Department for
Digital, Culture,
Media & Sport

FUTURE TELECOMS INFRASTRUCTURE REVIEW

Ministerial Foreword

There is a real opportunity for the UK to become a world leader in digital connectivity – increasing our competitiveness, boosting productivity and meeting future demands of consumers and businesses.

Over the past few years we have made significant progress, in both mobile and fixed connectivity. In December 2017, we met our target to extend superfast coverage to 95% of UK premises, and we expect to reach at least 97% by 2020. We have also put in place legislation to create a new Universal Service Obligation giving every household and business the right to request a broadband connection of at least 10 Mbps, to ensure no-one is left behind. Mobile coverage has significantly improved over recent years, with 87% of UK landmass having a 4G signal from at least one operator (compared to 78% in 2017).

The Government's ambitions for digital connectivity do not stop here. We want to provide world-class digital connectivity that is gigabit-capable, reliable, long-lasting and widely available across the UK – and to do so at pace. That's why we launched a £1.1 billion digital connectivity package, including the £400 million Digital Infrastructure Investment Fund to help investment in new fixed and mobile networks; the Local Full Fibre Network programme; and the 5G Testbeds and Trials programme. It is why we introduced legislation to exempt new full fibre infrastructure investment from business rates. And it is why we have also created the Barrier Busting Task Force, whose remit it is to identify barriers to fixed and mobile network deployment, and to work with industry, local authorities, and others to overcome them.

In our manifesto, we said that over the next decade we want to provide at least 10 million premises with access to full fibre, with a clear path to national coverage. We want to go further, faster – and have set an ambitious target for 15 million premises to be connected to full fibre by 2025, with nationwide coverage by 2033. We also want to be a world leader in the next generation of mobile technology, 5G, with deployment to the majority of the country by 2027 so that UK consumers and businesses can take early advantage of the benefits.

We announced the Future Telecoms Infrastructure Review last year, as part of the Government's Industrial Strategy, and launched our public Call for Evidence to gather views on how we can best achieve these ambitions. Since then, we have had extensive discussions with industry, consumer groups and investors, undertaken detailed market analysis, and drawn lessons from what has worked – and not worked – in other countries. I am grateful to all of those who provided evidence to support this Review.

We want to ensure that the UK has the strongest conditions in place to secure the investment we need. To do this, as we move from a part fibre, part copper roll out to a full fibre and 5G roll out, we will make sure that competition and innovation can thrive. This means regulation that is limited to where it is necessary, and provides the longer-term stability and predictability that investors need. The UK must become the easiest and the most attractive place to invest in new digital infrastructure.

We are determined to ensure the UK has the telecoms infrastructure to meet the growing demands of consumers and businesses and promote the benefits of connectivity across the UK. While our aim is to maximise commercial investment in digital infrastructure, we recognise that parts of the country are likely to need more support than the market will provide alone.

Digital infrastructure is central to the future of the UK economy. This national strategy will create the right market and policy conditions to secure world-class connectivity for all, but it needs to be accompanied by changes from within the sector. Industry has a critical role in delivering the world-class connectivity we need, and the focus should be on growing the market and improving consumer experiences. This is a long-term strategy and one which will only be achieved by government and industry working together.

JEREMY WRIGHT – SECRETARY OF STATE FOR DIGITAL, CULTURE, MEDIA AND SPORT

Executive Summary

In the coming decades, fixed and mobile networks will be the enabling infrastructure that drives economic growth. The UK is a world leader in superfast connectivity with more than 95% of premises covered. However, next generation Fibre to the Premises (FTTP) – or 'full fibre' – coverage is only 4%, where we lag behind current world leaders like South Korea (c.99%), and Japan (c.97%).[1,2] Mobile coverage is also improving – 87% of UK landmass has a 4G signal from at least one operator (compared to 78% in 2017).

For the UK to be the best place to start and grow digital businesses, we need greater investment to build fixed and wireless networks that are fit for the future, and take advantage of the benefits of fixed and mobile convergence. The wide-scale deployment of these next generation technologies will underpin the UK's modern Industrial Strategy and the Grand Challenges in areas where the UK can lead the global technological revolution. We want every part of the UK to be able to benefit from the significant economic developments that digital connectivity brings.

When looking at the speed, resilience and reliability that consumers want and businesses need in order to grow, it is clear that full fibre and 5G are the long-term answer. These technologies have the potential to transform productivity, and to open up new business models. Full fibre networks are faster, more reliable, and more affordable to operate than their copper predecessors. 5G will deliver faster and better mobile broadband, and enable revolutionary uses in industry sectors like manufacturing, health and transport.

The Government has set clear, ambitious targets for the availability of full fibre and 5G networks. We want to see 15 million premises connected to full fibre by 2025, with coverage across all parts of the country by 2033. We want the majority of the population to have 5G coverage by 2027.[3] The security and resilience of the UK's telecoms networks is also of paramount importance.

The Future Telecoms Infrastructure Review (FTIR), announced in the Government's Industrial Strategy, has considered the changes that need to be made to the UK telecoms market and policy framework to give us the best chance of meeting these goals.[4]

The Government and Parliament are responsible for setting the overall policy and regulatory framework for telecoms, consistent with relevant EU law. Ofcom, as the UK's independent regulatory authority, is responsible for implementing the framework, and for making regulatory decisions under its statutory duties.

The Digital Economy Act 2017 sets out the Government's role in defining the strategic priorities and outcomes in relation to telecoms through a Statement of Strategic Priorities (SSP), which Ofcom must have regard to when carrying out its regulatory functions. It is our intention to follow this Review with the Statement, based on the conclusions of the Review.

Nationwide Full Fibre Connectivity

The total level of investment required for the national roll out of full fibre is estimated to be in the region of £30 billion.[5] We would expect to see incremental revenue from the delivery of more valuable services to help pay for this investment. At the same time, earning a return on this large-scale investment will require the mass take-up of full fibre services. A range of fibre products and pricing will be important to encourage the migration of the existing customer base from copper networks and recover the costs of the new networks.

Commercial investment in full fibre networks is gaining momentum with major investments by established and alternative network operators. Over a million premises now have a fibre connection – more than 450,000 of those within the last year alone; and not just in towns and cities, but also in rural areas as well.

To meet our ambitions, there must be a sharp increase in the pace of full fibre roll out. The availability of capital is not the key constraint – but we do need the right conditions to attract investment. The current regulatory and policy environment has worked well to date in stimulating retail competition based on existing networks. However, changes will be necessary in the regulatory and policy environment, to incentivise the large-scale deployment of new networks in rural and urban areas across the UK.

The National Infrastructure Commission (NIC) published its National Infrastructure Assessment on 10 July.[6] We welcome their assessment which includes a strong focus on digital connectivity and recommends that a national full fibre rollout programme should be put in place to achieve nationwide coverage.

The analysis we have commissioned in support of this Review indicates that, absent change, full fibre networks will at best only ever reach three quarters of the country, and take more than 20 years to do so.[7] This is not good enough to meet our ambition of world class digital connectivity for the UK, with no part of the country being left behind.

The most effective way to deliver nationwide full fibre connectivity at pace is to promote competition and commercial investment where possible, and to intervene where necessary. We estimate that:

- At least a third (with the potential to be substantially higher) of UK premises are likely to be able to support three or more competing gigabit-capable networks[8];
- Up to half (or lower if there are more three network areas) of premises are likely to be in areas that can support competition between two gigabit-capable networks;

- There are likely to be parts of the country (c.10% of premises) that, while commercially viable for at least one operator, may not benefit from investment. The Government will use 'competition for the market' mechanisms to secure investment in areas. The proposed new Electronic Communications Code (EECC), for example, provides powers to designate areas where no operator has indicated plans to deploy; and
- In the final c.10% of premises, the market alone is unlikely to support network deployment and additional funding of some description will be required to ensure national coverage.

This strategy relies on getting five things right:

1. Making the cost of deploying fibre networks as low as possible by addressing barriers to deployment, which both increase costs and cause delays;
2. Supporting market entry and expansion by alternative network operators through easy access to Openreach's ducts and poles, complemented by access to other utilities' infrastructure (for example, sewers);
3. Stable and long-term regulation that incentivises competitive network investment;
4. An 'outside in' approach to deployment that means gigabit-capable connectivity across all areas of the UK is achieved at the same time, and no areas are systematically left behind; and
5. A switchover process to increase demand for full fibre services.

Addressing deployment barriers and reducing costs

Reducing the cost and making it quicker and easier to roll out new telecoms infrastructure is essential. There are currently too many barriers which make building networks expensive and too slow. The Government has already launched a Barrier Busting Task Force, with the single objective of reducing the cost of building fibre networks by identifying and removing barriers to their deployment. The Task Force has worked closely with industry to identify the biggest barriers that exist, and we are proposing new legislation and non-legislative approaches, to tackle them in the following areas:

- Simplifying wayleave agreements to facilitate easier access to multi-dwelling units. Operators face particular difficulties in identifying owners of multi-dwelling buildings and business parks, meaning tenants are often left without their choice of service. Enabling easier access will mean more full fibre can be deployed, faster;
- Reducing the costs and time caused by street works by standardising the approach across the country. We plan to work with operators and local authorities to establish a set of common operational standards and best practice which work within the current legislative and regulatory framework. Different interpretations of street works rules by local authorities mean that operators face differing costs and procedures across the country, hampering investment and creating uncertainty; and

- Ensuring fibre connectivity in new builds, so residents of new homes have full fibre technology. We welcome the efforts by operators and house builders to extend full fibre but further action is required as too many homes are still being built without fibre connections.

In addition, the Government has already supported fibre investment by introducing a five year relief from non-domestic rates (otherwise known as business rates) in April 2017.

Building infrastructure that will support world-class connectivity across the country is a significant project. The pace of roll out will depend on various factors, including availability of labour, sensible management of road closures and supply chain factors. The publication of a long-term strategy for infrastructure roll out will galvanise the sector behind a national plan and give the supply chain time to adjust. The Government will work with industry to identify and mitigate the practical challenges.

Easy access to passive infrastructure in telecoms and other utilities, to support market entry

The largest expense incurred when deploying a network is typically the costs of civil works in laying passive infrastructure like ducts and poles. There are limited benefits from the duplication of passive infrastructure and sharing such assets will reduce both costs and disruption, while preserving the ability of networks to compete. Ofcom's enhanced access regulations requiring Openreach to share its vast network of ducts and poles with rival operators has the potential to significantly reduce deployment costs.

Duct and Pole Access (DPA) could transform the business case for investing in competing full fibre networks.[9] If the evidence shows that this remedy is not being implemented properly by Openreach, all options should be considered to ensure compliance.

Where ducts and poles are not available or effective, there should be other options to enable market entry by alternative networks, for example, access to dark fibre. We encourage Ofcom to consider the regulatory options, in ways that do not undermine the case for operators to invest in their own networks using duct and pole access.

DPA can also be complemented by access to passive infrastructure owned by other utilities, where appropriate. Assets from utilities such as power, gas, water, and local authorities should be easier to access, and available for both fixed and mobile use. This not only includes multi-utility ducts and poles, but also potentially pipes in the case of water, sewers and gas. There are existing provisions for this, such as the Communications (Access to Infrastructure) Regulations 2016, but they have had limited success in the UK to date. The Government will carry out a review of these Regulations in 2019 to assess if there are improvements that could be made to further boost investment in infrastructure. Ofcom should also work collaboratively with other regulators to ensure that these opportunities are explored, and barriers addressed.

Stable and long-term regulation that encourages competitive network investment

A telecoms market that promotes competition between rival networks where possible is best placed to deliver the Government's objectives of extending full fibre coverage across the country as rapidly as possible.

Countries that have relied on infrastructure competition have generally seen higher levels of fibre coverage, particularly in Spain (c.71%), Portugal (c.89%), and France (c.28% and increasing quickly). This has been supported by access to passive infrastructure, deregulation of wholesale access and pricing flexibility, co-investment and risk-sharing, as well as convergence of fixed and mobile markets.

The Government's overarching strategic priority is to promote efficient competition and investment in world-class digital networks. Investment is key to improving consumer outcomes, in terms of choice, service quality, innovation and price over the longer-term. It is the Government's view that promoting investment should be prioritised over interventions to further reduce retail prices in the near term, recognising these longer-term benefits.

The Government has identified a set of outcomes with a view to achieving this strategic priority:

- **Greater regulatory stability and clarity**, through the availability of longer five year market review periods and a framework whereby firms making large, risky investments can have confidence that any regulation reflects a fair return on investment commensurate to the level of risk.
- **Recognising the convergence of business and consumer uses of networks**, through unified access market reviews, where appropriate. See section 4.
- **Regulation only where and to the extent necessary** to address competition concerns and ensure the interests of consumers are safeguarded as fibre markets become more competitive.
- **Recognition of the differences in local market conditions across the UK**, through, where appropriate, a geographically differentiated approach to wholesale regulation. For areas where there is actual or prospective competition between networks, we would expect there to be less need for regulation.
- **Flexibility for firms to develop new approaches** to reduce deployment costs and manage risks through commercial arrangements.

Ofcom must have regard to the Government's strategic priorities and outcomes in the exercise of its regulatory functions. Putting these into practice will require a large number of decisions which will be a matter of regulatory judgement for Ofcom.

This approach, alongside the Review's other proposals, should incentivise established players to invest more in fibre networks and also make it more attractive for competing providers to build their own networks rather than buying wholesale services from the incumbent.

Full fibre connectivity for all through an 'outside in' approach to deployment

Those areas that are likely to be unviable commercially for full fibre deployment will require additional funding of some kind. We estimate this will include around 10% of premises across the UK. These, often rural, areas must not be forced to wait until the rest of the country has connectivity before they can access full fibre networks. Widespread connectivity creates opportunities for small businesses to tap into a global customer base and for people to work more efficiently. We will pursue an 'outside in' strategy, meaning that while network competition serves the commercially feasible areas, the Government will support investment in the most difficult to reach areas at the same time. The additional funding from whatever source is likely to be region of c.£3 billion to c.£5 billion.

To make sure that fibre delivery in these areas starts early, we will prioritise delivery of full fibre networks through the existing BDUK Superfast Programme, which has already made FTTP available to over 200,000 premises in predominantly rural areas by March 2018. Phase 3 of the Superfast Programme is seeking to address superfast coverage in as much of the remaining 5% of the country as possible, and Government will now maximise the number of premises to be covered with full fibre. We have already identified around £200 million within the existing Superfast Programme that can be used for this purpose.

We will use competitive tenders to award contracts for these areas to commercial operators, in order to minimise any public subsidy requirements and ensure fairly priced services. Whilst full fibre is the long-term ambition, we recognise that there are alternative solutions that may also deliver ultrafast connectivity in harder to reach areas. In areas where it may not be cost effective to get fibre all the way to the home, even with additional funding, other technologies like hybrid fibre-wireless solutions can also deliver gigabit connectivity. Bidders will be encouraged to explore innovative solutions, including using a mix of mobile and fixed technologies where appropriate.

Switching to a full fibre future

As full fibre networks are rolled out, maximising the number of people using them will secure the full benefits of the technology. This will involve customers moving onto new fibre networks and retiring the legacy copper networks. Running copper and fibre networks in parallel is both costly and inefficient. A fibre switchover strategy is necessary to stimulate demand for fibre, to enable new networks to achieve scale quicker, and to ensure a smooth transition process for customers. This should be led by industry, working closely with Ofcom and Government.

The Government will set up a mechanism with Ofcom and industry for planning the switchover process. Switchover should meet a number of policy conditions:

- Plans support a **timely switchover**;
- **Efficient**, so that switchover is smooth with minimal consumer disruption;
- **Transparent**, so that customers have the information they need to make informed choices and clearly signalled via notice periods so operators have certainty;
- **Consistent**, with existing regulatory and consumer obligations;

- **Pro-competitive**, so processes are in place to support easy **switching between networks**; and
- A **fair deal** for consumers, including **adequate safeguards** for vulnerable customers.

It is realistic to assume that switchover could be underway in the majority of the country by 2030, but the timing will ultimately be dependent on the pace of fibre roll out and on the subsequent take-up of fibre products. We would only expect switchover to start when a significant proportion of the population has taken-up new fibre services. To aid mass migration from copper-based networks, we would expect fibre networks to have suitable 'entry level' products at prices similar to those provided on copper networks, including voice only services for those who want them. We also expect the Internet Service Providers (ISPs) to market and promote newly available fibre products to drive take-up.

Ofcom will have an important oversight role in ensuring industry readiness for switchover. It will need to protect the interests of consumers and guard against any anti-competitive behaviour.

Legal separation of BT and Openreach

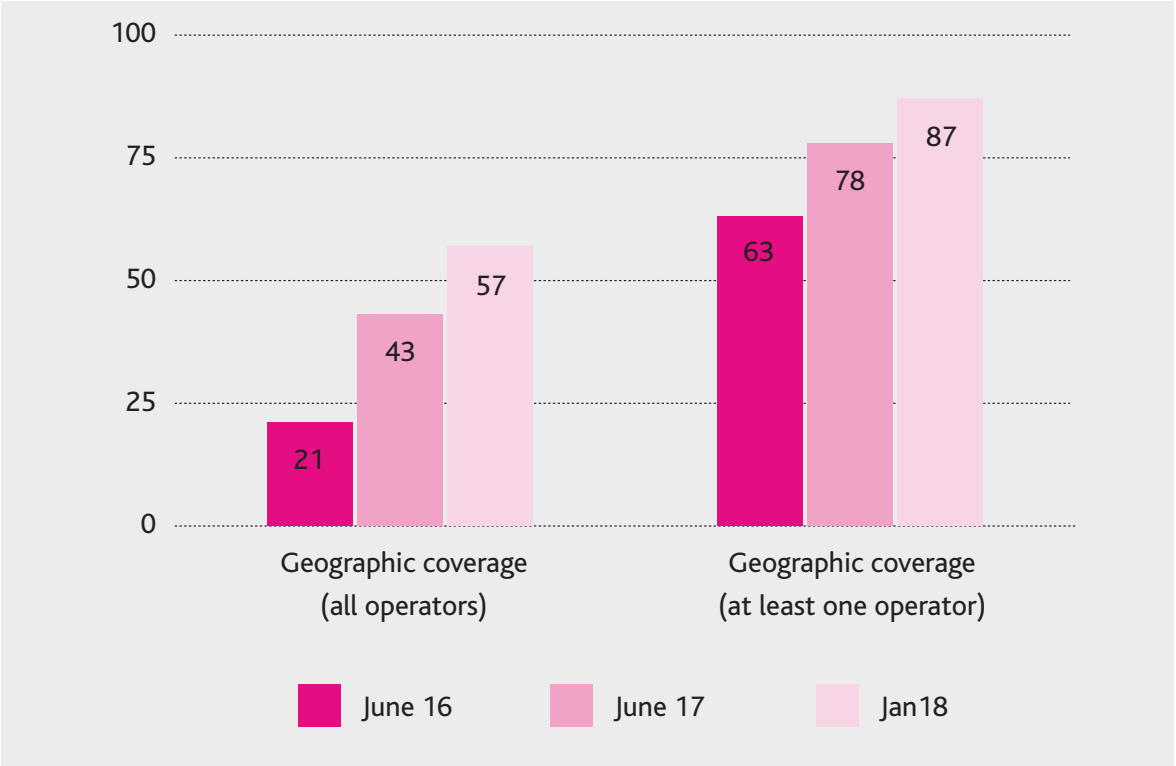
The legal separation of Openreach from BT Group has the Government's backing, and is critical to deliver better connectivity for consumers throughout the UK. We recognise the important steps that have been taken by BT Group and Openreach to implement legal separation, including: setting up the Openreach Board, responsible for setting Openreach's strategy and overseeing its performance; and proper industry engagement on technology investment choices. The Government wants legal separation to be completed as soon as possible and for Openreach to address all the outstanding actions identified in Ofcom's first progress report, particularly the transfer of staff from BT to Openreach.

