carbon smart

Our digital infrastructure needn’t cost the earth

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Commissioned by
CityFibre

About this paper

This research was conducted by Carbon Smart on behalf of CityFibre. Drawing on a variety of published academic, industry and media sources, it explores the environmental benefits of full fibre network solutions across the full life cycle from manufacture, transportation, installation, operation, maintenance and end-of-life.

Beyond a pure comparison of fibre versus copper networks, this document also considers the wider environmental benefits supported by FTTH networks in the context of the 2015 Paris Agreement and the need to achieve substantial cuts in global greenhouse gas emissions.

About Carbon Smart

Carbon Smart is an independent sustainability consultancy that works across the environmental and social agenda with private and public-sector organisations globally. Our mission is to "make sustainability work"; to find clear and practical sustainability strategies that contribute to a better world and to the bottom line for each of our clients.

We work in four core areas:

- Sustainability strategy – developing destinations, roadmaps and targets for businesses that need to respond to the changing sustainability demands of regulators, customers and investors.
- Sustainability data and reporting – award winning work for major corporations and government departments to manage, interpret and report large and complex sustainability data sets.
- Low carbon business – setting out the pathway to low carbon energy performance and generation, working with organisations to develop and implement energy management and renewables strategies.
- Responsible supply chain – helping businesses to understand the impact of their supply chains; focus on key risks and impacts; reduce waste, environmental damage and social harms; and enhance positive benefits to communities, markets and societies in which they operate.

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About CityFibre

CityFibre is the UK's builder of Gigabit Cities and leading alternative provider of wholesale full-fibre network infrastructure. With a long-distance network and dense duct and fibre footprints in over 40 cities throughout the UK, it provides a portfolio of active and dark fibre services to its customers which include service integrators, enterprise and consumer service providers, local authorities and mobile operators.

CityFibre has begun a roll-out of Fibre-to-the-Premises in a strategic partnership with Vodafone, targeting 5 million homes and businesses by 2025.

CityFibre is based in London, United Kingdom, and its shares trade on the AIM Market of the London Stock Exchange (AIM: CITY).

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Climate change represents the challenge of our generation.

Reducing global CO_2 emissions in line with internationally agreed targets will require transformational changes in almost every aspect of our lives. For many sectors, our ability to achieve the requisite emissions reductions will depend fundamentally on the adoption of ICT-enabled solutions. From smart grids and smart meters; buildings energy management systems and shared data centres, to reducing transportations emissions through remote working and autonomous vehicles; in every case the widespread adoption of ICT-enabled solutions will place ever increasing demands on our already stretched communications networks.

Global IP traffic has already grown from a 100 GB per day in the early nineties, to trillions of gigabytes every year today and is expected to triple by 2020, both globally and in the UK. With over 2 billion Facebook users sharing content from every corner of the world, the growth in our appetite for data is staggering. We have entered the Zettabyte era and yet much of the UK's communications network still dates back to Victorian times.

Tackling climate change and delivering a more sustainable economy requires an infrastructure that is fit for purpose. Now more than ever, we appreciate that the investment decisions we make today can have significant environmental consequences. Not only is full fibre the only communications infrastructure technology that can meet the ever-growing demands of today and tomorrow, on a full lifecycle assessment, it is also the right environmental choice.

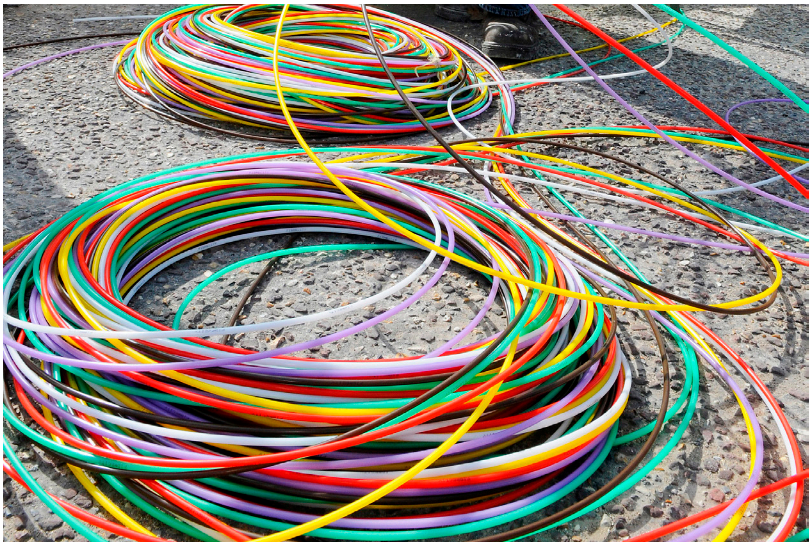
Introduction

We need to build a new digital infrastructure

The advent of new technology often leads to radical changes in the way we live, work and communicate. Just over 10 years ago, nobody had an iPhone and now there are over 2.3 billion smartphone users worldwide. With each new development in Information Communications Technology (ICT) we place ever increasing demands on the underlying infrastructure. Back in 1992, global IP traffic was just 100 GB per day but now we live in the "Zettabyte" era[1], producing and transmitting trillions of gigabytes every single year. Population growth coupled with rising demand and reliance on digital products and services means that data volumes are increasing exponentially, and our supporting infrastructure is struggling to cope. In the UK – where much of our telecommunications network was built over a hundred years ago – around 75 million miles of copper wire must now be replaced[2] with fibre to ensure that the benefits of new technology can be reliably shared by all, regardless of location.

We need to build it sustainably

As daunting as this task may seem, our society faces an even greater challenge. Climate change has been referred to as the challenge of our generation and one that requires "a mobilisation of resources on a scale not seen since World War II"[3]. The leaders of 195 countries signed the Paris Agreement, recognising the urgent need to rapidly reduce greenhouse gas (GHG) emissions and avoid the worst impacts of climate change. Across the globe, CEOs and customers alike are giving greater prominence to the environmental and social costs of our choices, and support for more sustainable approaches has never been higher. Now more than ever, we intuitively grasp that the longer-term, hidden costs of living in a throwaway age are simply too great.



