passengers are likely to soar.

Upgrading airspace will make flying more efficient".

Covid 19 has interfered with the pace of this programme. There are huge opportunities as aviation gradually establishes its new normal.

On 20 March 2021 the government announced £5.5m support for airports involved in the Airspace Modernisation Strategy to keep the project on track and avoid the risks identified by ACOG, the Airspace Change Organising Group (35).

RICHARD MORIARTY, CHIEF EXECUTIVE, CIVIL AVIATION AUTHORITY

Communications infrastructure in real time and in four dimensions has always been extremely important to the aviation industry, not only with traditional aviation, but also now with new technologies using our airspace like drones. Advanced network communications that are reliable, resilient and interconnected are critical for everyone's safety and efficient operations. The development of this communication infrastructure opens a tremendous opportunity to move quickly to modernise how we use airspace. Reforming the 'highways and byways' in the sky could bring environmental, fuel saving and noise reduction benefits. It is also important to ensure we have this vital invisible infrastructure ready to support the industry's recovery from COVID and future growth aspirations whilst integrating the needs of other airspace users such as an increasing number of drone operators and our important grassroots sport and recreational flyers.

NEXT STEPS TO A BETTER-CONNECTED UK

This report has demonstrated that every aspect of communications technology - fibre, 5G, satellite, wireless - is central to the new future digital networks for consumers, shopping, energy and transport.

Currently, although the government is beginning to become more joined up with the arrival of the National Infrastructure Commission and the Infrastructure & Projects Authority, responsibilities often remain in Departmental silos.

Government should review Departmental responsibilities for key infrastructure networks. It should consider handing functions to specialist taskforces reporting to No 10.

Brexit has disconnected the UK from the EU TENS-T transport network. As well as leaving a gap in the UK's transport network framework this provides an opportunity to rethink transport policy in a joined-up way, remedying historical neglect of connectivity to ports, surface access to airports, and other multi-modal connections between road and rail.

Following the Union Connectivity Review led by Sir Peter Hendy the UK should introduce a National Strategic Transport Network. To ensure that it does take a long term consistent approach it should be fully integrated with the work of the National Infrastructure Commission.

The UK should set a clear ambition for, and strategy towards, **a multi-mode, multi-operator contactless electronic ticketing / booking system covering the entirety of the Union with real time information systems.**

As civil aviation grows again, the government should examine systematically how to maximise connectivity to **boost road and rail access to airports and exploit the potential of communications technologies like 5G to make passenger journeys seamless, connections easy, data and information integrated and pricing competitive and transparent.**

New **'networks in the sky'** for civil aviation have the potential to modernise airspace control, increase capacity and remove the need for holding stacks, improving fuel efficiency, reducing noise levels, and cutting delays for passengers. This is made possible by satellite navigation and better data-sharing between airports, airlines and air traffic controllers. This work by NATS under the supervision of CAA s**hould be given high priority by government**.

Government **National Policy Statements** for planning should be reviewed and updated by the government, taking full account of the cross-sector network interactions.

Departments' **Strategic Policy Statements issued to economic regulators** should be updated accordingly and where appropriate replaced by a new cross-sectoral SPS, as recommended in the government's National Infrastructure Strategy.

The **UK Regulators Network** should focus on cross sector work and have an **independent chair** to boost its authority and demonstrate the independence of the independent regulators.

Government should examine the opportunities to use charging mechanisms to allocate motorway space efficiently. The opportunity to devolve charging policies and to align them with local investment in transport should be identified. The National Audit Office recommendation that government review **whether the Office for Zero Emission Vehicles has the capacity, skills and remit to enable it to effectively oversee the fast-paced transition implied by the 2030 target** should be acted upon at once. An expert taskforce reporting to No10 could be the solution.

The need to attract new private finance for communications, energy and transport networks should be prioritised by HM Treasury and the Office for Investment. **The remit of the UK Infrastructure Bank should include focus on developing communications, energy and transport networks. Learning from the success of the European Investment Bank it should concentrate on providing expertise, due diligence and guarantees to leverage private investment to develop these networks.**

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KINGS BUILDINGS
16 SMITH SQUARE
LONDON SW1P 3HQ

WWW.INFRASTRUCTURE.CC

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