It is too early to determine whether legal separation will be sufficient to deliver positive changes on investment in full fibre infrastructure. The Government will closely monitor legal separation, including Ofcom's reports on the effectiveness of the new arrangements. The Government will consider all additional measures if BT Group fails to deliver its commitments and regulatory obligations, and if Openreach does not deliver on its purpose of investing in ways that respond to the needs of its downstream customers.

A World Leader in 5G

We want the UK to have high quality mobile connectivity where people live, work and travel. Mobile coverage has significantly improved over recent years, with 87% of UK landmass having 4G coverage by at least one operator, up from 78% in 2017.

Figure 1: UK 4G geographic coverage



Source: Ofcom (2018), 'Connected Nations Spring Update'

Despite this progress, there remain areas where mobile connectivity must be improved. The Government has committed to extend geographic coverage to 95% of the UK by 2022 and so address these 'not spots'. We have introduced changes to the Electronic Communications Code and to planning laws, to make it easier and cheaper to deploy mobile infrastructure. We are working with Ofcom on options to extend coverage.

Alongside finishing the roll out of 4G networks to meet existing mobile demand, we want the UK to be a world leader in 5G to take early advantage of this new technology. We have set a target that the majority of the population will have 5G coverage by 2027.

5G is expected to enable both an evolution of existing mobile services and potentially revolutionary new services

5G is the next generation of mobile technology. It is likely to be deployed as an intricate patchwork of technologies, including advanced LTE, Wi-fi and New Radio, and will utilise a range of spectrum frequencies including re-farmed existing bands, new bands (below 6 GHz) and mmWave spectrum.[10]

The technical capabilities and performance characteristics of 5G are clear. 5G is expected to deliver faster and better mobile broadband services to consumers and businesses, and to enable innovative new services for industry sectors, including manufacturing, transport, immersive technologies and healthcare.

Unlike previous mobile generations, 5G networks will not be homogenous. Deployment will be in phases rather than a 'big bang', and will likely vary by geography. The Review assesses that a realistic scenario is for a low capacity layer providing wide-area 5G coverage (using 700 MHz band), with high capacity in areas of high demand such as towns and cities (using 3.4 – 3.6 GHz band) and, over the longer-term, smaller hotspots of very high capacity (using mmWave bands).

5G deployment will be driven by competition and efficiency benefits

The roll out of 5G will require significant investment by mobile network operators and other players in all network domains, including spectrum, radio access network infrastructure, fibre backhaul and core networks. The wireless sector will need to develop strategies to cope with this expected growth in network costs to meet future demand, including infrastructure sharing and new infrastructure models.

The competitive dynamics in the mobile market, alongside the efficiency and capacity benefits of 5G, are likely to underpin the early business case for 5G investment. Mobile operators may seek to gain a competitive advantage by marketing 5G to existing and potential customers, and thereby spur a response from other operators to protect market shares.

Mobile Network Operators (MNOs) are likely to deploy 5G first on existing sites to alleviate network congestion and efficiently meet the growing demand for data. Over time, MNOs are likely to use 5G-enabled innovations such as 'network slicing' to offer new services to industry sectors.[11] 5G is likely to see a greater deployment of small cells to provide extra capacity in specific locations such as city centres, local high streets, factories, and sports and entertainment venues.

While there is some uncertainty over the business models for 5G, we expect it to create new revenue opportunities for existing operators and also open up opportunities for new players to enter the UK market.

Market expansion – 5G will create opportunities for existing and new wireless players

The Government's strategic priority is to promote investment and innovation in 5G to ensure services and applications are widely available to the benefit of consumers and the UK economy. The Review concludes that there would be strategic advantages in a model that maintains the benefits of competition between multiple mobile network operators, while encouraging new solutions to connectivity challenges, such as small cell networks, indoor and rural coverage.

The mobile network operators will be central to 5G's successful delivery. 5G also creates the potential for market expansion with new infrastructure and service players. National mobile networks could be supplemented by 'neutral host' infrastructure to address the cost and practical challenges of, for example, small cell deployment in high demand areas, or to expand rural coverage. New private wireless networks could also serve new use cases, in particular locations such as factories, business parks, or rural communities. Enhanced mobile broadband services could be provided by existing mobile operators, alongside new 5G services for industry 'verticals' enabled by existing and new players.

There is a clear role for policy and spectrum management in creating conditions that grow a competitive mobile market and support investment and innovation in 5G. The Review has identified four priority areas:

- Make it easier and cheaper to deploy mobile infrastructure and support market expansion, including the implementation of the wide-ranging Electronic Communications Code (ECC) on site access and consideration of further planning reforms;
- Support the growth of infrastructure models that promote competition and investment in network densification and extension;
- Fund beneficial use cases through the Government's £200 million 5G Testbeds and Trials Programme that helps de-risk business models for 5G; and
- Promote new, innovative 5G services from existing and new players, through the release of additional spectrum. We should consider whether more flexible, shared spectrum models can maintain network competition between MNOs while also increasing access to spectrum to support new investment models, spurring innovation in industrial internet of things, wireless automation and robotics, and improving rural coverage.

5G is at an earlier stage of development than full fibre fixed services and so we will keep this strategy under review and return to areas as and when necessary.

Convergence between Full Fibre and 5G

In the longer-term, the Government expects to see a more converged telecoms sector.

Fixed fibre networks and 5G are complementary technologies, and 5G will require dense fibre networks. In some places, 5G may provide a more cost-effective way of providing ultra-fast connectivity to homes and businesses.

The technology synergies between 5G and fixed networks are likely to create strategic advantages for those operators that have interests in both. Those international markets with the best fibre infrastructure tend to be characterised by significant convergence and operators that have leveraged their assets for fixed and mobile services. Consumers will also benefit from an expansion of converged offers, allowing more seamless delivery of content and services across networks and enabling simpler billing and more flexible tariffs.

The policy and regulatory framework should be sufficiently flexible and forward-looking to reflect the growing convergence between fixed and mobile networks and services. This could be achieved through:

- Removing practical obstacles or barriers to converged networks given the benefits;
- Considering access network requirements holistically, where appropriate, through unified market reviews; and

- Allowing operators to benefit from unrestricted usage of Openreach's passive infrastructure for the provision of mobile backhaul services.

Next Steps

This document sets out a national, long-term strategy for digital connectivity. Building infrastructure across the country to support world-class connectivity is a significant undertaking. The Government, Ofcom and industry must work together to make it happen. We will create the supportive policy conditions and will look to industry to attract the necessary capital, roll out the infrastructure and promote take-up.

The strategy sets out a package of policy measures that the Government will take forward in the short-term. These are summarised in Section 5. We will shortly publish consultations on legislative changes to streamline wayleaves and mandate fibre in new builds. The EU's new directive for electronic communications – the EECC – is currently under negotiation. It is likely to be adopted by the EU shortly. If adopted, we are minded to implement, where appropriate, the substantive provisions in UK law, on the basis that it would support the UK's domestic policy objectives. This will enable the extension of market review periods to five years and provide mechanisms to aid fibre network roll out in certain areas.

The conclusions of the Review will also form the basis of the Government's Statement of Strategic Priorities to Ofcom, setting out the strategic objectives and outcomes that the regulator should have regard to in the exercise of its regulatory functions. In particular, the Statement will emphasise the importance of promoting investment as the key to achieving the UK's connectivity ambitions.

The delivery of this national strategy is a core part of the UK's Industrial Strategy and is of fundamental importance to the country's future global competitiveness. We will, therefore, monitor progress on an annual basis and undertake a full review of the strategy's impact after three years. At this point, we will consider all additional measures if not satisfied that the strategy is on track, including actions, if necessary, in those parts of the country that have not benefited from competitive deployment, but where operators could reasonably have been expected to have deployed fibre networks over this period. The Government will consider the more widespread use of 'competition for the market' mechanisms to ensure the roll out of fibre networks in those parts of the country.

1: INTRODUCTION

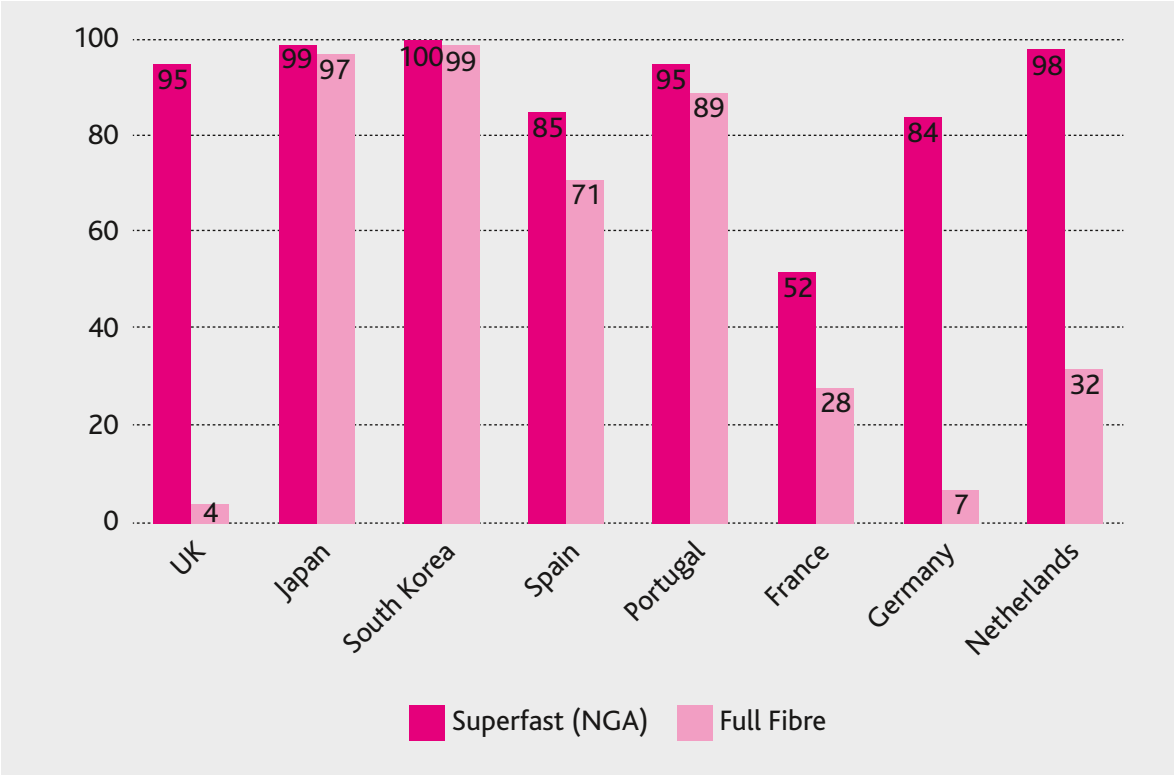
Introduction

1.1 The Government's connectivity ambitions

1. The UK has good digital connectivity to meet the needs of today's consumers. We compare well internationally for superfast broadband availability. Mobile coverage is also improving, 87% of UK landmass has a 4G signal from at least one operator (compared to 78% in 2017). However, the UK must prepare for the future. Demand for high capacity, reliable broadband will increase – particularly as homes, businesses and infrastructure become smarter.

2. The UK has only 4% full fibre connections and lags behind many of our key competitors. For the UK to be the best place to start and grow digital businesses, we will need much greater investment to build fixed and wireless networks that are fit for the future, and take advantage of the benefits of fixed and mobile convergence.

Figure 2: How UK compares internationally on superfast and full fibre broadband (as %)



Source: Ofcom (2017), 'International Communications Market Report; Ofcom (2018), 'Connected Nations Update'; European Commission (2018), 'Study on Broadband Coverage in Europe'

3. When looking at the speed, resilience and reliability that consumers will rely on and businesses will need to grow, it is clear that full fibre and 5G is the answer. Wide-scale deployment of these next generation technologies will be key to the UK remaining globally competitive, and support the regional rebalancing of the economy by creating new opportunities, in areas like health, education and public services.

4. The wide-scale deployment of these next generation technologies will underpin the UK's modern Industrial Strategy. Our Industrial Strategy sets out four Grand Challenges in areas where the UK can lead the global technological revolution. We must ensure that we have the digital connectivity to: put the UK at the forefront of the artificial intelligence and data revolution; to maximise the advantages for UK industry from the global shift to clean growth; to become a world leader in shaping the future of mobility; and to harness the power of innovation to meet the needs of an ageing society. We want every part of the UK to be able to benefit from these significant economic developments.

5. The Government has set ambitious targets on full fibre and 5G connectivity. These build on its Digital Strategy for making the UK the best place in the world to start and grow a digital business, and ensuring that our digital economy works for everyone. The Government is committed to 15 million premises connected to full fibre by 2025 and nationwide coverage by 2033. We also want to be a world-leader in 5G, with the majority of the population covered by 5G networks by 2027.

6. Achieving these targets will require the national roll out of gigabit-capable networks at pace, and significant investment in 5G infrastructure and services. The FTIR was set up to identify the market and policy conditions that could help secure this investment.

1.2 The benefits from world class connectivity

7. There is widespread evidence and agreement on the significant and long-lasting economic benefits from improved connectivity:

- Work commissioned by the NIC estimated net benefits from investment in FTTP with 100% coverage of up to £28 billion (in present value terms) by 2050.[12] [13] This is before taking account of the potential for FTTP to deliver wider economic benefits, for example, improvements in productivity.[14]
- A recent study commissioned by Ofcom finds that investment in broadband has had significant benefits to the UK economy and that increased connectivity has a positive relationship with economic growth and productivity.[15]
- A recent study undertaken for Cityfibre has predicted that the total economic impact of deploying 'full fibre' (FTTP) broadband networks across 100 distinct UK city and towns, could reach £120 billion over a 15 year period.[16]

8. We consider that it is important that network supply stays ahead of demand, otherwise it risks becoming a constraint on the potential for future innovation, productivity and growth.

9. The capabilities of FTTP go far beyond what can be provided over existing copper based services, with FTTP being able to provide gigabit services. The increased reliability and resilience of fibre services is also key. They will not only give consumers the quality of service they are demanding, but will also give businesses the certainty they need to grow.

10. There are long-term benefits for network operators. As well as improved quality of service, full fibre networks are more reliable and we would expect much lower maintenance time and costs compared to copper lines, with Ofcom estimating there were faults on over 12% of Openreach's copper lines in 2015.[17] This brings much lower operational costs over the life of the asset. Rather than focus on repairs, operators can continually improve their network, leading to long-term efficiency savings and better performance. This has positive knock-on effects. Service providers have a more competitive platform over which to sell services, and are able to guarantee consumers the services that they are paying for. This will result in a more competitive and dynamic retail market giving choice to consumers.

11. Full fibre is also an enabler of 5G. 5G is the first generation of mobile technology designed to support multiple applications, from mobile broadband and entertainment services, to industrial applications such as robotics and logistics.

12. The Government's previous 5G strategy publications explained how 5G has the potential to transform communications. It could impact almost all areas of life, from health and social care, to transport and agriculture, through to the provision of ultrafast wireless broadband connections. 5G also offers huge potential economic benefits.[18] A recent EU study estimated that in 2025 benefits from the introduction of 5G capabilities could reach €113.1 billion per year across the region.[19] The UK's 5G ecosystem is growing rapidly, with a wide range of players across the commercial and public sectors. The widespread availability of 5G networks could give the UK's tech companies a head start in creating the next generation of products and services.[20]

Figure 3: Examples of potential benefits arising from 5G[21]

Improved connectivity: Faster and more reliable 5G connectivity for users in a range of environments, including on road and rail networks, in dense areas and even at home.

- **Potential benefits:** Increased consumer value and productivity gains

New consumer devices and services: Smart devices and services enabled by 5G, from immersive media and entertainment through new healthcare wearables to connected and autonomous vehicles

- **Potential benefits:** A variety of consumer and business benefits driven by innovation

New IoT solutions: Opportunities for more advanced asset tracking, remote control, predictive maintenance and sensor-enabled optimisation of processes across sectors

- **Potential benefits:** Increased productivity

Smarter infrastructure and public services: Street lighting, traffic management systems, energy grids and other areas could be enhanced by 5G connectivity

- **Potential benefits:** More efficient and secure service delivery, environmental benefits

Source: Deloitte (2018), 'The impacts of mobile broadband and 5G. A literature review'

1.3 Scope of the Review

13. The FTIR was announced in the Government's Industrial Strategy, with the aim of examining the market and policy conditions that will enable greater investment in future telecoms infrastructure at pace. The Review also addresses key questions that could affect the evolution of the UK's digital infrastructure such as the convergence between fixed and mobile technologies, and the transition from copper to full fibre networks.

14. The Review builds on the Government's existing work to improve the business case for future infrastructure investment through its Local Full Fibre Networks and 5G Testbeds and Trials programmes, the Digital Infrastructure Investment Fund, and business rates relief for fibre networks.