Full fibre is the right technology choice and the right environmental choice

We already have the technologies to significantly reduce our emissions but adopting them on the required scale crucially depends on the availability of reliable, secure, high-capacity and high-performance networks. Given the substantial economic and environmental costs associated with delivering the infrastructure we need, we cannot afford stop-gap solutions and we certainly cannot afford to replace our infrastructure twice. The Victorian-aged copper we've relied upon for decades is already at its physical and technological limits. Not only is copper the weakest link in our networks technologically speaking, it also has a far greater ecological impact due to the energy, effort and resources associated with its extraction, manufacture, transportation, installation, operation and ongoing maintenance. By contrast, full fibre built using modern design and deployment techniques is more reliable and less prone to faults. It's also far more resource efficient, as substantially less cabling is needed to deliver far greater capacity over considerably greater distances. Full fibre is the only viable infrastructure technology that can support the vast expansion of ICT-enabled solutions we need. On a full lifecycle analysis, it is also the environmental choice we need to make today, to deliver the future we want tomorrow.

"Saving our planet, lifting people out of poverty, advancing economic growth... these are one and the same fight."

Ban Ki-Moon,
Former UN
Secretary General

[1] *"The Zettabyte Era: Trends and Analysis", Cisco, June 2017*
[2] *"Britain's copper telephone network could be switched off in near future", The Guardian, 10 August 2014*
[3] *"Democratic Platform Calls For WWII-Scale Mobilization To Solve Climate Crisis", Think Progress, 22 July 2016*

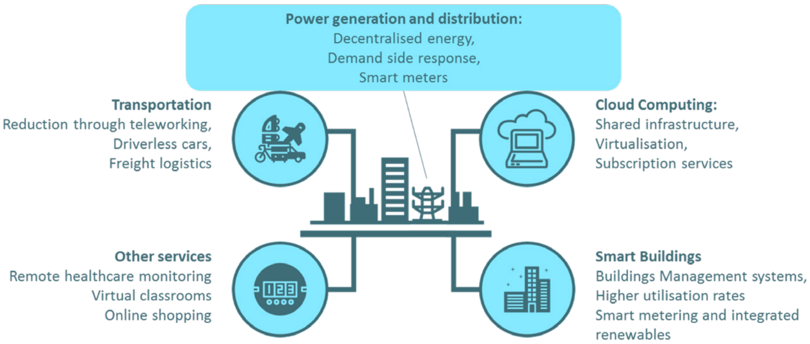
1. Reducing emissions through ICT-enabled solutions

Tackling climate change necessitates rapid and dramatic cuts to greenhouse gas (GHG) emissions in every sector and across every aspect of our lives. Delivering a sustainable economy means changing the way we work; our transportation systems; how we generate and consume power; the way we shop; our approach to education and healthcare; and how we communicate and store information. These changes have a shared dependency on the widespread adoption of ICT-enabled solutions, such as smart power grids, smart buildings, intelligent and autonomous transportation systems, virtualisation and remote service provision. Successfully implementing these solutions means that every business, individual, city and community will need reliable and secure access to a universal digital communications infrastructure that far exceeds our present-day capabilities.

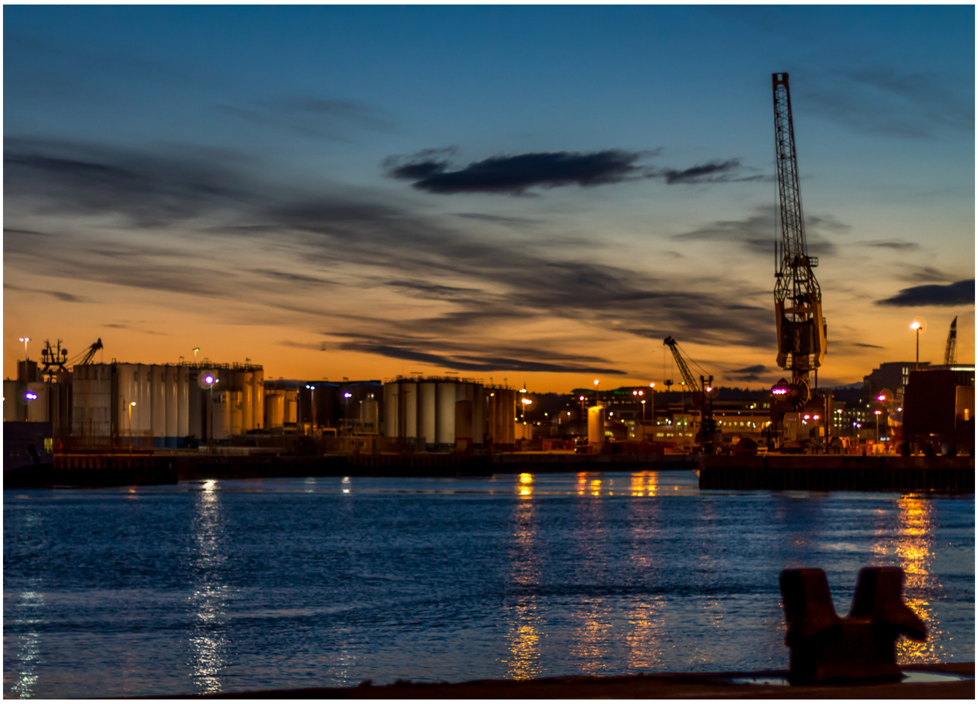
"ICTs are a cross-cutting technology that can drive the deep transformation needed in the global effort to combat climate change"

World Resources Institute

Fig 1. Reducing emissions through ICT-enabled solutions

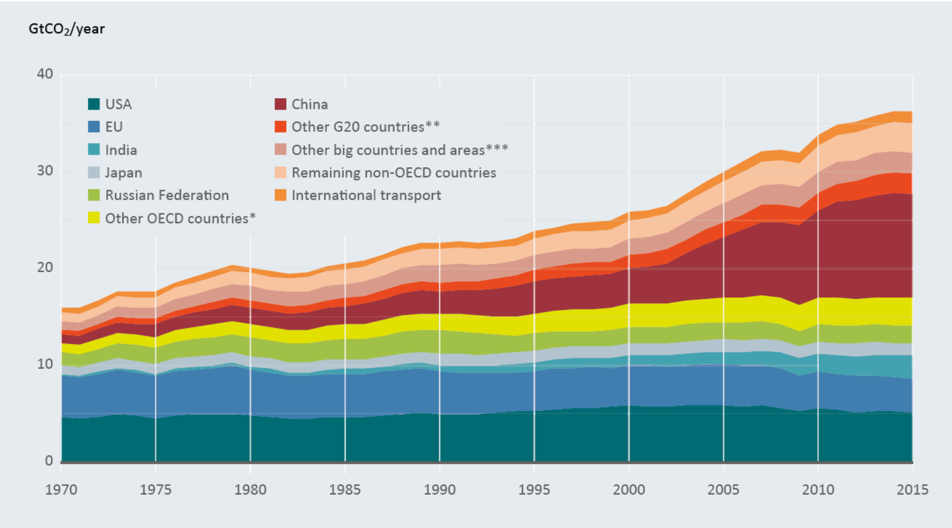


ICT-enabled solutions have the potential to reduce global emissions by an estimated 9.1 gigatonnes of carbon dioxide equivalent ($GtCO_2e$) annually by 2020[4]. This equates to around one fifth of global emissions and would be akin to removing all emissions from fossil fuel use and industrial sectors for the EU and US combined. It would also have significant implications for data volumes.