15. The strategic priorities set out in this Review will form a key part of the Government's Statement of Strategic Priorities for Ofcom. As per the Digital Economy Act 2017, the Statement will set out the Government's priorities in relation to telecoms and spectrum, which Ofcom must have regard to when carrying out its regulatory functions.

1.4 Our approach

16. In December 2017, we launched a public Call for Evidence that sought views on the conditions that would unlock investment in world-class fixed and mobile networks.[22] We have received, and have carefully considered, responses from industry, consumer groups, investors and other stakeholders.[23]

17. Since then, we have engaged extensively with stakeholders and experts to ensure we consider the best-possible evidence in our analysis. We have also used a range of other sources to inform our thinking – including commissioning an assessment of global broadband markets, and economic analysis of the competitive dynamics in the UK fixed and mobile markets.[24]

18. We have used this analysis and evidence base to identify the optimal market models for fixed and mobile, and the supporting policy and regulatory conditions. We have considered the various options across a range of criteria including the extent of coverage, pace of coverage, the costs and outcomes for consumers.

1.5 Structure of this report

19. This report (and supporting annexes) sets out the evidence we have considered, our analysis and our conclusions. The remainder of this report is structured as follows:

- **Section 2** discusses the full fibre market and sets out the policies and market conditions that are required to underpin investment to achieve our targets;
- **Section 3** discusses the 5G market and sets out the policies and market conditions required to underpin investment in 5G networks and services;
- **Section 4** discusses convergence in fixed and mobile markets, and how policies will seek to unlock the benefits of convergence; and
- **Section 5** sets out the next steps to deliver world class digital connectivity for the whole of the UK.

2: FULL FIBRE CONNECTIVITY

Full fibre connectivity

2.1 The UK fixed telecoms market

20. The UK telecoms market has been transformed over the past two decades by competition and innovation. The market for fixed telecoms services comprises a number of providers operating at the national level, with some others in specific areas of the UK.

Market today

The retail broadband market is characterised by strong competition with consumers having a range of services to choose from. BT holds a 37% market share, followed by Sky (24%), Virgin Media (20%), TalkTalk (12%) and other providers making up the rest of the market.[25]

- BT is the incumbent provider with the largest national network. In 2017, BT voluntarily agreed to the legal separation of Openreach (responsible for operating the 'last mile' of BT's access networks) which had been operationally separate since 2005. Openreach is required to provide regulated access to its network to retail communications providers such as Sky, TalkTalk, and BT's own retail division, on fair, reasonable and non-discriminatory terms.[26] Since 2010, Openreach has also been required to provide access to its ducts and poles with the intention of allowing rival network operators to build their own networks using this passive infrastructure.
- Virgin Media owns the second largest fixed communications network in the country, covering over half of all households. Over the last decade, the development of DOCSIS technologies has enabled Virgin Media to upgrade its networks to provide superfast and ultrafast services to customers with a road map to gigabit services. Virgin Media is vertically integrated, but unlike BT, it does not provide competitors with access to its network.
- KCOM operates a retail and wholesale network solely in the Hull area.
- There has also been the emergence of alternative fibre providers in recent years. CityFibre provides wholesale-only full fibre infrastructure in over 40 cities across the UK.
- Hyperoptic is a vertically integrated provider which focuses on building FTTP networks in urban areas, primarily to multi-dwelling units (MDUs).
- Gigaclear is a rural FTTP operator which has been rolling out networks in harder to reach areas, and more recently working with BDUK to roll out fibre to areas that would not have been targeted commercially.
- There are also a number of smaller providers who are building Fixed Wireless Access and FTTP networks through new and innovative business models, such as B4RN which has used community digs and funding to deploy networks at a lower cost, and Warwick Net which has focussed on business parks, where the existing infrastructure tends to be newer, by using Openreach's PIA product.

Regulatory and policy approach

21. Since its inception in 2003, Ofcom regulation has focussed on promoting competition at the retail level through regulated access to BT's copper networks. This has been successful in creating a competitive and dynamic retail market, with decreasing prices and consumers having a range of services and providers to choose from. Since the start of this decade, there has been an increased emphasis on promoting investment in superfast networks (networks that offer speeds of 24 Mbps or more), which has driven substantial progress in expanding broadband coverage.[27]

22. However, Ofcom recognised that this approach provided limited incentives for BT to upgrade the fixed network to full fibre and limited opportunities and incentives for others to invest in their own networks. Ofcom's Strategic Review of Digital Communications in 2015 led to a strategic shift towards encouraging investment in competing full fibre networks, and away from reliance on BT's existing copper-based network.

23. Ofcom's current regulatory approach is characterised by multiple levels of regulation, to promote infrastructure and retail competition through access regulation.[28] It also largely follows a national, rather than geographically differentiated, approach to regulation.

Actions to support full fibre roll out

Government:

- The £400 million Digital Infrastructure Investment Fund will unlock over £1 billion for full fibre broadband, and kick-start better broadband connections across the country.
- The £200 million Local Full Fibre Networks (LFFN) Challenge Fund is open for local bodies to bid into, to stimulate commercial investment in full fibre networks in both rural and urban locations across the UK.
- A further £67 million will fund the Gigabit Broadband Voucher Scheme for small businesses and the local communities to contribute to the cost of fibre installation.
- Funding of £35 million to deploy fibre and 5G connectivity along the Trans-Pennine Rail route.
- Five year business rates relief on full fibre investments.

Ofcom:

- Facilitating market entry by making it cheaper and easier for network competitors to reuse BT's existing network of underground ducts and telegraph poles.
- Reform of Openreach to a legally separate entity, with a greater openness to different models of investment and risk sharing, and stronger incentives to be responsive to all its customers, including in its consideration of technology investment choices.
- Continuing pricing flexibility for BT's wholesale services with speeds above 40 Mbps to support incentives to invest in fibre network build.
- Maintaining access and pricing controls on Openreach copper network to protect consumers in the transition to greater network competition.

2.2 The case for change

2.2.1 There has been some progress but more needs to be done

24. There has been positive progress on gigabit-capable network roll out. The UK today has over 1 million premises connected to full fibre, with increasing commitments and interest from industry and investors. These investments are not just in towns and cities, but also in rural areas, with roll out by a range of providers.

Investments in FTTP

- Openreach has committed to connecting 3 million premises by 2020, with 10 million premises connected to full fibre by the mid 2020s. They term this their 'Fibre First Programme' and it is subject to a number of enablers, including reducing costs, increasing demand and a supportive policy framework. Virgin Media has been implementing its Project Lightning programme since 2015, announcing in February 2018 that it had passed 1 million of the projected 4 million households (which it intends to pass by 2020); 50% of which is forecast to be FTTP and 50% DOCSIS. Upgrades via DOCSIS 3.1 equipment will allow the cable network to offer gigabit services and will have a key role to play in delivering future connectivity and competition.
- Gigaclear, Cityfibre and Hyperoptic have raised significant funds since 2016 to support the expansion of their networks. Gigaclear and Cityfibre now pass around 100,000 households today with coverage increasing, while Hyperoptic passes around 500,000 premises and is scaling quickly. Hyperoptic and Gigaclear both raised around £100 million in 2017, with the former targeting 2 million households passed by 2022 and the latter looking to connect a further 150,000 by 2020. Cityfibre recently announced a strategic partnership with Vodafone which will involve itpassing 1 million households by 2021, with the possibility of expansion to a further 4 million households by 2025.
- TalkTalk announced in February 2018 that it will participate in FTTH deployment with Infracapital to serve over 3 million homes and businesses in mid-sized towns and cities.
- KCOM announced that it is extending its Lightstream Programme to connect 200,000 premises with FTTP by March 2019.
- Community Fibre has connected or in the process of connecting 160,000 homes and business units in London, and has used the Digital Infrastructure Investment Fund to generate more capital. It plans to increase its coverage by passing 500,000 homes and businesses by 2022.
- A number of specialist providers are investing in niche markets, for example CallFlow (now relaunched as Trooli) which is investing using Duct and Pole Access (DPA) only, B4RN relying on community funding, and TrueSpeed, SSE Telecoms, WightFibre, Wessex Internet, COLT, exponential-E, Pinacl, VX-Fibre, Zayo all have growing fibre networks.

25. While these plans target over 20 million connections by 2025, there will be a degree of overlap as a number of these premises are in the same towns and cities meaning that homes will likely be served by more than one network.

26. Under current market and policy conditions, our analysis suggests that FTTP coverage will, at best, only ever reach three quarters of the country, and take more than 20 years to do so. The remaining premises would be left without access to full fibre networks. Many of these premises will be in harder to reach, rural or other costly areas where investment in FTTP is not commercially viable. Some of these areas may be able to support at least one commercially funded network but suffer from operators holding off their investments due to strategic uncertainties (so-called 'hold-up' problem).

2.2.2 Characteristics of full fibre investment

27. Investment in full fibre networks is risky which means that investors will need to secure higher, long-term rates of return to be willing to invest. This is because:

- **Sunk costs:** A high proportion of the costs of building networks are sunk (i.e. 'one-off costs' incurred in assets that cannot be diverted to other uses) and incurred before sales;
- **Demand risk:** Whilst the industry appears confident about the long-term demand for higher quality, reliable broadband services, there are substantial demand risks. Uncertainty remains about mass market willingness to pay for higher speeds. This can be expected to impact on the pace at which people migrate to full fibre services and on the price premium that networks can charge. Individual networks also face the risk of competition from rival full fibre networks.
- **Long pay-back periods and regulatory uncertainty:** Full fibre networks are long-lived assets, the costs of which investors can expect to recover over a long period. This could be 15 to 20 years, or even longer. Risks associated with uncertainty about future market conditions is inevitable over such long periods. Long pay-back periods are made more risky by the possibility of regulatory change; and
- **For the incumbent:** Deploying new technology will make existing copper assets obsolete. This has the effect of reducing its incentives to invest in full fibre networks.

28. The Review has sought to identify measures to mitigate these risks, whilst recognising that there are also benefits that investment in full fibre can bring. These include the benefits of defending against improving competition, offering new value added services to consumers and businesses, and the value of greater reliability and resilience.

Delivering Fibre Networks

Costs

As part of the Review, we undertook analysis of the likely economics of fibre deployment. This includes analysis by Frontier Economics, a Call for Evidence, follow-up engagement with industry and other stakeholders and using the work of the NIC on the cost of fibre infrastructure roll out.[29] [30]

The evidence indicates that fibre deployment costs today are broadly uniform across almost two thirds of the UK, beyond which costs begin to rise and become more uncertain.

The total level of investment required for the national roll out of full fibre is estimated to be in the region of £30 billion. We would expect to see downward cost pressures as network operators build at scale, refine their build processes and innovate with new techniques. This trend is observable in countries with extensive fibre deployments.

Build rates

As of January 2018, we had 1.2 million premises passed with FTTP, up from 840,000 in May 2017.[31] This shows that roll out is beginning to pick up pace. There are challenges to how quickly the industry can move to higher build-rates. Evidence from industry and other countries suggests that a peak build rate in the region of c.3 million per annum is achievable, but it will take time to scale-up.

By removing barriers to deployment we can help industry reach peak build rates more quickly, particularly through a more streamlined wayleave process, ensuring new build connectivity and a uniform approach to civil works (see section 2.4).

2.3 We will create an environment to support investment

29. We need a policy and regulatory approach that will help create the conditions to accelerate at-scale fibre investment and extend coverage across the whole UK. There are two broad types of market model that use different levers to address barriers and create incentives for commercial investment:

- **Models of 'competition *in* the market':** These models rely on encouraging competition between operators to drive investment. Competitive models could range from those that seek to promote competition at the retail layer only, to those that rely on network competition.
- **Models of 'competition *for* the market':** These models would give network operator/s *exclusive* build and operating rights to specific geographies (e.g. localised franchises) or nationwide (e.g. a national nominated provider). Each area would have a single wholesale network operator who competes for the right to serve a given market.

30. These models are not mutually exclusive. It is possible to combine their various aspects to reflect the differing potential for commercial investment in different parts of the country.

2.3.1 How we assessed these models

31. To test which model, or combination of models, would deliver the best outcomes, we have considered a range of criteria – including the extent of coverage, the pace of roll out, the costs, the incentives to improve quality and innovation over time, and feasibility.

32. We have assessed the models both quantitatively and qualitatively against these criteria.[32] For the 'competition in the market' option, we have examined the roll out of full fibre networks by BT/Openreach and by alternative network providers, to assess the pace and coverage of roll out and the intensity of competition. For 'competition for the market' options, we have considered the relative merits of a single national nominated provider and regional franchises. We also commissioned NERA to assess how different market models have been adopted internationally.[33]

2.3.2 What we see internationally

33. A variety of these models have been adopted internationally. Countries which have relied on market-based infrastructure competition have generally experienced higher levels of FTTP coverage – Spain (71%), Portugal (89%) France (c.28% and increasing quickly).[34] This was supported by access to passive infrastructure, deregulation of wholesale access and pricing, network sharing and co-investment by operators and the convergence of fixed and mobile markets.

34. The scale of FTTP coverage tends to correlate with the level of network competition. France, Spain and Portugal possess certain characteristics (e.g. higher number of apartment blocks and very high quality ducts) that are more favourable than in the UK, and there are also other factors including different telecoms network architectures that mean FTTC networks are less prevalent, especially in France with relatively long sub-loops. However, the policy and regulatory lessons from these countries are relevant and could be adopted. Conversely, Germany's incumbent operator was subject to ex-ante regulation in the form of wholesale access obligations which has resulted in much lower FTTP coverage (c.7% coverage). Germany is the most similar to the UK in terms of existing legacy/cable networks, distribution of population, and regulatory conditions that supported upgrades to VDSL rather than FTTP roll out which, like in the UK, has resulted in high superfast coverage of 82%.[35, 36]

35. The closest example to a single national provider model is Australia. A major risk of this option is not receiving a compliant or suitable bid to roll out, which occurred in Australia. The outcomes were slow delivery, expensive roll out and an eventual freezing of the market via a state-run monopoly.

36. New Zealand and Sweden have relatively high FTTP coverage as a result of Government-led roll out schemes, but their circumstances are very different. The approaches taken reflect different starting-points to the UK, with significant structural differences. New Zealand is largely rural with a relatively small number of premises, and Sweden's model is based on local authorities' historic investment in networks. New Zealand's local franchising approach has been largely successful, although it has required significant upfront public subsidy.

37. In areas not commercially viable, most countries have supported FTTP roll out with significant levels of public subsidy.

2.3.3 Our preferred model promotes competition where possible but intervention where necessary

38. The Review's conclusion is that the most effective way to deliver the Government's priority for full fibre is to promote competition where possible, but to intervene where necessary. This approach combines the benefits of network competition where the market can sustain it with 'competition for the market' mechanisms and/or additional funding where necessary in other areas.

39. This model relies on creating the right conditions to enable competition between network providers and a race to roll out fibre services, as the key driver of investment. There are significant benefits to consumers from network competition, versus competition based on access on regulated terms to BT's networks. Ofcom highlighted these benefits as part of their recent Wholesale Local Access (WLA) review, recognising that: "*Network competition is therefore a powerful driver of continued investment in high quality networks, delivering long-term benefits to consumers. By exposing more of the value chain to competition, network competition also provides strong incentives for firms to innovate, to become more efficient and reduce costs.*"[37] Network competition provides alternative operators with full control over the services provided, allowing them to differentiate and provide customers with higher quality services. Incumbent network owners are forced to invest rapidly in order to avoid losing market share.

Network competition in the UK

Historically, network competition has driven investment in network quality and speeds in the UK:

- One of the factors that drove BT to accelerate the launch of its initial broadband service was cable broadband getting to market first, and quicker than BT anticipated.
- BT announced its roll out of superfast broadband shortly after Virgin Media's upgrade to DOCSIS 3.0.
- BT's recent announcement on G.fast investment plans was made in the context of Virgin Media offering a maximum service speed of 200 Mbps compared to a maximum of 80 Mbps available from Openreach using its FTTC network.
- The announcement of significant investment by alternative network operators has coincided with BT's new investment plans for full fibre.

40. We expect different parts of the country to be able to support different levels of network competition:

- Given the relatively low costs of deployment per household, at least a third of UK households, (with the potential to be substantially higher) are likely to be able to support three or more competing gigabit-capable networks.
- Upto half (or lower if there are more three network areas) of premises are likely to be in areas that can support competition between two gigabit-capable networks.

- Network competition will not be possible in all areas of the country. The remainder (c.20%) is likely to be made up of areas that can only support a single network, and some areas may need additional funding to do so.

41. These market variations suggest a regulatory framework that is geographically differentiated (see section 2.6). While this would mark a change from the way the wholesale local access market is currently regulated, such a model would be compatible with telecoms legislation.

42. By contrast, 'competition for the market' models which seek to confer exclusivity rights on operators in prospectively competitive areas would be a departure from the current regulatory framework. This would require significant legislative change to deliver, leading to implementation delays and impacting the pace of roll out. Meanwhile, the market would likely take a wait-and-see approach when deciding whether to invest, potentially freezing investment for a number of years.

43. These models would see limited longer-term benefits from competition-driven innovation, lower prices and better consumer outcomes. In addition, in areas where existing fibre providers (and potentially other ultrafast providers) did not win the rights to build FTTP networks, Government would likely have to compensate providers for their losses. These factors are likely to significantly offset any static cost benefits that arise from single network build and reduced duplication of assets.

44. The success of the preferred market model will depend on getting five things right:

1. Making the cost per premises as low as possible by addressing barriers to deployment, which are delaying and increasing the cost of deployment (section 2.4);
2. Supporting market entry and expansion by alternative network operators, by reducing demand risk and through easy access to Openreach's ducts and poles, complemented by access to other utilities' infrastructure (for example, sewers) (section 2.5);
3. Stable and long-term regulation that incentivises network investment (section 2.6);
4. An 'outside in' approach to deployment that means fibre build across the country is achieved in parallel, and no areas are systematically left behind (section 2.7); and
5. A switchover process that stimulates demand for full fibre networks.

45. The total level of investment required for the national roll out of full fibre is estimated to be in the region of £30 billion.[38] We would expect to see incremental revenue from the delivery of more valuable services to help pay for this investment. At the same time, earning a return on this large-scale investment will require the mass take-up of full fibre services. A range of competitive fibre products and pricing will be important to encourage the migration of the existing customer base from copper networks.

46. The security and resilience of the UK's telecoms networks is also of paramount importance. The Government expects operators to invest in the security and resilience of the new networks, and build effective supply chain relationships that support this.

2.4 Addressing the barriers to deploying networks

47. The Government has set up a Barrier Busting Task Force to investigate and tackle barriers to the deployment of digital infrastructure. We know that investment cases are sensitive to build costs, which can be impacted by national and local issues. The Task Force aims to address the supply-side barriers to deployment in order to give greater certainty and lower the cost of building networks, enabling the market to deploy as fast and as far as possible.

48. The Task Force has focused efforts in three areas:

- Access agreements (or **wayleaves**), especially in relation to properties with disengaged landlords;
- **New build connectivity**, building on the voluntary agreements some operators have with the Home Builders' Federation to ensure full fibre connections for new developments; and
- **Street works**, promoting a uniform approach to maintaining the physical condition of roads and keeping road closures to a minimum, to make deployment easier and quicker.

49. We will be bringing forward new **primary legislation** to address issues with wayleaves and new build connectivity. We intend to deliver these changes in the next Parliamentary session. We are also publishing **best practice** for street works and wayleave issues, showcasing what has worked well in some parts of the country and encouraging local bodies to adopt progressive, pro-investment practices.

50. In addition, the Government has already supported fibre investment by introducing a five year relief from non-domestic rates (otherwise known as business rates) in April 2017.

2.4.1 Wayleave agreements for accessing property or land

51. Wayleaves are agreements between operators and site occupiers to install infrastructure on or over their land. The Electronic Communications Code was reformed in 2017 to give operators more rights and remove the prospect of so-called ransom rents being charged by landowners. It also amended the dispute resolution route from county courts to the Lands Chamber of the Upper Tribunal in England and Wales, and the Lands Tribunal in Scotland (recognising the specialist experience of these Tribunals in dealing with property issues).[39]

52. Despite these reforms, operators have told us that they continue to experience significant challenges gaining access to buildings because of the number of landlords who are not known or not interested. This can result in tenants being unable to receive the service they want. This problem is particularly acute for multi-dwelling units, large office blocks and business parks where multiple households and businesses can be prevented from improving their connectivity.

53. One operator has told us that there are around 750,000 premises which they could connect to ultrafast services, with minimal civil works, if they were able to agree wayleaves with landlords. With the economics of delivery placing an emphasis on high speed deployment there is an active disincentive for operators to consider connecting properties where there is potential for delay. Openreach have told us that they set aside up to 12 months for cases where they encounter an absent landlord and have to seek redress through the courts. Openreach have also told us that in the City of London alone, they have been unable to connect 7,500 tenants (76% of those in scope) to ultrafast broadband due to a failure to agree a wayleave with landlords.

54. We do not think it is acceptable for landlords to be able to deny their tenants a service if an operator is prepared to provide it. We want to bring telecoms operators in line with the gas, energy and water sectors by providing a 'right to entry', where a landlord is given notification of an operator's intention to access a property, with a magistrate providing the warrant to entry.

55. We will consult on the detail of this measure in the autumn. To support deployment in the short-term, we are producing a toolkit highlighting best practice and guidance, including template agreements for wayleaves. This will give all parties a firm starting point for commercial negotiations. This will be published in the autumn.

2.4.2 New builds must be connected to fibre networks

56. The majority of new build developments have historically been connected via either copper only connections – often with long line lengths to the nearest exchange – or more recently part-fibre/part-copper connections. The telephony Universal Service Obligation required only functional internet access (effectively a dial-up connection). Connectivity to new build developments is not as good as it should be, with the majority of developments being supplied with connections which are at least part-copper.[40] This is an improving picture, due to the voluntary building sector agreements between Openreach, Virgin Media and GTC. However, it is clear that there will be some new developments that will not receive full fibre connectivity, as it is either too expensive for the operator to provide this alone, or because there is no compulsion on developers to provide connectivity.

57. The Government is looking to improve the housing supply in the UK, and has an ambition of building 300,000 new homes a year over the next few years. We will ensure that the ambitions of significantly increasing the housing stock and world-class digital infrastructure are aligned. It makes practical sense to ensure that these new developments have future-proofed full fibre connectivity wherever possible.

58. Therefore, we are proposing new legislation to ensure all new build developments where appropriate are connected with full fibre which offers choice at the retail level for homeowners. We will look at what can be done through existing legislation, for example building regulations, or whether new legislation may be required. We intend this new legislation to be a backstop provision, designed to ensure that the commercial negotiations between developers and operators (as evidenced by the voluntary agreements) are not affected. We propose to place a joint obligation on

both operators and developers. We propose that lower and upper thresholds of cost per premises are applied, recognising that in some cases there are significant costs of building from the edge of the development to the network. We will consult on the detail of this measure in the autumn.

2.4.3 A consistent, collaborative approach to street works

59. We have developed measures to have a marked impact on how operators and authorities can work together to ensure that deployment happens at scale and pace, while minimising the impact on road users and ensuring the integrity of the roads.

60. Operators have told us that inconsistent interpretation by local authorities of laws designed to minimise the impact of street works and in particular local variations in permit schemes are barriers to deployment. This creates uncertainty for both operators and investors.

61. Local authorities argue that operators take an inconsistent approach to sharing their plans for network deployment, meaning that local authorities are unable to coordinate works effectively and that the quality of the work and reinstatement of the road and footway is often poor. This has bred a culture of mistrust in some areas and means that local authorities are often unwilling to consider quicker, more innovative deployment techniques, such as narrow trenching.

62. Our aim is to ensure a uniform approach across the country, with both local authorities and operators promoting a collaborative and flexible approach, based on consistent policies, as well as early and proactive engagement.

63. The Task Force has worked with local authorities and operators to develop a best practice and guidance toolkit for street works – 'A Framework for Fibre: Street Works'.[41] The toolkit aims to improve consistency between local authorities by sharing good practice examples of permit schemes and other approaches. The toolkit outlines the approaches that both authorities and operators should take in order to ensure deployment happens quickly and to a high standard. It includes a number of tools, including standard non-disclosure agreements and case studies of what has worked well and why. The toolkit has been agreed by Street Works UK on behalf of operators, and the Joint Authorities Group on behalf of local authorities.

64. In addition, as part of a wider strategic approach to street works, the Department for Transport is proactively delivering projects to reduce the impact of street works on congestion, support the effective planning, management and communication of works, and improve consistency and quality of work. These include the development of the new 'Street Manager' digital service which will improve coordination and planning between utility providers and local authorities. Additionally, a review of the Specification for Reinstatement of Openings in Highway (SROH) code of practice is underway, which will assist the approval process for innovative techniques and materials, including narrow trenching. DfT will continue to identify areas for further improvements that will minimise the impact of street works on road users, and assist the deployment of infrastructure.

Addressing local deployment issues

65. The Task Force has also engaged with operators and local authorities in current deployment issues, where roll out of infrastructure has stalled. In almost all cases, the issues were indicative of wider strategic concerns which the above measures will help resolve. Key successes have included:

- Caerphilly – mediation between Virgin Media and Caerphilly County Council to lower administration costs and establish market-level wayleave price. Secured expansion of the ultrafast broadband network to 45,000 homes.
- Dispute between Northumberland County Council and National Parks England – worked with the operator on a solution with most of the build now going underground. Secured superfast broadband for 125 premises in a very rural area.
- Provided clarity of legal position for wayleaves for local authorities regarding social housing, making investment possible for an additional 2,500 premises in the Cityof York.

2.5 Promoting market entry and expansion for new network operators

2.5.1 Promoting passive infrastructure reuse is key

66. Civil works, in particular installing ducts and poles, comprises around 70% of the costs of deploying fibre networks.[42] Reusing existing infrastructure can significantly reduce the time it takes to roll out a new network. Ofcom estimates that while it can take days to build 200 metres of duct using traditional construction methods, fibre cables could be installed in the same length of existing duct in a matter of hours.[43]

67. Ofcom recently strengthened the requirements on Openreach to allow other providers to use its ducts and poles on a national basis. The Duct and Pole Access (DPA) remedy allows for other providers to access ducts and poles *"as easily as BT itself using (as far as is possible) the same processes, service levels, systems and digital data maps"*. Rental prices were also halved.[44] Ofcom expects this to reduce up-front deployment costs by around 50% and reduce deployment time.

68. It is imperative that Openreach fully implements these requirements to open up its passive infrastructure. If the evidence shows that this remedy is not being implemented properly, we will consider all options with Ofcom to ensure compliance.

69. There are existing provisions such as the Communications (Access to Infrastructure) Regulations 2016 (the 2016 Regulations) which allow for communications providers to access physical infrastructure owned by other utilities on commercially negotiated terms.[45] This has had limited success in the UK to date, particularly given the complexities of negotiating contractual terms that work for parties with different levels of risks and needs.

70. Making sure existing, non-telecoms infrastructure can be used, as far as possible, is critical to enabling deployment at pace and supporting market entry. This could be achieved through:

1. Recognising convergence and access network requirements holistically, where appropriate, through unified market reviews – this is discussed further in section 4;
2. Where ducts and poles are not available or ineffective, there should be other options to enable market entry and expansion by alternative networks, such as dark fibre; and
3. Encouraging passive sharing with other utilities by addressing barriers.

71. These measures are also necessary to support the Government's 5G and convergence strategies, which are covered in sections 3 and 4.

Where ducts and poles are not available or ineffective, there should be other options to enable market entry and expansion by alternative networks

72. Access to ducts is only possible when there is space available. Existing DPA remedies include 'ready for use' provisions under which Openreach must repair faulty infrastructure and clear blocked tunnels where necessary for providers to access them. While these provisions lead to space being made available, they do not provide adequate safeguards for areas where ducts are full (even after re-organising cables, for example).

73. Some countries, for example Portugal, have mitigated this by introducing dark fibre backstop remedies, whereby the incumbent must provide access to dark fibre in areas where the DPA product is not sufficient. In Spain, Telefónica has an obligation to provide a dark fibre connection in cases where no spare capacity in its ducts is available. Where ducts and poles are not available, there should be other options to enable roll out by alternative networks, for example, through dark fibre access as a backstop remedy. We encourage Ofcom to consider the regulatory options, in ways that do not undermine the case for operators to invest in their own networks using duct and pole access.[46]

Encouraging passive sharing with other utilities by addressing barriers

74. There are further benefits to be had from extending the reuse of existing passive infrastructure which could be complementary to using existing Openreach infrastructure. These opportunities are recognised in the 2016 Regulations.

75. These Regulations require infrastructure operators to provide access to their physical infrastructure on fair and reasonable terms to communications network providers for the purposes of deploying elements of a high-speed network.[47] This obligation applies to telecoms network providers as well as infrastructure operators in other sectors including gas, electricity, water and sewage and drainage systems, heating and transport services. The aim is to reduce the cost of deploying high-speed electronic communications networks.

76. The potential for the reuse of infrastructure assets includes not only the re-use of multi-utility ducts and poles, but also pipes in the case of water, sewers and gas, and fibre embedded in power cables. Ofcom issued guidance at the end of 2016 and, at the time, said that it would keep this guidance under review as more information becomes available on the demand for access to particular infrastructure.

77. We are seeing many examples of commercially-led infrastructure sharing emerge across the country, both within the telecoms industry and also with other utilities:

- SSE and Zayo have partnered with Thames Water to use sewer networks to deploy fibre networks in urban areas across the country, including London.
- Gigaclear is running fibre optic cables under the Clifton Suspension Bridge, extending gigabit connectivity from Bristol into North Somerset.
- 'Dig once' policies: when there is any civil digging in an area, spare ducting – which can hold fibre – is installed at the same time. In addition to minimising traffic disruption, it reduces costs and time associated with civil works. The policy has been adopted by Tameside Metropolitan Borough Council and also by Transport for London when upgrading its transport network.
- Municipalities across the country making their ducts available to wider use. For example the Tameside Metropolitan Borough Council is making its ducts available through a cooperative alliance which offers the passive infrastructure as a wholesale open access product. Multiple service providers are then able to use the infrastructure to develop their own products and services.[48]

78. The commercial agreements with Thames Water provide an opportunity to understand the impacts of using different approaches for deploying telecoms networks. By deploying fibre in the sewer network, operators have the potential to build their network at considerably less cost due to minimal civil works required. At present, this approach is limited to large sewer networks in metro areas, but technology is developing to enable deployment in smaller size pipes. There remain challenges regarding liabilities but we understand these can be addressed, especially where solutions can be provided to be mutually beneficial to both operator and water company – such as the installation of fault monitoring equipment. Whilst these initiatives are mainly to provide business connectivity, rather than for residential deployments, we recognise that these reflect alternative ways of deploying networks. We will continue to monitor these developments and will engage with operators and utility companies to ensure that the potential of this type of infrastructure sharing is maximised.

79. The 2016 Regulations provides for a right to access information (location, route, type and current use, and contact point for further requests) concerning existing physical infrastructure and civil works. The Review recognises the potential benefits that a coordinated approach to information sharing on available infrastructure could have to aid the network planning process for full fibre networks. The Government will, therefore, work with industry, Ofcom and local authorities to consider whether there is a sufficient case to introduce a centralised ducting database to track

existing ducting networks and promote a coordinated approach to network expansion and roll out, similar to current centralised systems available in Germany and Portugal which are managed by their respective national regulators.

80. We want to ensure that the 2016 Regulations work as effectively as they can. The Government will carry out a review of these Regulations by 2019 to assess if there are improvements that could be made to further boost investment in infrastructure. Ofcom should also work collaboratively with other regulators to ensure that these opportunities are explored, and barriers addressed.

2.5.2 Increasing demand and reducing risk

81. The mass take-up of full fibre services will be necessary to ensure operators secure a return on their investment that justifies further roll out. Targeted approaches can be used to stimulate demand. These include demand aggregation approaches that guarantee levels of take-up before commiting investment, and voucher schemes to encourage consumers to move to gigabit capable networks.

82. The Government has previously used voucher schemes to drive superfast take-up by businesses, for example through the Broadband Connection Voucher Scheme, and has more recently announced that, through the Gigabit Broadband Voucher Scheme, £67 million of funding will be allocated to vouchers which will help households, SMEs and local communities to cover the cost of a fibre connection. We are already seeing strong demand for this scheme with over £7 million of vouchers already requested and nearly £2 million of these have already resulted in a live connection. Aggregation of vouchers by suppliers is resulting in entire business parks or communities getting gigabit-capable connections.

83. There have also been examples of industry testing new models which mitigate demand risk including the anchor tenant model used by CityFibre and demand aggregation approaches used for example, by Gigaclear. The LFFN Gigabit Broadband Voucher Scheme is specifically targeting market models which promote such behaviours. Other potential risk sharing options include minimum volume commitments between the wholesale provider and ISPs, which could encourage ISPs to move consumers onto full fibre networks.

84. The public sector can play an important role in generating greater demand for fibre networks. The LFFN programme has demonstrated clear benefits to full fibre investment from the Government, including:

- Targeted funding to local bodies to harness public sector connectivity and aggregate private sector demand to build new and extend existing fibre networks;
- Using hospitals, health centres and GP surgeries as 'anchor tenants' – providing a full fibre 'hub' which surrounding homes and businesses can then also be connected to;
- Upgrading schools, libraries and emergency response buildings to gigabit-capable full fibre connections; and

- Strategic re-purposing of existing infrastructure, allowing full fibre to be rolled out at a fraction of what it would otherwise cost.

Improving connectivity through LFFN schemes

- West Sussex County Council have received funding to upgrade 152 public buildings across the country to full fibre. The successful bidder for the work is CityFibre who have announced a much wider investment in fibre across the county, using the Council as their anchor tenant to strengthen their investment case.
- DCMS working with the Department for Education have just upgraded the first of over 100 schools. Cheselbourne School in Dorset was running on less than 2 Mbps and their new gigabit-capable fibre service is transformational. Over and above the benefits to the school, the supplier Wessex Internet intend to leverage this fibre connection and invest in providing onward FTTP to the entire village. Thus the school has become the anchor for a much larger investment by industry.
- 13 further projects were announced in the Spring Budget Statement 2018 totalling £95.5 million. In total this will provide fibre connectivity to 3,376 public buildings (council offices, schools, libraries, medical facilities etc.) whilst bringing fibre to within 50 metres of over 200,000 premises and to within 200m of nearly 800,000 premises. We anticipate that like West Sussex, these UK wide projects will similarly encourage network operators to make broader investment in these areas.
- Fibre investment along the Trans-Pennine Route, as well as providing backhaul connectivity for a 5G trial to the trains, will be used for fibre connectivity between communities along the route. It will also be used to provide enhanced connectivity between the Manchester and Leeds Internet Exchanges.
- Bidding for a further wave of projects totalling £95 million is planned to open during July 2018.

85. The Government will continue to build on the successes of these schemes and actively consider full fibre solutions when purchasing government services. For example, we are working with Crown Commercial Services as it develops best practice and procurement frameworks for the public sector to source fibre-enabled network services.

2.6 Stable and long-term regulation that incentivises competitive network investment

86. Addressing deployment barriers and making sure existing passive infrastructure is utilised as far as possible, will support the business case for full fibre roll out by reducing the cost of deployment. However, we also need a policy and regulatory environment that recognises the inherent risks of major infrastructure investments and that reflects the different competitive conditions across the country.

87. The Government and Parliament are responsible for setting the overall policy and regulatory framework for telecoms, consistent with relevant EU law. Ofcom, as the UK's independent regulatory authority, is responsible for implementing the framework, and for making regulatory decisions according to its statutory duties.

88. The Digital Economy Act 2017 sets out the Government's role in defining strategic priorities and outcomes in relation to telecoms, to which Ofcom must have regard when carrying out its regulatory functions.[49]

89. The Government's overarching strategic priority is to promote efficient competition and investment in world-class digital networks. Investment is key to improving consumer outcomes, in terms of choice, service quality, innovation and price over the longer-term. It is the Government's view that promoting investment should be prioritised over interventions to further reduce retail prices in the near term, recognising these longer-term benefits.