[4] *"The Role of ICT in Driving a Sustainable Future", Global eSustainability Initiative and Boston Consulting Group, December 2012*

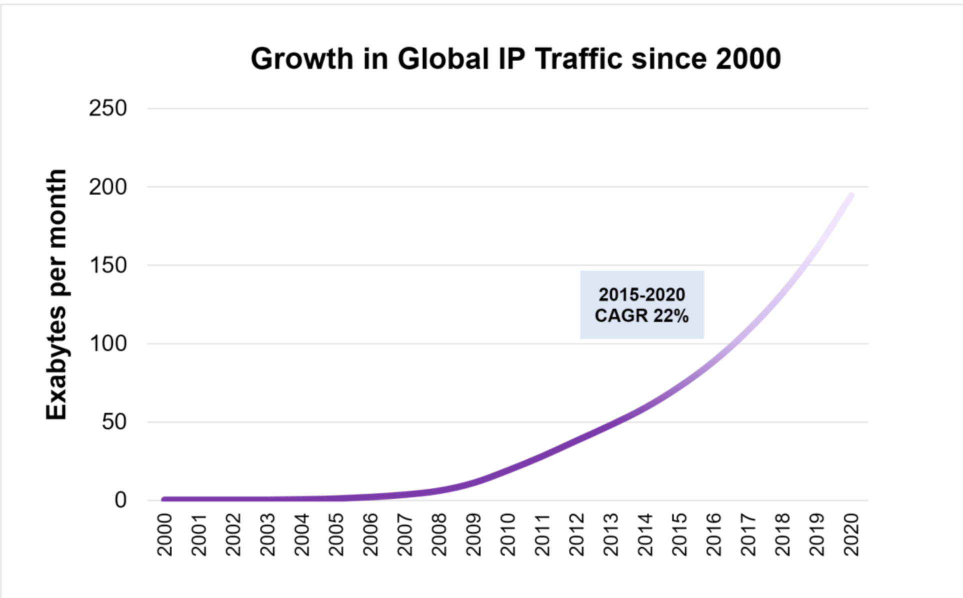
Fig 2. Global CO_2 emissions from fossil-fuel use and industry



* Other OECD countries include Australia; Canada; Mexico; Republic of Korea and Turkey.
** Other G20 countries include Argentina; Brazil; Indonesia; Saudi Arabia; South Africa and Turkey.
*** Other big countries and areas include Egypt; Iran; Kazakhstan; Malaysia; Nigeria; Taiwan, Province of China; Thailand and Ukraine.

Source: UNEP Emissions Gap report 2016

Fig 3. Growth in Global IP traffic since 2000



Source: Cisco VNI

1.1 Power generation: Smarter grids, smarter systems.

To achieve the necessary reductions in global emissions, power generation needs to become almost entirely emissions free. We have the technologies to produce zero-carbon electricity, but replacing our current fossil-fuel dominated power system requires significant changes to the way we produce and consume energy. ICT-enabled solutions will be an integral part of our future power system, as the expansion of renewable energy creates additional challenges around balancing of supply and demand across the grid. In contrast to conventional fossil fuel generation, renewable energy technologies are "intermittent" and "variable", producing only when the wind blows and the sun shines. This involves more complex and detailed forecasting, which in turn means more data.

Changing consumption patterns also introduces significant demand volatility, making peaks harder to predict by grid operators. On the consumption side, traditionally, most energy consumed by businesses and homeowners was produced by large, centralised power plants. With renewables, some consumers are now able to meet their own energy requirements and even sell surplus generation back to the grid. When combined with complimentary technologies like battery storage, smart meters and smart appliances, individuals can also adjust their consumption patterns to use less energy and sell back to the grid when prices are high, or increase their consumption when prices are low.

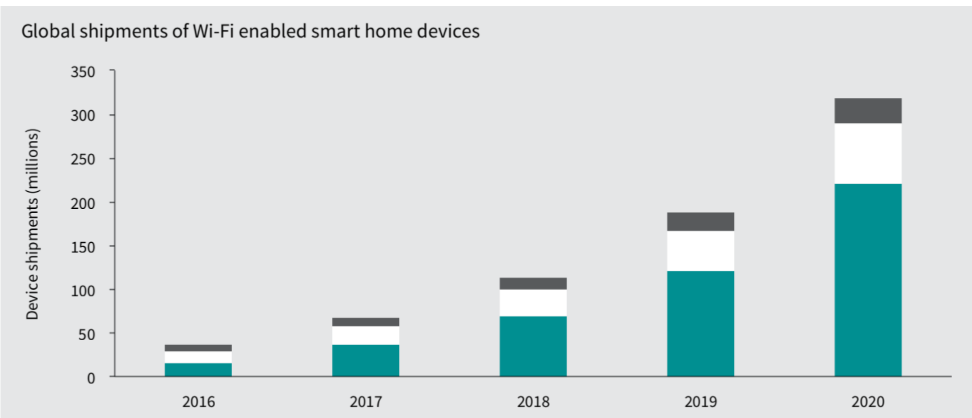
This is known as Demand Side Response (DSR) and is central to reducing power sector emissions by incentivising the uptake of renewable technologies and reducing overall grid capacity. But DSR means more data. In the UK alone, approximately 53 million smart meters are being fitted across 30 million households and businesses[5] to enable bidirectional communication of consumption data. According to research by IHS Markit, 319 million Wi-Fi enabled smart home devices are expected to be shipped globally by 2020[6], further increasing required data volumes.

In short, moving to a decentralised, low carbon power system will be significantly more data intensive. The provision of secure, reliable data transmission will therefore be essential to ensure effective load balancing, avoid blackouts and system failure across future "smart grids".