90. The Government has identified a set of desired outcomes with a view to achieving this strategic priority:

- **Greater regulatory stability and clarity**, through longer, five year market review periods and a framework whereby firms making large, risky investments can have confidence that any regulation reflects a fair return on investment commensurate to the level of risk.
- **Recognising the convergence of business and consumer uses of networks**, through unified access market reviews, where appropriate. See section 4.
- **Regulation only where and to the extent necessary** to address competition concerns and ensure the interests of consumers are safeguarded as fibre markets become more competitive.
- **Recognition of the differences in local market conditions across the UK** through, where appropriate, a geographically differentiated approach to wholesale regulation. For areas where there is actual or prospective competition between networks, we would expect there to be less need for regulation; and
- **Flexibility for firms to develop new approaches** to reduce deployment costs and manage risks through their commercial arrangements.

91. Ofcom must give regard to the Government's strategic priorities and desired outcomes in the exercise of its regulatory functions. Putting these into practice will require a large number of detailed decisions which will be a matter of regulatory judgement for Ofcom. Where Ofcom is unable to consider regulatory options that reflect the strategic priorities due to existing statutory duties, the Government will consider legislation to allow it to do so.

92. This approach, alongside the Review's other proposals, should incentivise established players to invest more in fibre networks and also make it more attractive for competing providers to build their own networks rather than buying wholesale services from the incumbent.

2.6.1 Greater regulatory stability and clarity

93. Full fibre networks typically have asset lives of more than 20 years, and have relatively long pay back periods. This means attracting patient long-term investors. The more stable and predictable the regulatory environment, the lower the risks for investors, making investment in fibre networks more attractive.

94. Ofcom conducts market reviews every three years for specific markets. The regulatory framework for telecoms market reviews is set out in UK legislation and is transposed from EU Directives. The EU's new directive for electronic communications – the European Electronic Communications Code (EECC) – is currently under negotiation. It is likely to be adopted by the EU shortly. If adopted, we are minded to implement, where appropriate, the substantive provisions in UK law, on the basis that it would support the UK's domestic policy objectives.

95. The EECC provides for longer review periods of up to five years. The Government believes that a move to longer review periods would provide greater regulatory stability and promote investment.

Greater regulatory clarity on assessment of risks and rewards, including 'fair bet'

96. The regulatory environment should seek to ensure that there is ex ante clarity regarding the application of Ofcom's 'fair bet' principle over an extended timescale. Applying the 'fair bet' principle will require Ofcom to exercise its regulatory judgement.

97. In the Government's view, an effective 'fair bet' regime would be one that allows firms making large and risky investments to have confidence that any regulation will reflect a fair return on investment, commensurate to the level of risk incurred at the time of making the investment decision.

98. Ofcom has previously stated that there are benefits in providing investors in new networks with greater clarity on the 'fair bet' principle and how it will be applied, so this can be factored into decisions on new risky investments.[50] We would encourage Ofcom to publish clear guidance that clearly sets out the approach and information it will use in determining a 'fair bet' return so that investors can factor this into their decision-making ahead of making major investments.

2.6.2 Regulation only where and to the extent necessary

99. The Government's strategic priority is to promote efficient competition and investment in new networks. This can be supported by regulation that is proportionate, consistent, and targeted only where necessary, and transparent.

100. Regulatory forbearance – by which we mean that the regulator refrains from intervening in markets or reduces the scope or level of regulation – could be key to giving investors the commercial flexibility, confidence and incentives they need to make large, risky investment in gigabit-capable networks. Regulatory forbearance has been successful in other countries in helping to drive investment in fibre networks. For example, forms of forbearance like not imposing access obligations on high-speed wholesale products, combined with effective passive access regimes, have been successful at incentivising fibre investment in Portugal and Spain.[51]

101. It is Government's view that regulatory forbearance should be considered by Ofcom, where appropriate, in developing its regulatory approach to incentivise the roll out of full fibre networks. The best outcome for full fibre rollout is likely to result from giving the market the freedom to evolve and only regulating if competition concerns clearly emerge.

102. In addition, the policy and regulatory framework should seek to provide reassurance that the interests of consumers are safeguarded as fibre markets become more competitive. One option would be to retain some price controls on copper-based products (which would serve as an 'anchor' on fibre products) during the transition to full fibre networks.

103. Ensuring that services are reliable and of high quality will be critical so that consumers are able to benefit from improved connectivity. While most consumers have a satisfactory experience in telecoms, quality of service is less strong than in other consumer markets. The Institute of Customer Service ranks energy, water and telecoms among the weakest performing markets for customer service. Ofcom's second annual service quality report, published in May 2018, found that broadband customers' overall satisfaction has fallen since 2016, although the proportion of mobile customers satisfied with their service has remained stable since 2016.

104. The Government is determined to work with Ofcom, communication providers, and other key stakeholders such as consumer groups to improve the overall quality of service delivered by the telecoms sector, drive up standards and ensure that the consumer environment supports our full fibre ambitions. The Government's consultation on the Consumer Green Paper closed recently. The Government will be considering the responses to that consultation and what further steps it needs to take to ensure that consumer markets, including the telecoms market, work for all, both now and in the future.

2.6.3 Recognition of the differences in local market conditions across the UK

105. The Government's view is that adapting regulation to market-specific competitive dynamics will likely be critical to achieving an appropriate balance between promoting investment and deployment at pace, and protecting retail competition and the interests of end users[52].

106. The UK wholesale local access market, today, is regulated as one geographic market, with the same set of regulations applying across all parts of country.[53] This approach has worked well for legacy networks where the incumbent has a nationwide footprint, and where investments have largely been based on incremental upgrades to existing networks. However, the roll out of full fibre will require significant, risky investments in new networks.

107. Investment decisions will likely vary across areas, reflecting the differing cost of rolling out networks – depending on the type of property, property density, difficulty of accessing roads and sites, and the proximity to existing passive infrastructure – in different areas. They may also be driven by expectations of the overall level of demand and willingness to pay.

108. This means that while some areas are likely to be commercially attractive for multiple networks to roll out, other areas may only be able to sustain one commercial fibre network, or none at all. Our analysis suggests that there will be three broad zones for fibre roll out:

- **Areas that can support commercial roll out of two or more gigabit-capable networks.** These would typically include cities, towns and some rural areas where the costs of deployment and demand conditions mean that it is commercially viable to invest. These areas are likely to comprise around 80% of premises.
- **Areas that can support commercial roll out of single fibre networks.** These would typically include smaller market towns and some rural areas where the costs of deployment and demand conditions would mean that it is commercially viable for one player to invest (c.10% of premises).
- **Areas that are unable to support commercial roll out.** There will be some parts of the country (c.10% of premises) which would not be commercially viable, and would require additional funding. These could comprise higher deployment cost remote or rural areas, with low population density and challenging geographies. See section 2.7.

109. Our analysis suggests that a large majority of the country will be able to support two or more competing gigabit-capable networks. In the early years, these areas may see only a single network; however, over time, these areas would see the presence of multiple networks.

110. The degree of any regulation should be proportionate to the characteristics of the market and competitive conditions – one would only expect to see regulatory interventions where competition concerns clearly arise. For areas where there is actual or prospective effective competition between networks, we would not anticipate the need for regulation as competitive pressures will shape investment and pricing decisions. For other areas, we would expect the regulatory model to evolve over time as networks are established. If market power emerges, regulated wholesale access (including price controls) may be needed to address competition concerns. However, this may not be necessary in the near term if there are regulated copper-based superfast products available to customers. These detailed regulatory decisions will be for Ofcom to take.

111. There may be some areas which, while commercially viable for at least one operator, do not benefit from any investment. There are a numbers of reasons why this could occur, for example there may be significant uncertainties on costs or the investment case is only attractive where it protects an incumbent's competitive position. These scenarios lead to 'hold-up' problems.

The 'hold-up' problem

There may be a 'hold-up' problem in areas where competing with other providers may not be profitable. In these areas the existing copper provider has little incentive to invest in FTTP unless it faces losing customers to a rival FTTP network. However, a rival network contemplating investment in these areas will anticipate that if it invests the incumbent will follow, with a headstart on existing infrastructure and customers. The incumbent, in turn, will be aware that this risk will be sufficient to deter new providers from entering the area. As a result, there is no investment.

112. The choice for this zone is between a bespoke solution and relying on the combination of competition and additional funding (see section 2.7) 'meeting in the middle'.

113. The package of measures set out in this document could, by reducing costs of deployment and uncertainty about future market conditions, be sufficient in some of these areas to 'unlock' investment. Similarly, the Local Full Fibre Networks programme is exploring the extent to which stimulating and aggregating public sector, SME and consumer demand can trigger commercial investment in full fibre networks.

114. Where we can identify and define the boundaries of areas in this zone, we will consider using 'competition for the market' mechanisms to secure deployment. There are a number of ways in which this might be achieved. We want the intervention to reflect the underlying factors that are holding back investments.

115. The proposed EECC gives new powers that can be used to identify areas where there is limited or no planned investment. It provides for national mapping of the current and forecast geographic coverage of broadband networks, which can be used to designate areas where no operator has indicated plans to deploy very high capacity networks. Ofcom or the Government could then use this information to invite operators to declare an intention to invest in these areas (e.g. percentage of premises by a certain date), and, where an operator does so, require other operators to confirm their intentions.

116. More generally, the Government is not persuaded that 'overbuild' should be discouraged in order to roll out full fibre. We are, however, interested in the effect that greater transparency might have on accelerating commercial network roll out. Transparency of build plans could give alternative operators the option to compete with Openreach, as we want and expect them to do in many parts of the country, or alternatively to allocate capital to roll out in other areas. We will discuss with BT and Ofcom how transparency measures such as this might be introduced, building on existing requirements under the terms of legal separation.[54] For example, Openreach could publish in advance an agreed medium-term plan of the areas in which it is planning to roll out its fibre network (suitably redacted for commercially sensitive information on the costs and revenues of roll out). Any approach should allow Openreach to roll out its FTTP network wherever it is profitable to do so.

Pricing under a geographically differentiated approach

117. We recognise that a geographically differentiated approach to wholesale regulation, if pursued, may lead to some variation in wholesale prices, reflecting differences in underlying costs and demand characteristics. This would be a departure from the current regulatory model, where BT is regulated to set a uniform national price.

118. Our analysis indicates that any retail pricing variations that may emerge are likely to be small.[55] Build costs are largely similar across the majority of the UK and competition between network providers should serve to lower prices. The areas where network build costs are significantly higher, correspond with areas where there is likely to be less competition. In these areas, operators can recover build costs from a larger pool of subscribers (given absence of competing networks). This should serve to reduce the per premises cost, which should be reflected in prices – and regulatory levers are available to protect consumers where necessary.

119. There are many benefits to retail service providers from uniform national prices, including enabling national marketing campaigns and enhancing customer relationships. Given these benefits, where any differences were to emerge in wholesale prices, we would expect retail prices to be largely uniform.

2.6.4 Flexibility for firms to develop new approaches to reduce deployment costs and manage risks

120. It is important that firms are able to agree appropriate commercial deals that share the risks (and gains) from fibre networks and support investment. Risk-sharing arrangements between networks and service providers and co-investment agreements between network providers have been important in the successful deployment of full fibre in other countries, notably in Spain, Portugal and France.[56]

121. Retailers of internet services to both residential and business customers have an important role in driving investment in full fibre networks. Wholesale agreements between network providers and ISPs could benefit both parties:

- For the network provider, an agreement from an ISP to quickly migrate its existing customer base provides demand certainty, reducing the risk that their network may remain unused after its commercial launch.
- ISPs can benefit from negotiating an attractive price for using a network, or agreeing a period of exclusive access, meaning that it can gain more customers by offering a faster, more reliable service in an area.

122. Generally, ISPs who have the relationship with customers are well-placed to promote the take-up of full fibre products through marketing, pricing and customer support. There is already evidence of such arrangements securing investment by new entrants. In 2014, TalkTalk, Sky and Cityfibre formed a joint venture agreement for a pilot project to build FTTP network to 14,000

homes in York. Since then, TalkTalk has begun the next stage of the build, which will extend the network to an additional 40,000 homes. Vodafone and CityFibre announced an agreement to deliver FTTP to up to 5 million UK homes and businesses by 2025 whereby Vodafone guarantees a minimum volume in return for a period of exclusive rights (predominantly during the build phase of each city network).

123. Co-investment arrangements typically allow operators to share parts of their networks and could be an important means to reduce costs and should be pursued on a commercial basis, where justified. Operators, including wholesale providers and retail service providers, are free to negotiate commercially between themselves within the bounds of competition law. Arrangements involving operators with significant market power raise more complicated regulatory issues. The new EECC is expected to make provision for the regulator to incentivise operators with significant market power to pursue co-investment arrangements to support the deployment of new fibre networks.[57]

2.7 Ensuring world class connectivity for all

2.7.1 The case for world-class connectivity for all

124. People's ability to enjoy world-class digital connectivity should not be determined by where they happen to live or work. There are strong economic and social reasons for national coverage. Fast, reliable fibre networks will offer significant benefits for rural areas

125. The approach described in this strategy aims to ensure that commercial investment in full fibre networks covers as much of the UK as possible. However, there will be some parts of the country that will be too costly for the market to deliver to alone. These parts of the country are likely to be largely in remote rural areas, with low population densities and, in many cases, topographic challenges. These factors increase the costs of deployment and reduce returns from fewer premises. The combination of high costs and low returns means the market is unlikely to reach them.

126. We have seen that fast, reliable connectivity can deliver economic, social and well-being benefits for both rural businesses and residents. Easier access to learning resources helps with schoolwork; improved video-calling to distant family reduces loneliness; and reliable access to national and local government services increases fairness.

127. The economic benefits of improved connectivity for rural businesses are potentially significant.

- A report published by Rural England and Scotland's Rural College, supported by Amazon, explored the economic potential from rural based businesses across the UK taking-up digital opportunities that arise from broadband, mobile and other networks.[58] The impacts most frequently mentioned by rural business as bringing significant benefits are: assisting remote working, improving access to customers/suppliers, improving business efficiency, improving data storage and security and enabling more business flexibility.

- A study by BT estimated the benefits of the Government's proposed £150 million investment in extending ultrafast broadband to rural areas of Northern Ireland at around £1.2 billion. Increased employment was identified as the largest source of benefit, alongside a significant contribution to productivity growth.[59]

128. Reliable, world-class connectivity also means that businesses and employees do not have to commute or move to more urban centres, and potential benefits from innovation in agri-tech can also be delivered. The longer-term impact of greater connectivity, reduced travel and greater innovation in rural businesses, not only have the potential to reduce pollution and improve productivity, but to help retain and attract young, talented people and families to rural areas, and reinvigorate rural societies and economies. Broadband providers' assessment of commercial viability is unlikely to capture these wider social and economic benefits to rural communities. As a result, commercial investment in connectivity may not reach the socially optimal level.

2.7.2 We will adopt an 'outside in' approach to deployment

129. We will pursue an 'outside in' strategy, meaning that the Government will look to support deployment of full fibre to the commercially most difficult to reach premises – likely to be around 10% of the total (approximately 3 million premises) – starting at the same time as the market deploys to commercially viable areas.

130. This strategy would enable these premises to receive gigabit-capable connectivity within the same timeframe as commercial areas, with all areas covered by 2033. This would be substantially faster than if these areas were left to the market to deliver. Investment in these areas will be phased, starting with areas that currently do not have superfast (and for which the productivity gains would be maximised given the low baseline of existing connectivity). A staged programme of investment would allow for testing and developing different technologies and implementation approaches before deploying them more widely. The Government sees advantages in a reverse auction-style model, in which operators would competitively bid for funds to roll out to the maximum number of premises in an area by a certain date.

We will build on current interventions so that investment in fibre networks starts now

131. To make sure that fibre delivery in these areas starts immediately, we will prioritise delivery of full fibre networks through the existing BDUK Superfast programme, which has already made FTTP available to over 200,000 premises by March 2018, in predominantly rural areas. Phase 3 of the Superfast programme is seeking to address coverage in as much of the remaining 5% of the country as possible, and Government will now maximise the amount of premises that can be covered with full fibre solutions.

132. We will also ensure that programmes delivered through the National Productivity Investment Fund (NPIF) are consistent with our objectives of maximising deployment of full fibre across the country. The Gigabit Broadband Voucher Scheme is already succeeding in stimulating new fibre investment and extending existing deployment plans by funding fibre connections for UK homes and businesses – including in very rural and hard-to-serve areas. The LFFN programme will continue

to explore how public sector demand and reuse of public sector assets can support full fibre deployment in these areas.

133. Government and Ofcom will consider further how our connectivity ambitions can complement existing programmes, including the roll out of the broadband Universal Service Obligation (USO) from 2020, to maximise investment in full fibre.

More support will be needed to ensure a roll out in uncommercial parts of the country

134. Further funding of some kind would be required to complete an 'outside in' approach. As well as premises identified as being in the 5% of the UK without superfast, other areas in the rest of the UK will not attract commercial investment to deliver full fibre due to various local factors. The analysis for the Review and the experience of the BDUK Superfast programme provides good insights into the areas where commercial investment in new networks is very unlikely to happen.

135. Our current analysis suggests that the additional funding requirement – i.e. in excess of the level of investment in commercially viable areas – for the c.10% of premises not likely to attract commercial roll out of FTTP could be in the range of £3 billion to £5 billion. We have already identified around £200 million within the existing Superfast programme that can further the delivery of full fibre networks. The Government will determine the longer-term options for funding rural connectivity as part of the forthcoming Spending Review process.

136. In common with previous Government interventions, competitive tenders will be used to award contracts in order to minimise subsidy requirement and ensure reliable and fairly priced services. Bidders will be encouraged to explore using a mix of wireless and fixed technologies to ensure value for money.[60] We envisage that single networks in these areas would be subject to wholesale access and pricing regulations to secure retail competition.

2.7.3 Innovative solutions can help reduce the costs of gigabit connectivity

137. Whilst national full fibre coverage is our long-term ambition, for the most remote areas we recognise that there may be instances where the geographical challenges are so great that providing gigabit-capable connectivity through alternative solutions will be the most effective approach. For example, hybrid fibre-wireless solutions might be a pragmatic solution, providing these areas with gigabit-capable fixed wireless access in a cost-effective way. On a small scale, an alternative means of fibre deployment could be a community-led model where local groups are involved in the build.