53m

smart meters are being fitted across 30 million UK households and businesses

Fig 4. Global shipments of Wi-Fi enabled smart devices



Source: IHS Markit, Internet of Things trend watch 2017

5 www.smartenergygb.org/en/smart-future/about-the-rollout/roles-and-responsibilities/ofgem
6 "IoT Trend Watch 2017", IHS Markit, 24 January 2017

1.2. Transportation: Fewer journeys. Less emissions. A lot more data.

Reliable, secure connections are essential for reducing transportation emissions

Transportation accounts for around a quarter of UK emissions and has other adverse effects, such as air pollution and injuries or loss of life from traffic accidents. ICT-enabled technology can reduce these issues in several ways, for example, through increased teleworking, improved logistics and autonomous cars. According to the Telework Research Network, if the 50% of the UK workforce that could feasibly work from home were to do so twice each week it would reduce UK transportation emissions by 4%, equivalent to taking 2.5 million cars off the road[7].

Using video-conferencing removes the need for some travel altogether. Between 2006 and 2012, Cisco employees conducted 1.37 million telepresence meetings, saving an estimated $1.21 billion from avoided travel costs, 653,000 tonnes of CO_2 and gaining $454 million back in productivity through reclaimed travel time[8]. Reaping the benefits derived from remote working requires employees to be 'location agnostic'. Without the requisite investment in universal Fibre-to-the-Home connectivity, home connections will be insufficient, constrained or unreliable and therefore increasingly less likely to be suitable.

Where teleworking reduces the number of car journeys, the adoption of autonomous cars over the next 10-20 years has the potential to achieve further substantial reductions in emissions through increasing efficiency[9]. Individual journeys are optimised as automated vehicles interact with one another and with traffic control systems to improve traffic flow and reduce congestion. Automakers and tech companies also agree that a further major benefit of driverless vehicles will be improved safety.

A plethora of sensors that collectively record and transfer vast amounts of data will enable autonomous cars to monitor a constantly changing 360-degree environment and react immediately to any danger in a way that far exceeds human capabilities. Google car 'Velodyne' with its 64-beam laser, for example, can take up to 1.3 million readings per second[10]. The overall implications for data generation are immense, as, when driven for an average of one hour, an autonomous car is expected to create 4,000 GB of data per day[11]. Any delay in the ability to receive, transfer and analyse vital 'safety sensor' data in real-time could expose road users and pedestrians to potentially life-threatening risk, thereby placing both a unique demand and responsibility on the underlying communications infrastructure.

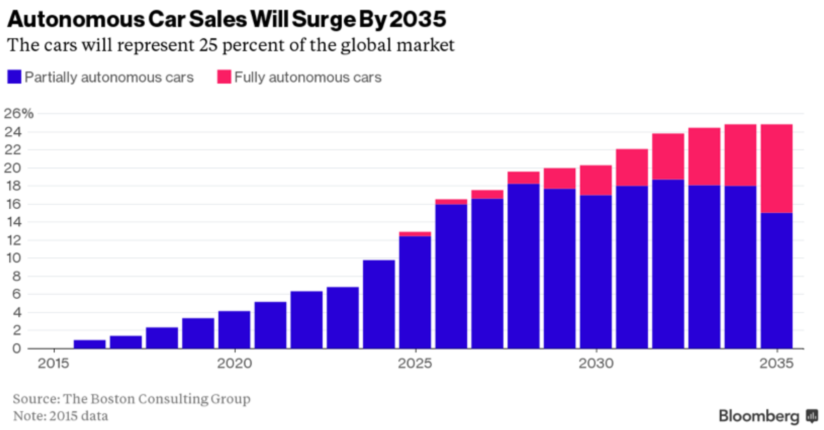
The full environmental benefits associated with autonomous cars will only be realised through significant uptake, which in turn relies on proving to consumers that these vehicles can operate safely in a real-world environment. Any critical data transfer failures arising from inadequate or unreliable connectivity, including connectivity dead-zones or 'not spots', will limit the advance of this technology.

With the market for such vehicles expected to reach $87 billion by 2030[12] and other ICT-enabled driver-assist features becoming near-universal, it should not be surprising to hear that data has been described as "the new oil" for the automotive industry. With every autonomous car generating around 2 petabytes of data annually[13], replacing even a small fraction of the UK's 26 million cars with self driving vehicles will create phenomenal amounts of data and further increase demand for secure, reliable, high capacity full fibre infrastructure.

"Each car will generate as much data as about 3,000 people

Brian Krzanich, CEO, Intel

Fig 5. Projected growth in autonomous cars to 2035[14]



[7] "The Shifting Nature of Work in the UK - Bottom Line Benefits of Telework", Telework Research Network (2011)
[8] "UK Broadband Impact Study – Literature review", SQW (2013)
[9] "Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles", Wadud et al, Transportation Research Part A: Policy and Practice, Volume 86, April 2016
[10] "This palm-sized laser could make self-driving way cheaper", Wired.com, 25 September 2014
[11] "Data is the New Oil in the Future of Automated Driving", Brian Krzanich, 15 November 2016
[12] "Set Autopilot for Profits: Capitalizing on the $87 Billion Self-Driving Car Opportunity", Lux Research, 29 April 2014
[13] "Self-driving Cars Will Create 2 Petabytes Of Data, What Are The Big Data Opportunities For The Car Industry?", Datafloq.com, 19 July 2017
[14] "The most revolutionary thing about self-driving cars isn't what you think", World Economic Forum, 14 June 2017

1.3. Shared data centres

Cloud computing is changing the way we work, making businesses location agnostic, enabling collaboration and boosting productivity. The use of shared infrastructure significantly reduces a company's emissions, typically through higher utilisation rates and the use of more energy efficient hardware in controlled environments. A study by Microsoft[15] found that cloud-based operations provided average emissions reductions of:

- **30 – 60%** for large operations (per approx. 10,000 users)
- **60 – 90%** for medium operations (per approx. 1,000 users)
- **90%** or more for small operations (per approx. 100 users)

Similarly, research by the Carbon Disclosure Project found that, by moving to shared data networks, large companies in the UK and France could achieve a 50% emissions reduction by 2020, delivering annual energy savings of £1.2 billion in the UK alone[16].

The use of shared data centres combined with server virtualisation technology is also considerably more resilient, making glacial overnight backup processes a thing of the past – but only where the capacity of the network connection allows. Increasing our reliance on shared infrastructure is therefore correlated with increased demand for higher capacity, symmetrical connections, i.e., the ability to upload and download data simultaneously at the same speed.

Hybrid fibre-copper solutions that are unable to meet such demands for increased bandwidth capacity or are even specifically designed to ration scarce bandwidth resource, are clearly not fit for the future. In such cases, critical backups are often scheduled outside business hours to avoid conflicting with other data intensive activities, including large media file transfer, simultaneous Voice over IP (VoIP) and video conferencing as well as the everyday operational demands that arise from a multi-user office environment.

[15] "Cloud Computing and Sustainability: The Environmental Benefits of Moving to the Cloud", Microsoft, Accenture and WSP, 2010
[16] "Cloud computing can cut carbon emissions by half, report finds", The Guardian, 7 November 2011

1.4. Less office space required in smarter buildings

Buildings are another major source of emissions, and energy waste can be especially high due to inefficiencies in heating, cooling and lighting, particularly in older properties. Monitoring is fundamental when trying to better understand the energy consumption behaviour of buildings. Buildings energy management systems (BEMS) significantly extend capabilities of sensing, control and automation, utilising data from multiple streams to reduce the energy consumption of individual buildings by up to 30%[17]. When combined with smart design, BEMS have the potential to reduce buildings emissions by an estimated 1.6 $GtCO_2e$ per annum by 2020[18]. The market for BEMS is growing rapidly and revenues for hardware, software and services are projected to rise from $2.7 billion globally in 2016 to $12.8 billion by 2025[19]. Ensuring the effective operation of BEMS will require highly reliable connections to transfer high volumes of data.

Aside from smarter buildings, the overall office space requirements for companies can be reduced through teleworking, allowing large organisations to benefit from lower real estate costs. According to a Workplace Unlimited study, Microsoft was able to accommodate 30% more staff in the same office space due to flexible working practices[20,] and research commissioned by Vodafone found that the UK could save £34 billion by freeing up desk space and encouraging flexible working[21]. As noted above, these benefits will only be realised if employees have access to reliable, secure, high-capacity connections outside the office environment.

£12.8b

projected revenues globally for hardware, software and services by 2025 (from £2.7 billion in 2016)

[17] "Building energy metering and environmental monitoring – A state-of-the-art review and directions for future research", Ahmad et al, Energy and Buildings, Volume 120, Pages 85-102, 15 May 2016
[18] "UK Broadband Impact Study – Literary review", SQW (2013)
[19] "BEMS: Market Intro and Overview", Schneider Electric Blog, 29 November 2016
[20] "UK Broadband Impact Study – Literary review", SQW (2013)
[21] "Flexible working cacn save British business £34 billion", Vodafone, 8 March 2013

1.5. eHealth

The provision of 'eHealth' services is another area where emissions may be significantly reduced alongside delivering the core benefits of increased access to care and reduced cost of service provision. By offering virtual consultations and remote healthcare monitoring, a substantial portion of transportation emissions produced by patients and care workers can be eliminated. For example, a 2014 study in Sweden found that by replacing physical visits with telemedicine appointments, a 40–70 times reduction in carbon emissions was achieved[22].

In Canada alone, it has been estimated that over 11 million home visits could be replaced by virtual appointments, avoiding 120 million km of travel and saving 33.220 tonnes of CO_2e every year[23].

Aside from the ability to conduct consultations using video technology and remote diagnostics, eHealth also refers to electronic documentation of health services, such as electronic health records (EHR), prescriptions and remote monitoring and surveillance. Once more, these services will place additional demands on our digital communications infrastructure. Healthcare is already a data intensive industry due to detailed records of patient care being required for medical purposes and to meet various regulatory and compliance standards.

Whilst much of this data has historically been recorded in hard copy form, the current trend is towards digitisation. The volume of patient health data is increasing exponentially; from digital global health data volumes of 153 exabytes in 2013 to an expected 2,300 exabytes by the end of this decade.

Some experts predict that, by 2020, around 30% of a projected 200 billion connected devices globally will be used in portable health monitoring, electronic recordkeeping and pharmaceutical safeguards. This will place unprecedented pressure on our underlying communications infrastructure, not just at key sites such as hospitals, surgeries and clinical labs, but on the connections that serve staff and patients at home and on the move. The ability to deliver quality patient and community-based care will therefore depend upon robust fibre infrastructure coverage across whole cities as well as gigabit-speed connectivity at key sites.

30%

of a projected 200 billion connected devices globally will be used in portable health monitoring, electronic recordkeeping and pharmaceutical safeguards.

1.6. If we build it, they will come

There are countless examples where ICT-enabled solutions achieve substantial reductions in emissions with a corresponding increase in data volumes. From yesterday's replacement of DVDs and CDs with online streaming, to today's appetite for online shopping and tomorrow's introduction of autonomous vehicles. In every case, the widespread adoption of the solution is made possible by the supporting communications infrastructure. To achieve the Paris Agreement target of limiting the global temperature increase to 2 degrees or lower, global GHG emissions must peak by 2020 and then decline precipitously. Across every sector, ICT-enabled solutions are a vital component of the transition to a low-carbon economy and we cannot afford their adoption to be hamstrung by a lack of suitable communications network. Although the cost of making the requisite investment in our infrastructure is significant, the costs of deferring this investment or making the wrong choice will be far greater.

[22] *"Carbon Footprint of Telemedicine Solutions - Unexplored Opportunity for Reducing Carbon Emissions in the Health Sector", Holmner et al., PLOS One, 4 September 2014*
[23] *"Climate change and eHealth: a promising strategy for health sector mitigation and adaptation", Holmner et al., Global Health Action, 05 June 2012*

2. Choosing the right infrastructure

To meet the challenges of the 21st century and realise the benefits presented by ICT-enabled solutions, everyone will need access to affordable, reliable, high bandwidth connectivity. To deliver an infrastructure that will serve us for the next 100 years, what are the options available to us? And what will each option cost, in environmental terms.

2.1. Full copper and Fibre-to-the-Cabinet (FTTC)

Built long before the Internet existed, the Victorian-aged copper infrastructure that we've relied upon in the UK for decades is simply no longer fit for the needs of today's homes and businesses. This fact is recognised in part by the recent rollout of Fibre-to-the-cabinet (FTTC) solutions across the UK – in so much that it is considered by many as an interim step.

FTTC involves overlaying fibre to new, parallel built, street cabinets, leaving the copper in place between the original cabinet and the home or business. FTTC in this form can deliver download speeds of up to 80Mbps and upload speeds of up to 20Mbps[24]. However, in all cases of FTTC deployment, actual speeds experienced are heavily dependent on distance from the cabinet, number of users being served from that cabinet and the quality of the final copper connection itself.