Locally led innovative solutions for connectivity

Using mixed technologies

Alternative network provider Wessex Internet (M12 Solutions), offers a mix of fibre optic and fixed wireless based superfast broadband services to rural parts of North Dorset, South Wiltshire and East Somerset in England. The provider deploys fibre to a mast (FTTM) in a location, such as the village centre, where wireless sector antennas are mounted for the final mile delivery to homes or businesses. When sufficient homes have taken-up connectivity and demonstrated there is enough demand, Wessex Internet then replaces it with FTTP, recovers the fixed wireless equipment and deploys it to the next village down the road. This way it has a growing 'bubble' of fibre radiating outwards and pushing the fixed wireless solution further and further outwards into rural communities. The result is that all premises in the area are eventually connected with full fibre, but in a way that reduces the investment risk for those installing the infrastructure.

Community led fibre deployment models

Broadband for the Rural North (B4RN), has over 4,200 full fibre connected properties and had investment of £4.8 million from local communities. As well as having its own engineering team, B4RN makes extensive use of resource from the communities themselves to dig and lay ducts. This works particularly well in rural communities where some of those involved are landowners who are willing to give permission for fibre to be laid across their land, as well as physically digging the trenches themselves using their own equipment. With communities supporting the deployment in this way, as well as making commitments to finance the build (through investing in B4RN) and becoming customers of the network, the business case for the network expansion – in areas most other operators would dismiss as unviable – is significantly improved.

Openreach have also created their Community Fibre Partnerships Programme which encourages poorly connected communities to group together to work with Openreach to jointly fund, and sometimes jointly build, new fibre infrastructure, with grant funding of up to £30,000 available from Openreach

2.8 Supporting the timely switchover to new full fibre networks

138. As full fibre networks are rolled out, maximising the number of end users will secure the full benefits of the technology. This will involve customers switching to new fibre networks ('switchover') and retiring the legacy copper networks ('switch-off'). It is realistic to assume that switchover could be underway in the majority of the country by 2030, but the timing will ultimately be dependent on the pace of fibre roll out and subsequent take-up of fibre products.

2.8.1 Customers and operators will benefit from switchover

139. In addition to the benefits of improved connectivity, reliability and choice of services that new networks will offer to consumers and businesses, there are significant benefits to network operators and service providers.

140. Once fibre networks are deployed in competitive areas and customers have switched, there are potentially strong commercial incentives for Openreach to retire its copper network. Running the two networks in parallel would be costly. Migrating all customers on to full fibre networks will also

allow network providers to manage their demand risks and spread their costs over a larger number of customers. This will provide greater certainty on their investment case, whilst also reducing costs per user.[61]

141. For internet service providers, the reliability and performance of fibre networks can reduce operational costs, such as network maintenance, customer service and customer retention. They will be able to offer a wider range of higher quality services to consumers.

142. While we would like to secure the benefits of fibre as quickly as possible and are supportive of industry moves to migrate customers from copper to fibre, we also recognise that fibre switchover and copper switch-off are substantial undertakings. The majority of consumers may welcome the move to fibre, but vulnerable consumers and those that have a telephone line but no broadband may be more reticent. It is important that these consumers are not disadvantaged by the switch to fibre. We also recognise that there may be business applications dependent on copper network connectivity that would need to be replanned and delivered in new ways. This means that a clear strategy is required to ensure a smooth, hassle-free transition from copper to fibre, and to provide vulnerable customers with further support they may need.

Switchover in Spain

In Spain, where they have adopted a pro-competition approach, Telefonica has switched off copper services as take-up of fibre has reached around 70-85%. As copper is being switched off, the regulator CNMC has imposed conditions on Telefonica to notify competitors within specific timescales (e.g. five years notice for access seekers).[62]

Migration from legacy networks is compatible with EECC provisions, and would require a reasonable timeframe and transition period from the network operator with oversight from the national regulatory authority.

2.8.2 Fibre switchover strategy – industry led, subject to conditions

143. Switchover should be led by industry, working closely with Ofcom and Government. The Government will set up a mechanism with Ofcom and industry for planning the switchover process. Switchover should meet a number of policy conditions:

- Plans support a **timely switchover**;
- **Efficient**, so that switchover is smooth with minimal consumer disruption;
- **Transparent**, so that customers have the information they need to make informed choices and clearly signalled via notice periods so operators have certainty;
- **Consistent**, with existing regulatory and consumer obligations;
- Pro-competitive, so processes are in place to support easy **switching between networks**; and
- A **fair deal** for consumers and **adequate safeguards** for vulnerable customers.

144. It is realistic to assume that switchover could be underway in the majority of the country by 2030, but the timing will ultimately be dependent on the pace of fibre roll out and subsequent take-up of fibre products.[63] We would only expect switchover to start when a significant proportion of the population has taken-up new fibre services.

145. The process would build on the work of industry and Ofcom preparing for the switch-off the Public Switched Telephone Network (PSTN), which is coming to the end of its life. PSTN will be retired by industry by the mid-2020s and be replaced by Voice over Internet Protocol (VoIP) technology, which uses a broadband connection to make calls.

Industry must ensure a smooth switchover process

146. Industry must be responsible for putting in place robust processes and systems required to support a quick, smooth and hassle-free migration of a large of number of customers from copper to fibre. They will need the capacity to handle a larger than usual number of people switching service and network providers.

147. To aid the migration of customers to fibre networks, we expect that network operators will offer suitable 'entry level' products at prices close to those offered on copper networks.[64] This would have the further benefit of protecting the interests of customers who do not want to pay for higher broadband speeds. Internet Service Providers will benefit from operational cost savings from the move to fibre (e.g. fewer faults) and we expect these to be passed on to consumers, reducing any cost increase to end users from switching. However, we note that the incentive to pass-through cost savings will be influenced by the level of competition. Additional safeguards for vulnerable consumers might include a requirement to provide an affordable land-line only product.

148. We expect that some of the problems associated with copper-based services that would not work on fibre networks (including care, home and security alarms) will have been addressed in the move to the IP-protocol telephone network. If further issues arise we would expect these to be addressed by providers and relevant industry stakeholders working together with Ofcom, including specific actions to identify and address the needs of potentially vulnerable people Ofcom will protect the interests of consumers.

149. Ofcom will have an important oversight role in ensuring industry readiness for switchover. Ofcom must protect the interests of consumers in the migration from copper to fibre and guarding against anti-competitive behaviour (e.g. Openreach has a large incumbent customer base and every incentive to migrate people to its own full fibre services).

150. Ofcom will continue to have a role in ensuring that switching processes are easy and reliable for consumers. This should include, in future, where customers switch between ISPs on different fibre networks (what is termed 'cross-platform' switching). Ofcom should also consider whether their regulatory approach to existing copper assets needs to change in light of the switch to fibre networks.

2.9 Legal separation of Openreach from BT

151. This Review should encourage Openreach to prioritise its future network investment in full fibre roll out, over upgrading legacy copper networks. Openreach can make a significant contribution to securing the goal of nationwide full fibre roll out. We also want to avoid a situation where investment in upgrading copper networks deters fibre investment by alternative operators, thereby reducing overall full fibre roll out and infrastructure competition. We would be concerned at any strategic behaviour that excluded rival operators by the threat of pre-emptive investment.

152. As part of our consideration of different market models, our Call for Evidence asked if the current arrangements for BT's legal separation were working effectively. We received a range of views on the respective merits of delivering legal separation compared to full structural separation.[65]

153. Under legal separation, a more independent Openreach, with a greater openness to different models of investment and risk sharing, and sharper incentives to be responsive to all its customers, has the potential to increase infrastructure roll out. At the same time, the option of structural separation could increase Openreach's incentive and ability to invest in full fibre by allowing greater access to lower cost capital.

154. We recognise the important steps that have been taken by BT Group and Openreach to implement legal separation, including setting up the Openreach Board, responsible for setting Openreach's strategy and overseeing its performance, and industry engagement on technology investment choices.

155. While Ofcom is broadly satisfied with progress towards legal separation, it has concluded that more needs to be done to fully realise greater independence, especially in decision making. The Government wants legal separation to be completed as soon as possible and for Openreach to address all outstanding actions, particularly the transfer of staff from BT to Openreach.[66] Openreach should also fully comply with Ofcom's regulatory obligations on ducts and poles access. This will be fundamental to ensuring all market participants are able to compete on a level playing field, whilst reducing costs of fibre deployment.

156. It is too early to determine whether legal separation will be sufficient to deliver the positive changes on investment in full fibre infrastructure. The Government will consider all additional measures if BT Group fails to deliver its commitments and regulatory obligations and if Openreach does not deliver on its purpose of investing in way that responds to the needs of its downstream customers.

3: A WORLD LEADER IN 5G

A world leader in 5G

3.1 Government's 5G ambition

157. We want the UK to have high quality, mobile connectivity where people live, work and travel. Mobile coverage is improving fast. 87% of UK landmass has a 4G signal from at least one operator (compared to 78% in 2017). Despite this progress, there remain areas where mobile connectivity must be improved, including extending geographic coverage to 95% of the UK by 2022 to address 'not-spots', increasing capacity in urban areas and improving connectivity on the UK's main roads and railways. We have recently introduced far-reaching changes to the Electronic Communications Code and to planning laws in England, to make it easier and cheaper to deploy mobile infrastructure. We are also working with Ofcom on options to extend coverage.

158. Alongside finishing the roll out of 4G networks, we want the UK to be a world leader in 5G and take early advantage of the benefits from this new technology. We have set a target that the majority of the population will be covered by a 5G signal by 2027. This Review sets out the Government's assessment of the policies and market conditions required to underpin investment and innovation in 5G.

159. 5G creates an opportunity for an expansion of the market – in the range of consumer and industry 'use cases', in the type of mobile services provided, and in the number of wireless operators. The Review's conclusion is that there would be strategic advantages in a model that maintains the benefits of network competition between multiple mobile network operators, while enabling solutions to specific connectivity challenges, including indoor coverage, rural coverage and enterprise applications.

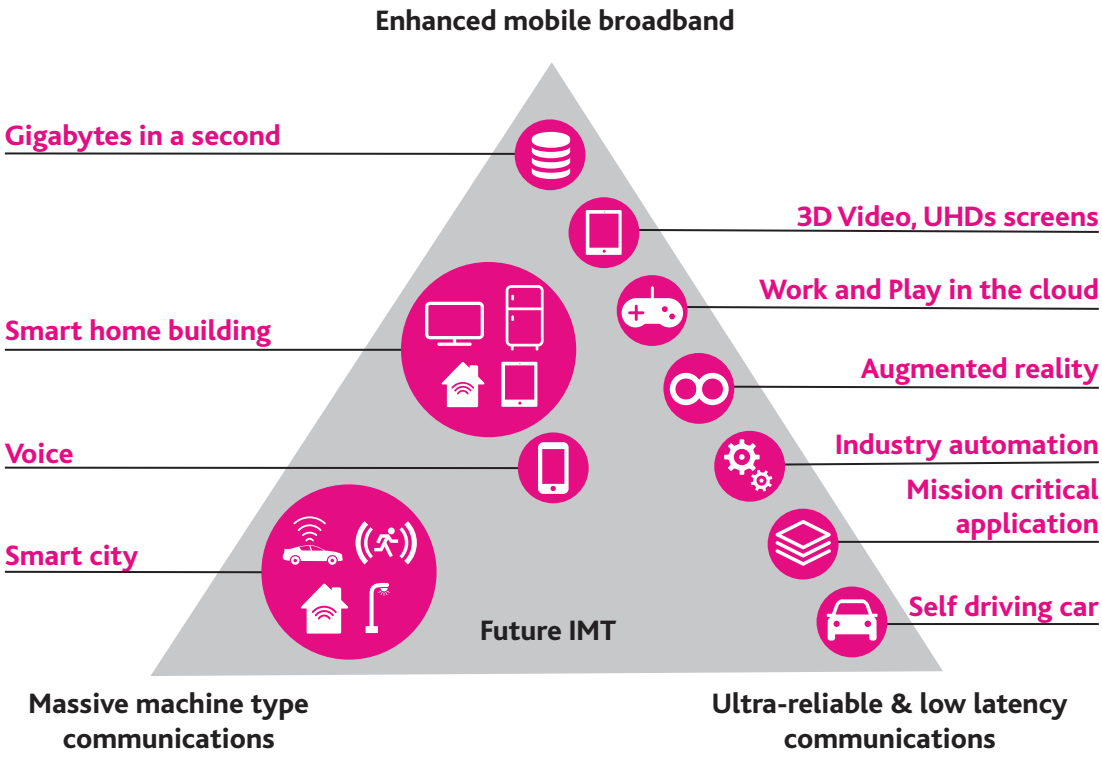
160. There is a role for policy and spectrum management in creating conditions that help to grow a competitive mobile market and support investment and innovation to realise the full benefits of 5G. In parallel, the Government will allocate public funding to promote beneficial 5G use-cases and therefore reduce risks around 5G investments.

3.2 What benefits will 5G bring?

161. The Government published two reports in 2017 setting out its views on the potential opportunities for the UK from next generation mobile networks.[67] 5G is the next generation of mobile technology; its technical capabilities and performance characteristics are clear. 5G will offer new capabilities over existing mobile technologies, including higher data rates, lower latency, higher energy efficiency and improved performance. 5G is the first generation of mobile technology designed to support multiple applications, from mobile broadband and entertainment services, to industrial applications such as robotics and logistics.

162. These applications will be delivered through different combinations of the three broad capabilities expected of 5G: enhanced mobile broadband; massive machine-type communications, with ten times as many devices able to be connected than with 4G; and ultra-reliable, low latency communications (near real-time communications with 99.999% reliability). Network 'slicing' will facilitate the simultaneous delivery of services with guaranteed technical performance that are tailored to the specific requirements of different sectors. These capabilities are illustrated in the diagram below.

Figure 4: Capabilities of 5G



Source: International Telecommunications Union (2015), 'IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond'

The 5G challenge

5G presents a policy puzzle. 5G has the potential to generate significant economic benefits from the digital transformation of many sectors. It will support enhanced consumer mobile broadband services. It could also enable the development of new use cases across a range of sectors where, to date, the provision of connectivity has not been a part of the business model. This includes advanced manufacturing and robotics, health and social care, transport and logistics, and smart agriculture. A recent EU study estimated that in 2025 benefits from the introduction of 5G capabilities could reach €113.1 billion per year across the region.[68]

The commercialisation of new use cases will be underpinned by the uptake of the technology by different sectors. Network operators may not be able to fully capture these external benefits via new business models, or else generate revenues to cover the costs of future infrastructure. On the demand side, there remains uncertainty about exactly where 5G will make the biggest impact and the extent to which demand for new applications and services will emerge. On the supply side, it is not yet clear how and where 5G networks will be deployed. It is likely that their development will be part of a wider ecosystem of wireless connectivity, building on investment in 4G networks and the ongoing development of fixed network infrastructure, with different upgrades required to deliver different use cases in different areas.

This puzzle could mean that 5G deployment may be less extensive than would be optimal for society.

While industry is best placed to respond to market demand, the Government has an important role to play to secure the positive benefits of 5G. Sections 3.5 – 3.8 set out the role that policy and regulation can play in supporting 5G investment and innovation.

3.3 What can the current market model deliver?

3.3.1 Competition and efficiency benefits will drive 5G investment

163. The UK mobile market is widely viewed as being competitive. Mobile operators differentiate themselves from their rivals in terms of different measures of network quality (e.g. speed, data and coverage), alongside other factors such as price and brand. These services are delivered through a market-based network competition model, with three main elements:

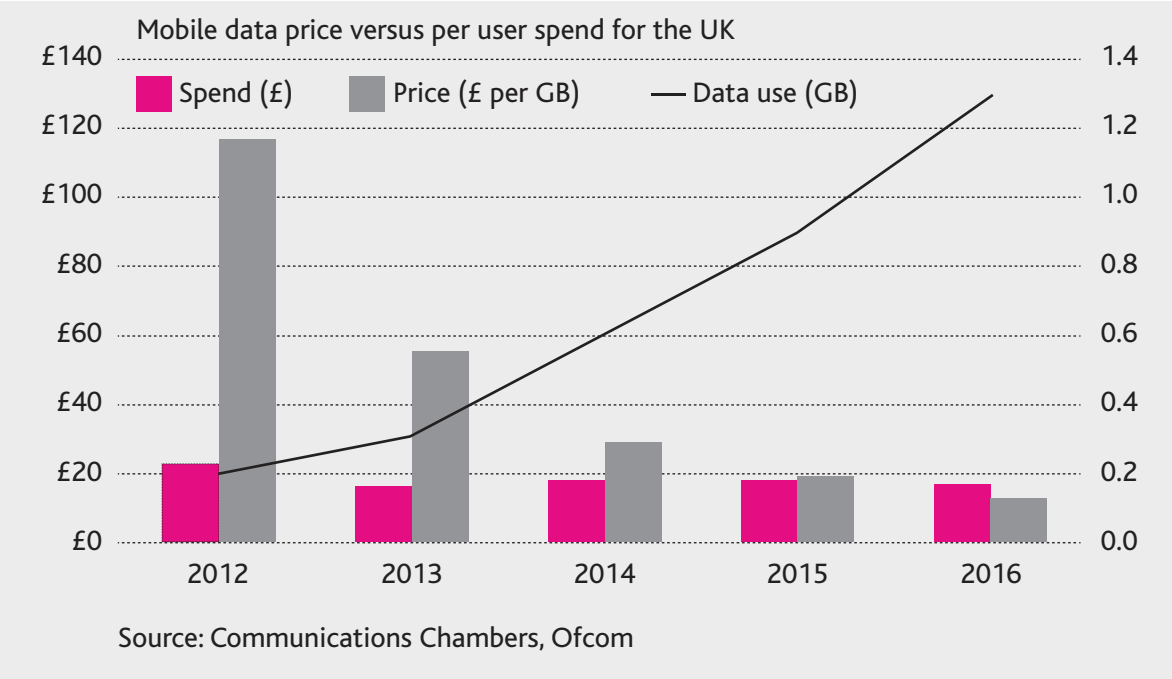
- **Retail services** are mainly provided by the four Mobile Network Operators (MNOs) who have c.85% share of retail mobile subscriptions, with around 90 Mobile Virtual Network Operators (MVNOs) also providing retail services.[69] The vast majority of MVNOs are focused on consumer mobile services; MVNOs also provide other services, including the Internet of Things (IoT).
- **Network infrastructure** is largely managed through two network sharing companies which are each a joint venture (JV) between two MNOs, supplemented by wholesale infrastructure providers (WIPs).[70] There are approximately 40,000 cell sites (e.g. mobile masts) in the UK, of which around a quarter are provided by WIPs.[71] These network sharing arrangements have been entered into commercially and support better services by reducing certain fixed infrastructure costs, whilst maintaining the benefits of network competition.