The objective of the FTTC rollout was to bring faster speeds to the highest possible percentage of the population in the shortest space of time and at the lowest costs by leveraging existing network assets. In that sense FTTC has delivered but, in the time it has taken to deploy, demand for bandwidth has risen further still prompting additional investment to be sunk into 'boosting' technologies such as "G.Fast".

Commonly referred to as "Ultrafast Broadband", G.Fast is capable of raising FTTC download speeds to 500Mbps, but only where customers are within 100m of the nearest cabinet[25]. Since only 5% of UK properties fall into this category, making G.Fast technology scale will require yet further investment – either in technology research or to bring the fibre component closer to more customers.

Although FTTC and G.Fast technology has delivered a much needed bandwidth boost via its 'Superfast' and 'Ultrafast' Broadband products, copper remains a limiting factor and the speeds offered fall far short of what can be delivered over a full-fibre infrastructure. FTTC is therefore seen by many as a short-term investment chosen to maximise returns from existing copper assets, diverting resources and distracting focus from what is really needed: the delivery of a full fibre infrastructure capable of the gigabit speed needed to underpin and enable the UK's social, economic and environmental advancement through ICT.

[24] *"The Forgotten Importance of Broadband Internet Upload Speeds", ISPreview, 20 August 2014*
[25] *"Five common FTTH myths debunked", FTTH Council Europe, 12 September 2013*


2.2. Full Fibre-to-the-Home or Premises (FTTH / FTTP)

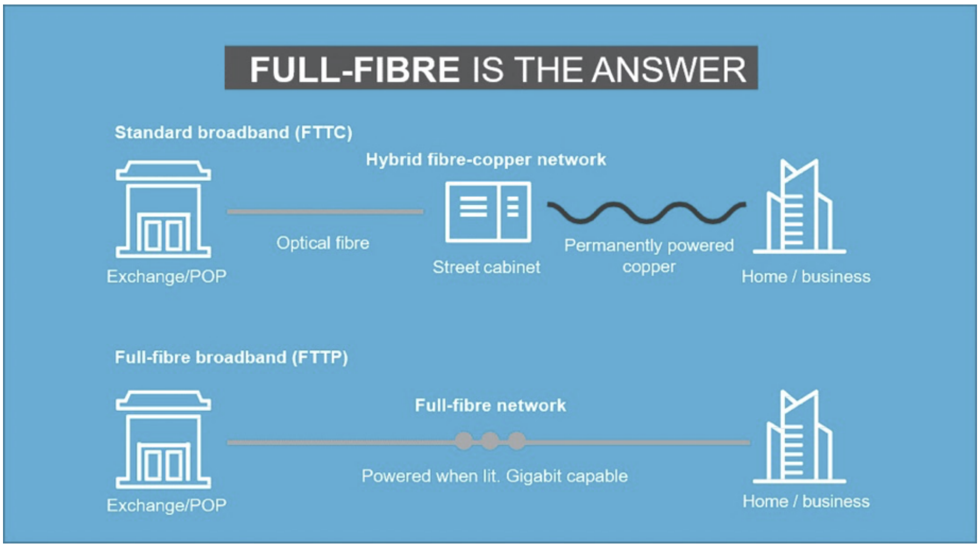
With gigabit speeds already being sought, advocates of full fibre have long since labelled FTTC and G.Fast a short term sticking plaster[26] and believe that the investment already sunk in these technologies would've been far better directed at a wide scale full fibre infrastructure upgrade. FTTP or 'full-fibre' provides an end-to-end fibre optic connection all the way to a customer's premises. In contrast to FTTC, it is more robust, offers far greater performance and is often referred to as future proof, since its theoretical maximum transmission capacity is large enough to be considered unlimited[27]. Once installed, the network can be upgraded by changing the electronics that create and receive light pulses, without needing to replace the cables.

FTTP

cables can be 'split' or 'shared' to serve multiple premises off a single fibre - allowing cost to the user to be brought down.

Fibre networks can also be easily manipulated to ramp speeds up and down in accordance with customer needs. If less speed is required by end customers, FTTP fibres can be 'split' or 'shared' to serve multiple premises off a single fibre – allowing cost per user to be brought down too. The same core fibre infrastructure can also be used to support urban or wireless access services too. Fibre-to-the-Premises (FTTP) and Fibre-to-the-cabinet (FTTC) are both technologies with the potential to deliver ultrafast speeds but only FTTP can deliver gigabit broadband.

Fig 6. FTTC and FTTH infrastructure compared



Connecting our homes, offices and public-sector buildings directly to a full fibre network is the only technology platform that can deliver the reliable, future-proofed capacity we need. Based on a full lifecycle assessment that considers direct power consumption, it will also do so at a lower environmental cost.

[26] "BT has our ultrafast broadband future locked in a copper noose", The Times, 17 July 2016
[27] "Five common FTTH myths debunked", FTTH Council Europe, 12 September 2013

3. A life cycle comparison

FTTP offers a more advanced technological performance, but which is the better choice on environmental grounds?

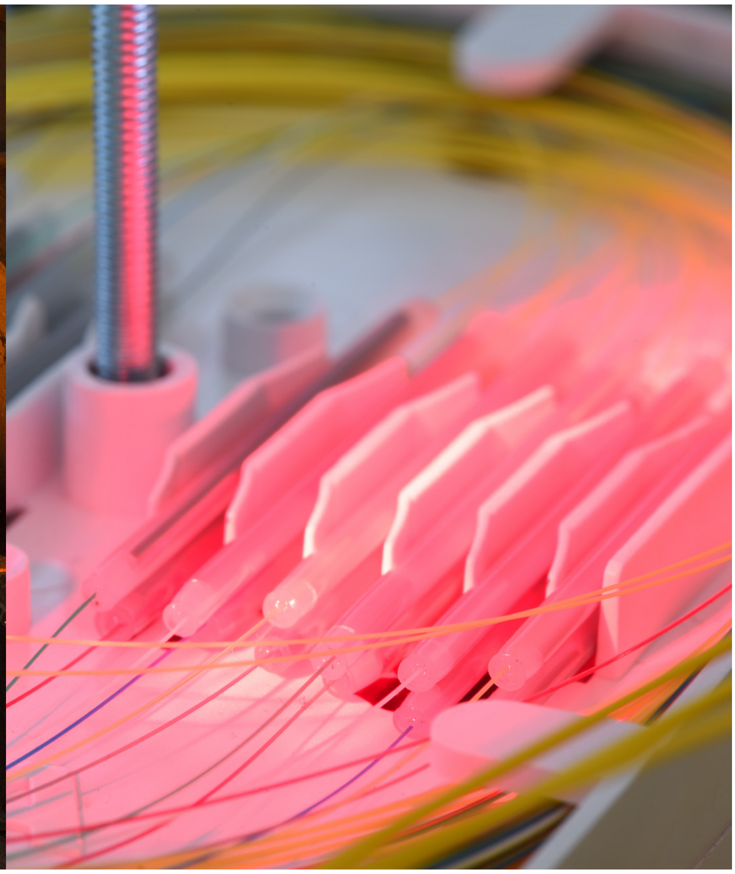
If we compare the environmental impacts of both technologies over their full lifecycle, here too we see that full fibre is the clear winner. When compared with copper, you need substantially less material to provide significantly greater capacity. That full fibre has a lower environmental footprint should come as no surprise. It is lighter, easier to manufacture, transport, install and maintain, requires less energy to operate and is less prone to faults. And we have known this for some time. Back in 2008, a lifecycle assessment of FTTH networks by PwC found that a typical network will be environmentally positive within less than 15 years[28]. In other words, without factoring in knowledge of modern-day ICT upsides, the environmental impact associated with every stage of the life cycle in deploying full fibre would be offset by the environmental benefits derived by network users within little more than a decade.