- **Spectrum** is a critical national asset and the Government wants to maximise the economic and social value for the UK from its use. The Government can set out its strategic priorities in relation to spectrum management, which Ofcom must take account of in exercising its functions in relation to spectrum. Mobile spectrum is currently licensed to mobile operators on a long-term basis. Spectrum management has been used by Ofcom as a means of maintaining competition in the mobile market – for example, by imposing caps on spectrum holdings in the most recent spectrum auction – as well as a vehicle to extend geographic coverage via licence obligations.

164. This competitive market structure has driven investment in previous mobile generations. For example, since the spectrum auction in 2013, the MNOs have rolled out 4G coverage at a relatively rapid pace, so that, by January 2018, 87% of the UK geographic area was covered by at least one operator.[72]

165. Investment in new, more efficient mobile technology is the primary means by which the unit costs and prices of mobile services have reduced over time. The chart below shows that whilst per user spend on mobile has been more or less constant since 2012, rapid data growth via 4G has led to a fall in the unit price of mobile data use.[73] [74]

Figure 5: Unit costs and prices of UK mobile services



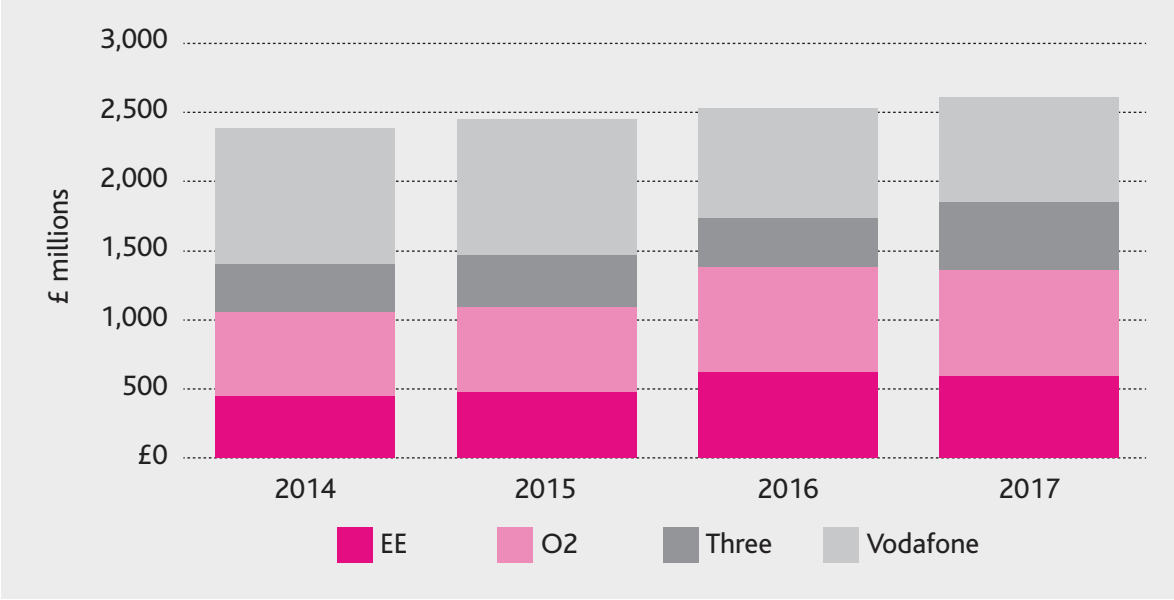
Source: Williamson, B (2018), 'Keeping an eye on the prize – investment in mobile networks to deliver coverage, capacity & the 5G strategy: A reappraisal of recurring spectrum fees'

166. At the same time, overall investment in the UK mobile market – and many European markets – has, historically, lagged behind global peers such as the US and Japan.[75] Although the retail mobile market in the UK appears to have stabilised following a number of years of declining revenues, overall growth is low.[76] Recent analysis shows that UK mobile service revenue growth hovered between 0.9% and 1.5% in the second half of 2017.[77] These growth figures mirror a wider global trend, with industry body GSMA noting that worldwide mobile revenue growth is expected at around 1% between 2017 and 2020.[78]

167. Despite this position, there is evidence that competitive market pressures are already incentivising investment in 5G. The MNOs have recently spent hundreds of millions of pounds acquiring spectrum in the 3.4 – 3.6 GHz 5G 'pioneer band'.[79]

168. This suggests that the relationship between past performance and investment in the mobile industry is weak, and investment decisions are largely driven by the competitive dynamics in the market and the desire to retain existing and attract new customers. The UK MNOs publish data on capital expenditure on an annual basis, which shows that overall capital expenditure has increased slightly over the past four years.[80]

Figure 6: UK Mobile Network Operators capex over time



Source: Frontier Economics

169. It is likely that market competition, efficiency benefits and consumer demand will incentivise further investment in 5G deployment. Some mobile operators may seek to gain a competitive advantage by marketing 5G to existing and potential customers, and thereby spur a response from other operators to protect market shares.

170. While the size of future economic opportunities is unclear, we would expect 5G to provide some new revenue opportunities for existing market players and so improve investment incentives.[81] The potential new use cases offered by 5G could also open up opportunities for network innovators and new service providers in the UK market.

3.3.2 Initial 5G deployment strategies are likely to focus on growth in capacity demand

171. For previous generations of mobile technologies, deployment strategies have been aimed at wide area coverage as far as possible. 5G is unlikely to follow a 'one size fits all' approach to deployment.

172. 5G is likely to be deployed as part of an intricate patchwork of technologies, including advanced LTE, Wi-Fi and 5G New Radio (a 'network of networks'). Deployment will be in phases rather than a 'big bang', and will likely vary by geography due to different demand levels and costs.

173. The diverse set of services and applications enabled by 5G will also require access to different spectrum bands with different characteristics. A realistic scenario is for a low capacity layer providing wide-area 5G coverage (using sub 1 GHz bands), with high capacity in areas of high demand such as towns and cities (using 3.4 – 3.6 GHz band) and, over the longer-term, smaller hotspots of very high capacity (using mmWave bands).

174. The Review's assessment is that early 5G launches will likely focus on enhanced mobile broadband services to increase the capacity and capabilities of existing networks, subject to the availability of consumer handsets. We expect to see the launch of the first commercial 5G consumer services in the UK in 2019. The first 5G deployments are likely to be in the 3.4 – 3.6 GHz band, which has been licensed to the national mobile network operators. This band is likely, initially, to be used to provide additional network capacity in highly populated areas, such as town centres.[82] It is likely to be deployed on both existing macro-cell sites and, where necessary, on additional sites using small cells.

175. 5G, in the longer-term, is likely to see a much greater deployment of small cells. These will be useful to provide extra capacity in specific outdoor locations with high demand, for example city centres, transport hubs and sports stadia. We are also likely to see the growth of small cells indoors to support new 5G-enabled services like factory automation.

176. Spectrum at very high frequencies (so-called 'millimetre wave' spectrum) can provide much higher data throughput, but will cover much smaller areas and cannot penetrate through walls. 5G deployments in these bands are, therefore, likely to be focused in specific locations requiring services with very high capacity.

3.3.3 Significant investment in 5G is likely over the next five years or so

177. The roll out of 5G will require substantial investment by MNOs and other players in all network domains, including spectrum, radio access network infrastructure, fibre backhaul and core networks.

178. We have undertaken initial analysis[83] to understand the level of investment and capital expenditure associated with 5G network roll out, if MNOs were to deploy both 700 MHz and 3 GHz spectrum on existing sites (subject to the outcome of future auctions), with:

- 700 MHz spectrum deployed on all existing sites; and
- 3 GHz spectrum deployed predominantly to provide additional capacity in areas of high demand.

179. In addition to the costs of the new radio equipment, capital investment is also likely to be required to strengthen some masts to support new equipment. Taken together, our high-level assessment is that the total capital expenditure that would be required to upgrade existing sites as per above is likely to be in the region of £4 billion to £5 billion.[84]

180. We have also considered a variety of scenarios for small cell deployments. The level of deployment across areas will be influenced by a variety of factors, including costs, site access, the new 5G services that emerge and the level of capacity demand.

181. There is no consensus on the number of small cells required for 5G and on the level of infrastructure sharing. As a purely indicative example, our estimates suggest that the capital costs of deploying 200,000 small cells (which could, for example, provide outdoor coverage in most urban areas) could be in the region of £3 billion, based on current costs.[85]

182. High-band 5G (in millimeter wave bands) would likely require a fundamentally different architecture, with a much greater density of cell sites and is not included in this analysis.

183. As noted in section 3.3.1, MNO capital expenditure has stayed broadly flat in the last few years. Information gathered for this Review, suggests that MNOs should be able to collectively invest around £1 billion per year on 5G rollout.[86]

184. This suggests that rolling out 5G on a mid-2020s timetable on existing sites is feasible within existing capex envelopes. Rolling out small cells in dense urban areas, which is where MNOs are likely to be most significantly capacity constrained, also appears feasible on a mid-2020s timetable. However, rolling out a more extensive 5G network that meets the needs of all potential use cases, may take considerably longer.

185. Given the greater number of cell sites likely required for 5G over the longer-term, the traditional model of cell deployment is likely to be too expensive and impractical to adopt. Operators will need to work together with local stakeholders to improve processes to enable more efficient small cell deployment.

3.4 What is the best future market model for 5G?

186. The Government's strategic priority is to promote efficient investment and innovation in 5G, and ensure that 5G deployment can occur at sufficient pace as new use cases and demand materialises.

187. There are a range of alternative market models that could emerge in the UK, with different approaches to service provision, network infrastructure and spectrum authorisation. We have considered three broad potential models and how they might promote 5G investment, innovation and availability:

- **Current Model.** In this model, there would continue to be multiple vertically integrated national operators, sharing infrastructure through commercial arrangements and supplementing this with the use of independent infrastructure providers. Competition at the retail level would be largely driven by the MNOs, with a degree of wholesale access provision to resellers, including MVNOs. Spectrum authorisation would continue to be on the basis of long-term national licences.
- **Single National Wholesale Network.** Under this model, a monopoly infrastructure provider would offer a wholesale service to MNOs and other wireless operators, with the aim of reducing costs and improving coverage. Spectrum might be pooled and allocated to the monopoly provider. An example of this model is the 'Red Compartida' or 'shared network' in Mexico. This is a wholesale-only network created as a result of government policy to expand mobile coverage, competition and create an environment for 5G services.
- **Market Expansion Model.** This relies on competition between multiple national networks but also enables new infrastructure and spectrum access models. In this model, the UK would continue to benefit from network competition between multiple national operators. National networks would be supplemented by 'neutral host' infrastructure and private networks to, for example, deliver small cell deployments in urban areas and in-buildings, or to expand rural coverage beyond that delivered by the MNOs, or to serve new micro-markets such as industry 'verticals'. Such infrastructure models could be supported by promoting access to 5G spectrum, through spectrum trading or potentially new spectrum sharing models. At the service level, enhanced mobile broadband services would be provided by MNOs and MVNOs, alongside new services enabled by existing and new players.

3.4.1 How we assessed these models

188. We have considered the potential models against a range of criteria – including the extent of 5G coverage, the pace of roll out, the costs, the incentives to improve quality and innovation over time, and how feasible it would be to implement the models.[87]

189. The Government recognises there is a debate about the optimal level of competitive intensity and consolidation in the UK mobile sector, and notes the number of recent mobile merger control cases across Europe, with a range of outcomes. The Government is clear that network competition between MNOs has been an important driver of mobile investment and expects that this will continue to be the case for 5G.

190. As far as the Government is concerned, there is no magic number of mobile network operators. Each merger control case should be assessed on its merits at a particular time, by the relevant authorities. The European Commission, supported by Ofcom and the Competition and Markets Authority, rejected a proposed merger of O2 and Three in 2016 because of pricing concerns resulting from a reduction in retail competition; concerns about the impact that a merger of MNOs in different network sharing arrangements would have on innovation and network roll out; and unease that there would be a reduction in wholesale competition with fewer potential hosts for MVNOs.[88]

191. There can be a tension between incentivising investment (with positive consumer benefits in the longer-term) and protecting consumers from the risk of higher retail prices in the short-term. Some argue that the increased cost efficiencies and increased scale from consolidation would enable greater investment and better consumer outcomes.[89] At the same time, other analysis suggests there is no significant difference in industry-level investment between four and three player markets.[90] Mobile investment should be closely monitored by Ofcom and appropriate options considered if it were to become clear that the current market structure was not supporting network investment in 5G at sustainable levels.

3.4.2 5G market expansion

192. The Review concludes that market expansion has the potential to deliver the best outcomes in terms of 5G investment, innovation and availability. The national mobile network operators will be central to 5G's successful delivery. 5G also creates the potential for innovative market entry via new infrastructure and service players. There could be strategic advantages in a model that maintains the benefits of competition between multiple national mobile network operators, while encouraging innovative solutions to specific connectivity challenges – for example, dense small cell networks to address in-building and outdoor hot-spots and not-spots, and improve rural coverage.

193. There is a role for policy and spectrum management in creating conditions that help to grow a competitive mobile market and support investment and innovation in 5G. The Review has identified four priority areas:

- Make it easier and cheaper to deploy mobile infrastructure and support market expansion, including the implementation of the wide-ranging reforms to the Electronic Communications Code (ECC) on site access and consideration of further planning reforms;
- Support the growth of infrastructure models that promote competition and investment in network densification and extension;
- Fund beneficial 5G-enabled use cases through the Government's 5G Testbeds and Trials Programme, to help de-risk business models for 5G; and
- Promote new, innovative 5G services from existing and new players, through the release and authorisation of additional spectrum.

3.5 Make it easier and cheaper to deploy mobile infrastructure

194. The Government has introduced recent reforms to planning policy and the Electronic Communications Code (ECC) to make it easier and cheaper to build mobile networks.[91] Measures to date have largely focused on macro cells; however, 5G, in the longer-term, is likely to require greater deployment of small cells. Additional measures will be required to make small cell deployment cost effective and practical. The Government has created the Barrier Busting Task Force to work with both the fixed and mobile telecoms industry to identify barriers to network deployment. Industry has asked us to prioritise a number of actions to reduce deployment barriers:

- Ensuring the ECC reforms achieve their intended effect;
- Considering further planning reforms to support macro site expansion and small cell deployment;
- Improving access to public sites and exploring ways to reduce costs;
- Facilitating access to power supplies; and
- Local solutions to address deployment barriers.

3.5.1 Electronic Communications Code

195. The ECC reforms came into force in December 2017. Independent economic analysis projected that these reforms could reduce the cost of accessing sites by around 40% over time.[92] The Government's view is that the reforms provide an effective regulatory framework to support infrastructure deployment. However, we recognise that there is a risk that these changes might lead to some market uncertainty and consequent negotiating difficulties during the transitional period. We are working closely with stakeholders across the sector to address these risks. The Government will consider undertaking a formal review of the ECC reforms to assess their impact in 2019.

3.5.2 Planning reforms

196. The Government recognises the need to keep planning regulation under review and to listen to suggestions from industry for how new technology is best supported in the planning regime. Therefore the Government will continue to work with the sector to promote understanding and take-up of the wide range of planning reforms brought forward and reflect on them to understand where the current planning regime could further support the deployment of digital infrastructure. If the telecoms industry can demonstrate that there are further reforms that could support deployment which warrant changes to planning, and make a clear case for change, we will work swiftly to consider the proposals and consult more widely on appropriate reforms. Our ambition, subject to the Parliamentary timetable, is to deliver any reforms as rapidly as possible.

3.5.3 Access to public sites

197. The Government, as a major landlord in the UK, will open up its own estate to support the deployment of mobile infrastructure wherever possible. We have developed a Digital Infrastructure Toolkit to aid this process and are publishing it alongside this Review. This toolkit addresses feedback from industry about barriers to deployment on government buildings, and seeks to streamline the agreement process between departments and industry. The Government will keep the toolkit under review and publish updates on the number of sites that are hosting mobile infrastructure.

198. In the longer-term, the toolkit has the potential to inform best practice for the wider public sector – from town halls to museums. The Government encourages other public sector landlords to make their own assets more readily available for network deployment.

3.5.4 Transmission and power

199. The Government recognises that the successful rollout of networks depends on seamless collaboration between communications providers and local authorities, energy suppliers, and landowners. Government will facilitate dialogue between MNOs and Distribution Network Owners to discuss access to the electricity system, to enable the timely and cost-effective deployment of fibre that is suitable for mobile backhaul.[93]

3.5.5 Local solutions are required to address deployment barriers

200. Local solutions are essential to address deployment barriers and require better collaboration between all parties. The Government's new Local Connectivity Group – bringing together local areas, industry and landowners – will publish best practice guidelines relating to the deployment of digital infrastructure at the local level by the end of the year. The Government intends to use the full range of available levers, including funding available through the 5G Testbeds and Trials Programme and Local Full Fibre Networks Programme, to encourage local areas to use the best practice guidelines to reduce or eliminate local barriers to deployment.

Aberdeen – A city with a long-term vision to maximise connectivity

Aberdeen City Council had a vision to maximise connectivity through world class infrastructure to ensure the long-term health of the City's digital economy. The Council shaped its street furniture concession to target significant long-term investment in enabling infrastructure for 4G, 5G and other wireless services and sought to maximise wireless connectivity by ensuring that new infrastructure would be available to all network providers. It awarded the concession to Wireless Infrastructure Group (WIG) – an independent provider of wholesale infrastructure.

After awarding the concession, the Council formed a steering group comprising representatives from several departments within the Council, including IT, Legal, Transport, Street Lighting, Planning, Roads and Digital Economy departments. This group worked in partnership with the concessionaire and played an essential role in developing efficient processes to access street furniture and ducts. This resulted in the delivery of wireless enabling infrastructure (shared antennas, cabinets, power, fibre, equipment hubs) ready to support future 5G services.

3.6 Supporting infrastructure models that promote competition and investment in network densification and extension

201. The UK mobile sector has a range of different infrastructure models. The MNOs are vertically integrated, enabling downstream benefits generated by new investment (e.g. from retail customers or MVNOs) to be captured. 'Neutral host' or wholesale-only models could unlock new investment[94], address some of the 5G deployment challenges and reduce barriers to entry for service providers.