Fig 6. FTTC and FTTH infrastructure compared

3.1. Manufacture

Copper is one of the world's rare resources and must either be recycled or mined and extracted from a handful of countries in the world, notably from Latin America and parts of Africa. Some countries rich in copper ore also have a poor track record of working conditions, notably in the mining sector, and a long history of human rights abuses. According to Corning, the extraction of 2kg copper ore needed to produce a 200-foot length of copper wire would produce around 1,000 kgCO_2e. Creating the equivalent length of fibre optic cabling would produce just 0.06 kgCO_2e, less than 0.01% of the emissions associated with copper[29]. As the speed of transmission via copper directly correlates to the weight of cable used, you would also need far more than 200-foot of copper to equal the performance of the same length of fibre cabling.

[28] Developing a generic approach for FTTH solutions using LCA methodology", PwC Ecobilian (2008)
[29] "Corning Helps Data Centers Go Green with Fiber", Corning, April 2010



3.2. Transportation and installation

Optical fibres are only slightly thicker than a human hair. They are a fraction of the size and weight of copper wiring and are therefore easier to transport, require less duct space and are considerably easier to install. Given their smaller size, fibre optics can be deployed using alternative techniques such as 'micro-trenching', which is cheaper, quicker and far less environmentally disruptive than traditional deployment.

A micro-trench is typically between 30mm and 100mm wide, compared to a traditional 300mm wide trench[30]. This significantly reduces both the volume of extracted material and required volume of backfill. Trenches are often backfilled using asphalt, with an estimated carbon footprint of 39 kgCO_2e/tonne for production alone, notwithstanding all the emissions associated with transporting the asphalt, additional waste and the backfilling process itself. As the micro-trenching process is considerably quicker, installers can cover between 5 - 10 times the distance in a single day, making more efficient use of space and requiring fewer truck rolls to complete the installation when compared to a traditional copper network build. It is also possible to install more capacity than is presently needed without incurring any operational costs or emissions, thereby future proofing networks and eliminating the need for supplementary installations later[31].

3.3. Operation

Operating FTTC networks requires power to transmit the signal down the copper leg from the cabinet to the premises. Even when the network is not in use it must be powered to prevent the copper from rusting. FTTC cabinets also require a 12-volt battery to provide limited back-up power supply in the event of a power outage[32].

By contrast, fibre networks consume significantly less power, typically less than a single watt per connection versus several watts for copper to transmit the same signal. In fibre networks, light signals can travel tens of kilometres without degradation and therefore require far fewer exchanges throughout the network to boost performance.

In data centres where there are thousands of connections, the additional heat generated by power consumption from copper networks also means a substantial increase in cooling requirements and energy costs[33]. Contrasting the operational power consumption requirements of copper and fibre networks reveals a substantial difference and, over time, the energy and emissions savings from full fibre networks are significant. After replacing the copper network at its New York central office with fibre in the aftermath of Superstorm Sandy, Verizon reported energy savings of 40 – 60% and required a far smaller exchange to service the equivalent FTTP area, further reducing real estate costs by 60-80%[34].

[30] *"Case Study: Microtrench Cover for FTTH Network Installation", Duratex UK, 03 September 2015*
[31] *"Microtrenching and Street Works: An advice note for Local Authorities and Communications Providers", Department for Culture, Media and Sport, November 2011*
[32] *"Criminals Could Target BT's UK Superfast Fibre Optic Broadband Batteries", ISPreview, 28 March 2012*
[33] *"Optical Fiber in the Green Data Centre", OFS Optics*
[34] *"Verizon: Fibre is much cheaper than copper, we're going all FTTP", The Register (2015)*

3.4. Maintenance

The need to boost copper signals over longer distances, means more electronics and more cabinets. The old copper network in the UK requires over 6,000 exchanges, whereas a nationwide fibre network would require less than 70 exchanges[35]. The closure of redundant but currently heavily powered buildings would bring enormous cost, energy and emissions savings. Maintaining fibre-only networks also requires fewer technicians and truck rolls. In New York, Verizon reports a 60% reduction in truck rolls and savings of 40 – 60% on maintenance for its New York network[36]. In the UK, at CityFibre's pilot FTTH network in York, fault rates have been recorded at a small fraction of the level experienced with legacy networks.

Water ingress is the single largest cause of network faults and outages in copper-based networks. Telecoms companies pump gas, such as nitrogen, down pressurised cables to keep water out in the event of a puncture. When Superstorm Sandy flooded Verizon's downtown New York office, the units responsible for pumping the gas failed, thereby rendering miles of copper wiring useless. Fault scenarios are further exacerbated in an aging copper network environment. Regardless of the cause of an initial fault, any human intervention (via truck roll) to repair one fault often causes additional – often fragile – copper or component faults that are often not discovered until later. Each fault triggers yet another truck roll and so the cycle may continue.

As fibre is a light-based data transfer and composite material, it can withstand a lot more abuse from extreme weather events like these. By increasing resilience to such issues, fibre networks significantly reduce the energy, economic and emissions costs associated with their maintenance. In the UK, when serious flooding caused the River Ouse in York to burst its banks in January 2016, the legacy copper infrastructure was badly hit causing a series of outages and service issues. At the same time, CityFibre's pilot FTTH network had no reported outages at all. This is because the full fibre network had no active components located outside the customer premises. Fibre components within operational buildings were also able to continue providing service uninterrupted, even when completely submerged.

Copper is a highly valuable commodity and has been the subject of repeated incidents of opportunistic and planned copper theft over the years[37]. The outcome of such theft can render communities, businesses and public services without connectivity for days or even weeks. When widespread service loss is experienced as a result of such theft, service restoration is always the priority and typically achieved fastest by using replacement copper rather than deploying a superior fibre solution that would eliminate the risk of repeat theft.

60%

reduction in truck rolls in New York since Verizon installed fibre technology.

3.5. End of life decommissioning

Fibre optic cable manufacturers say cables are designed for an approximate 40-year lifetime, although operators typically presume a service life of 25 years[38]. In practice, optical fibre cable has already been in commercial use for more than 30 years and several technical papers have shown that optical cables recovered from the field still meet the optical specifications for which they were installed[39]. Although copper wiring has been used to support telecommunications for the last century, it is subject to corrosion, short circuiting, electrical faults, and other failures, all of which can shorten its practical working life.

And as indicated above, there is also no guarantee that copper networks will remain in situ for the duration of their operational lifetime. According to Openreach, the cost of metal theft to the UK economy is around £770 million per annum. Despite the formation of a copper theft "super squad" in 2011 by BT and Scotland Yard and a number of successful prosecutions since, businesses and individuals continue to face economic losses and disruption from thousands of metres of copper cabling being stolen from across the UK.

[35] *"Floods reveal weaknesses in the resilience of UK broadband", Computer Weekly, January 2016*
[36] *"Verizon: Fibre is much cheaper than copper, we're going all FTTP", The Register (2015)*
[37] *"The UK's infrastructure is being stolen", New Statesman, 27 October 2016*
[38] *"The Lifetime of Fiber Optic Cable", Useful Goods, 7 May 2015*
[39] *"Frequently Asked Questions on Fiber Reliability", Corning, April 2016*

4. Conclusion

The evolution of our technology has enabled individuals and businesses to enjoy unprecedented levels of connectivity. We now communicate and collaborate with one another in ways that were previously unthinkable, but this newfound capacity has exposed a previously hidden cost. Our ability to share information from every corner of the globe has laid bare the true extent to which our lifestyles and working practices are impacting on the environment, notably in relation to greenhouse gas emissions.

We are at a crucial juncture in history and the choices we make need to stand the test of time. If we consider the growing demand for data and our dependency on ICT-enabled solutions to support the transformation of our economies and societies, full fibre to the home or business premises is the only technology that can deliver the reliability, security and capacity required.

Climate change is already creating more extreme weather, with so-called 'once-in-a-hundred-year' events now happening every three to 20 years. Extreme weather poses a far greater threat to the copper networks, raising serious questions about the resilience of FTTC in a changing climate. After all, it's virtually impossible to waterproof a cabinet.

Not only is FTTP the better technological choice, it has a lower environmental impact at every stage in its lifecycle. Whilst FTTC may represent a cheaper, easier solution in the short term, can we afford increased environmental and economic costs over the longer term?

As former BT executive Peter Cochrane said, "Fibre-to-the-Cabinet is one of the biggest mistakes humanity has made". A damning statement certainly and one that disregards the benefits FTTC has brought in upgraded speeds, especially in rural areas who may have had to wait much longer for any improvement otherwise. However, as our analysis has shown, it is clear we need an infrastructure for the future and not the past.

If the UK is to uphold its commitments under the Paris Agreement, we urgently need an infrastructure capable of supporting the ICT-enabled solutions that will underpin our future economy and deliver the required reduction in our GHG emissions. On that basis, it would certainly be an egregious mistake to look to the technology of yesteryear to deliver tomorrow's data infrastructure. Individuals, businesses and governments can no longer ignore the environmental costs associated with our choices. Time is not on our side and we need to choose wisely.

"We are the first generation to feel the effect of climate change and the last generation who can do something about it."

Barack Obama,

"Fibre-to-the-cabinet is one of the biggest mistakes humanity has made"

Peter Cochrane,
Former CTO, BT

5. Key findings: Why full fibre is better for the environment

Full fibre unlocks potential of data hungry devices, applications and services that promise to reduce emissions:

- The adoption of data dependant ICT-enabled solutions, has the potential to reduce global emissions by 16.5% per annum by 2020
- Increased teleworking in the UK will be equivalent to taking 2.5 million cars off the road – but only if connectivity can support it
- Over 300 million connectivity-enabled smart home devices will be shipped globally by 2020, with smart energy solutions already dependant on 53 million smart meters being fitted in the UK
- Autonomous cars have the power to reduce congestion and emissions, but to do so, each car will generate 2 petabytes of data per year.
- Replacing physical visits with connectivity dependent, data-hungry telemedicine appointments can achieve a 40- to 70-fold reduction in CO_2 emissions.
- Switching to reliable, high-capacity shared data networks could reduce emissions of large UK companies by 50% and annual energy savings of £1.2 billion.

Sourcing fibre is more ethical and has a lower environmental impact:

- Copper is a rare resource that must either be recycled or mined and extracted from a handful of countries around the world, some of which have well document human rights issues.
- Extracting the 2kg copper ore needed to produce a 200-foot length of copper wire would produce around 1,000 $kgCO_2e$. Creating the equivalent length of fibre optic cabling would produce just 0.06 $kgCO_2e$.

Fibre is faster and more environmentally friendly to install:

- Optical fibres are only slightly thicker than a human hair - a fraction of the size and weight of copper wiring.
- Given their smaller size, fibre can be deployed using alternative techniques such as 'micro-trenching', which is cheaper, quicker and more environmentally friendly.

Operating a fibre network requires less power and fewer truck rolls:

- The copper within FTTC networks requires power to transmit the signal from the cabinet to the premises, even when not in use
- The old copper network in the UK requires over 6,000 powered exchange buildings to prevent signal degradation. A nationwide fibre network would require less than 70 exchanges.
- Fibre requires less general maintenance. Verizon reported a 60% reduction in truck rolls and savings of 40 – 60% on maintenance for its New York network.
- Fibre can withstand a lot more abuse from extreme weather events. Fewer faults mean fewer engineers despatched to site.
- Fibre is more secure. Metal theft costs the UK economy around £770 million per annum. Unlike copper, Fibre eliminates the risk of such theft and the need for premature replacement.
- Overall, fibre has significantly lower full life cycle costs. A typical network will be environmentally positive in less than 15 years.

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