202. Sharing of sites and network infrastructure, such as masts and antennas, could make the deployment of 5G more cost effective. The Government will support industry initiatives to build on current MNO commercial agreements to share infrastructure, provided this does not restrict competition in the market.

203. We also anticipate that different infrastructure models may be needed in different areas and as demand evolves. There are many potential forms of 'neutral host' infrastructure. At one extreme, a wireless infrastructure provider might supply passive mast and tower infrastructure only. At the other extreme, a neutral host provider could deploy their own active equipment, transmitting on behalf of MNOs and MVNOs either in their own spectrum or the MNOs' spectrum and delivering a data stream back to the MNO or MVNO.

204. Neutral host providers could help boost network coverage in the following areas:

- In remote rural areas, where there could be insufficient demand to justify multiple networks;
- In dense urban areas, where shared networks could be desirable in order to reduce deployment costs and minimise street clutter; and
- In offices and factories, where landlords may wish to self-deploy a single network (possibly through a third party service provider) to provide coverage and capacity within the building.

205. The Government has already recognised the role that wholesale infrastructure providers play in delivering investment, through its approach to reforming the Electronic Communications Code.[95] Our 5G Testbeds and Trials programme will aim to trial a range of infrastructure models.

206. In urban areas, where operators are most likely to densify their networks, sites suitable for hosting 5G infrastructure will be at a premium. Publicly-owned assets, such as streetlights, CCTV networks, and buildings, could be ideal for the siting of wireless infrastructure, in particular small cells; local authority underground cable duct networks can also be useful to enable the installation of the dense fibre networks needed to connect small cell networks.

207. Competitively tendered concessions are one way in which local authorities can make these assets available to the market. However, the Government understands that many recent concession contracts have tended to prioritise short-term revenues over connectivity benefits for the local community.

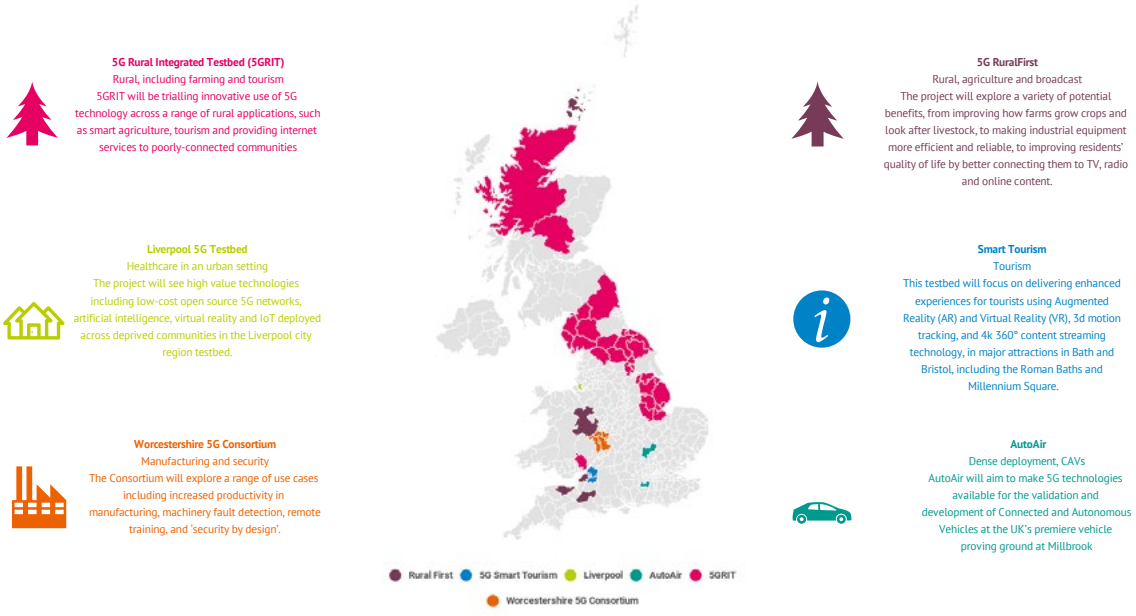
208. The Government would like to see all future concession awards giving greater priority to the proposed investment plans and quality of the mobile infrastructure provision of the bidders. The Government also believes that all future concession contracts should mandate the provision of the assets on an open access basis, under fair, reasonable and non-discriminatory terms. This approach should deliver better long-term outcomes for local areas. The Government's new Local Connectivity Group will help to develop best practice in this area.

3.7 Stimulating demand and new use cases through the 5G Testbeds and Trials Programme

209. Given demand uncertainty and the fact that some 5G benefits (e.g. to productivity and public service provisions) may not be fully captured by the market, the Government has a major role to play through stimulating the growth of new use cases and so de-risking deployment.

210. The Government's 5G Testbeds and Trials Programme is funding a series of projects that bring together existing telecoms players with those in 'vertical' industry sectors to explore different connectivity solutions and, critically, the business models. In addition to the world-leading project that the Government funded at the 5G Innovation Centre at Surrey University, the University of Bristol, and King's College London, the Government has announced an initial phase of testbeds and trials (see figure 7), as well as an intention to fund a major urban connected community project. We will set out the next stages of the Programme shortly.

Figure 7: 5G Testbeds and Trials Programme Phase 1 projects



Source: DCMS 5G Testbeds and Trials Programme

3.8 Securing a diverse set of innovative 5G services through spectrum policy

211. The Government is clear that the national mobile operators will be central to the successful delivery of 5G. Competition between existing operators, coupled with infrastructure sharing to reduce fixed costs, will remain an important driver of investment. Alongside this, 5G brings the potential for the expansion of a competitive mobile market with new players also playing an important role: attracting new sources of capital; introducing new business models; and stimulating innovation.

212. Under measures introduced by the Digital Economy Act 2017, the Government can set out its strategic priorities in relation to spectrum management, which Ofcom must take account of in exercising its regulatory functions. The Government has two key strategic priorities for the 3.6 – 3.8 GHz band – first, to ensure the most efficient use of the spectrum and, second, to facilitate access to spectrum to support the availability of new 5G services and applications, thus promoting dynamic efficiency and innovation.

213. Ofcom has set out a plan for releasing 5G spectrum in line with the timeframe for development of 5G standards and technology.[96] This includes the 3.4 – 3.6 GHz auction which concluded in April 2018 and the plan to auction spectrum in the 700 MHz and 3.6 – 3.8 GHz bands in 2019. Ofcom is also considering a more flexible approach for the future licensing of the 3.8 – 4.2 GHz band and spectrum above 20 GHz.

214. The Government wants Ofcom to complete the award of the remaining 5G spectrum bands of 700 MHz and 3.6 – 3.8 GHz in a timely manner. We are also mindful, however, that the development of a set of innovative 5G services and new investment models may require more flexible approaches to spectrum licensing. This was also a key recommendation of the NIC's 5G report.[97]

215. Ofcom has indicated plans to extend shared access to 3.8 – 4.2 GHz, allowing for coordination arrangements between new and existing users.[98] However, this band is used by satellite earth stations and the Government understands that it may be a number of years until this band is widely available in consumer handsets and other 5G equipment, compared with the 3.6 – 3.8 GHz band and other bands harmonised for 5G in Europe.

3.8.1 Increasing spectrum utilisation, to promote efficient use of spectrum

216. Increasing demand for mobile data can be addressed, in part, by the use of higher frequency spectrum, which enables the provision of higher bandwidth services. In the short to medium-term, demand for capacity is likely to be concentrated in highly populated areas. In addition, the characteristics of spectrum propagation are such that the higher the frequency, the less far it travels (although this could be partially mitigated by 5G technological advancements). This means that, as higher frequencies are used, deployments are likely to be increasingly localised and targeted at areas of higher demand. There is therefore a possibility of higher frequency spectrum being under-utilised without the introduction of flexible authorisation approaches.[99]

217. The NIC recognised this challenge in their study: *"Auctioning spectrum licences in large, national scale blocks, at these very high frequencies, risks a significant share of the radio spectrum lying fallow in large parts of the country where it is not profitable for operators ... deploying the dense networks described above may not be profitable for the major operators in these areas, yet the spectrum will still be inaccessible to other users. This could act as a barrier to entry for new firms to compete in the provision in mobile services and may impede the most widespread deployment of 5G high frequency small cells."*[100]

218. The 5G Innovation Centre at the University of Surrey has estimated that a traditional licensing route for 3.6 – 3.8 GHz spectrum could lead to a low geographic spectrum efficiency outcome.[101]

3.8.2 Providing access to spectrum, to promote dynamic efficiency and innovation

219. Spectrum sharing models could enable new players, alongside existing mobile operators, to access spectrum and invest in new business models. They could unlock opportunities for innovative 5G use cases and help increase the availability of services by addressing specific connectivity challenges, including:

- Community or small provider solutions (e.g. fixed wireless access) to meet the needs of local, often rural, areas;[102]
- Wholesale-only providers to address urban hot-spots and not-spots (indoors and outdoors) through small cell networks; and
- Private networks to support innovation in the industrial internet of things, including wireless automation and robotics.

220. Evidence provided to this Review has found that potential market entrants are seeking more certain access to 5G spectrum to support their investments, for example access to light-licensed spectrum on a first come, first served basis.[103]

221. The evidence this Review has received indicates that there are various *potential* shared access models that merit consideration, including:

- **Light-licensing models**, which permit coordinated use of spectrum across the country by multiple operators through a registration process and database. This could be through localised or pay as you go licences. Having some 5G spectrum set aside for light-licensing would ensure that there would always be some spectrum available for shared access, to create investment certainty for new entrants, even in urban areas where MNOs are likely to deploy these frequencies.[104] Access to this block could be controlled by database access in order to provide future flexibility. This could support use cases including indoor coverage for factories, office buildings and event venues in urban areas; neutral hosts for mobile network densification; and road and rail corridors.

- **Dynamic spectrum access (DSA)**, which uses a database to identify spectrum that is unused at any time and location by the licensed incumbent and make it available to other users without causing interference. This model would provide opportunistic access to spectrum to existing and new players by making available unused 5G spectrum, and would give priority to the principal licensee. DSA techniques are already used in so-called TV White Space, which is unused spectrum in the frequency bands used for Digital Terrestrial Television broadcasting. This method is likely to be particularly useful to enable the provision of wireless broadband services in rural areas that are less likely to be covered by 5G mobile networks.
- **Other models,** include licence-exempt access like Wi-Fi, or concurrent shared access, where multiple operators are licensed to operate in the same spectrum, and coordinate interference management between themselves – an example of which is the 1800 MHz guard band.

222. Different models will raise trade-offs around network competition, innovation and widespread deployment of 5G. The Government recognises that operators have a preference for national licences and that wide spectrum holdings will be needed to provide high quality 5G services. At the same time, we have a strategic priority to ensure the efficient use of new 5G spectrum and encourage innovative uses.

223. We would, therefore, encourage Ofcom to assess the feasibility, costs and benefits of potential flexible licensing models, and also consider the trade-offs involved, as part of its continuing consultation on the planned release of spectrum in the 3.6 – 3.8 GHz band, in addition to its work on the 3.8 – 4.2 GHz band.

224. The Review observes that many other national authorities are adopting flexible 5G licensing strategies to enhance efficiency and innovation in the use of spectrum:

- In Germany, where there are three national MNOs, 3400 – 3700 MHz spectrum will be assigned on a national basis to cater for the nationwide operators, and the remaining 100 MHz (3700 – 3800 MHz) will be assigned on a local and regional basis. The aim is to ensure that spectrum is used efficiently and emerging spectrum requirements can be met, including for small and medium-sized enterprises, and industrial applications;[105]
- In Sweden, the regulator is planning to award the 3400 – 3800 MHz frequency bands in sub-national areas defined according to population density;
- In France, the regulator has made 3410 – 3460 MHz available for regional licences for wireless broadband services to be deployed in areas where high speed networks are not available in the short-term, subject to deployment and coverage obligations;
- The Italian regulator has announced that it will auction two blocks of 80 MHz and two blocks of 20 MHz in the 3.6 – 3.8 GHz band, with measures to encourage roll out in rural areas and with the express intention of encouraging independent infrastructure providers, as well as service providers targeting specific industry sectors; and

- In the US, the Federal Communications Commission has established the Citizens Broadband Radio Service for shared wireless broadband services in the 3550 -3700 MHz band. This operates through a tiered framework to allow for a number of commercial uses, and will be managed by a dynamic spectrum access system.

Using 'White Spaces' to deliver superfast broadband

Broadway Partners is using dynamic spectrum management techniques to access unused spectrum in TV White Space to deliver superfast broadband on the Isle of Arran. Broadway Partners uses hybrid state-of-the-art 5 GHz (Wi-Fi) and TV White Space networking solutions that are well suited for both hard to reach rural areas and urban not-spots. They work in collaboration with leading experts in White Space technology, including Microsoft, Nominet, Strathclyde University and King's College London.

The 5G Testbeds and Trials Programme is supporting further projects looking at this area. The 5G Rural First project will trial rural use cases (such as agri-tech, broadcasting and community connectivity) using spectrum sharing, including dynamic spectrum access technologies. The focus is on testing and demonstrating innovative approaches for ensuring that 5G connectivity is accessible and affordable in hard-to-reach rural areas, such as Somerset, Shropshire and the Orkney Islands. The project partners hope to test the potential for 5G to encompass and integrate licensed, licence-exempt and shared spectrum, as well as new models for infrastructure ownership such as community mobile networks.

225. In order to identify the opportunities for spectrum sharing in the mobile bands and the extent to which spectrum sharing policies are increasing the utilisation of spectrum, the Government will ask Ofcom to report on the utilisation of spectrum in the mobile bands. This information will identify the parts of the UK where spectrum in each mobile band is not being fully utilised and the extent to which it is being used by non-MNOs and/or through spectrum sharing arrangements.

226. More broadly, the Government believes that there should be greater liquidity in the spectrum market. The Government would like Ofcom to provide clarity that leasing of mobile spectrum is not prohibited, to promote greater liquidity in the spectrum trading market.

4: CONVERGENCE OF NETWORKS AND MARKETS

Convergence of networks and markets

4.1 Government's ambition

227. In the longer-term, the Government expects to see a more converged telecoms sector, recognising the benefits of convergence across fixed and mobile networks.

4.1.1 Convergence of networks

228. Full fibre networks and 5G are complementary, and the distinction between fixed networks and mobile networks is increasingly being eroded.[106] Delivering the high speed and high capacity capabilities of 5G will require dense fibre networks. In some places 5G could provide a more cost-effective way of providing ultra-fast connectivity to homes and businesses. 4G and 5G technology can be used to provide high capacity wireless broadband connections to the home. 5G has the potential to deliver seamless connectivity, so that consumers with wirelessly connected devices will be able to move easily between mobile and fixed networks.

229. The technology synergies between 5G and fixed networks are likely to create strategic advantages for operators that have interests in both. These will likely derive from economies of scope and higher utilisation of network capacity, on the cost side, and from the ability to bundle services and offer new products like fixed wireless access on the revenue side.

4.1.2 Convergence of markets

230. Consumers can benefit from an expansion of converged offers, allowing more seamless delivery of content and services across networks and enabling simpler billing and more flexible tariffs. We should ensure that obstacles are removed that could prevent or impede the greater convergence of fixed and mobile networks in the UK, given the benefits for long-term infrastructure investment.

231. The UK market has recently seen the growth in the availability of retail bundles that include multiple services such as broadband and pay-TV, with quad-play bundles now also adding mobile telecoms services.

232. However, in the UK, there are fewer converged or integrated network operators compared to some other markets. Countries with the best fibre infrastructure tend to be characterised by significant network convergence and the use of fibre networks for fixed, mobile and IPTV services. For example, in Spain, 96% of fixed broadband services are bundled with other types of communications services, and in France the four leading French operators[107] have also implemented converged strategies by launching fixed-mobile and pay TV bundles.[108]

4.2 A flexible policy and regulatory framework that recognises convergence

233. Our preferred market models, detailed in section 2 and 3, will create greater opportunities for network convergence in the UK, by supporting strategic relationships between fixed and mobile operators seeking to exploit these synergies. We would expect to see operators, in future, considering the benefits of using their assets for both fixed and wireless networks, rather than operating as stand-alone providers.

234. The policy and regulatory framework should be sufficiently flexible and forward-looking to reflect the growing convergence between fixed and mobile networks and services. This could be achieved through:

- Removing practical obstacles or barriers to converged networks;
- Considering access network requirements holistically, through unified market reviews; and
- Allowing operators to benefit from unrestricted usage of Openreach's passive infrastructure for the provision of mobile backhaul services.

4.2.1 Removing practical obstacles or barriers to converged networks

235. One of the key challenges in building fibre networks that support multiple services (i.e. fixed and 5G) will be to forecast accurately where 5G cell sites will be needed in future. This will be necessary to identify extra fibres and break-out points that can be incorporated into physical networks today, thereby reducing the need for subsequent civil engineering when 5G networks are rolled out. It is important that the networks required for full fibre services are built in ways that can support 5G cells.

236. The Government would like network operators and mobile operators, working with local authorities and other relevant parties, to engage on the likely locations for 5G cell sites, for the purpose of ensuring that fibre networks can be future-proofed.[109]

237. The Government will support this by ensuring that existing programmes, in particular 5G Trials and Testbeds and LFFN, promote investments that recognise convergence, and use the new Local Connectivity Group to share information from these programmes more widely.

4.2.2 Recognising convergence and considering access network requirements holistically, through unified market reviews

238. Ofcom currently conducts separate market reviews for business connectivity and wholesale local access market (covering homes and small businesses). As wholesale access networks move from copper to fibre, networks are increasingly able to support a range of uses. For example, FTTP networks built for residential broadband can also be used for mobile backhaul.

239. This distinction between markets may lead to inefficient investment decisions. For example, the DPA remedy only applies to the WLA market and can be used only for fibre deployments which are primarily intended for residential or small business use[110], but not for fibre networks that serve dedicated mobile backhaul links or core network links for fixed networks. Fibre providers who want to exploit synergies and provide multiple services, including for mobile network backhaul, may therefore be excluded from using DPA, increasing their costs, and increasing the costs of 5G roll out.

240. Ofcom should consider moving to single, unified market reviews. Combined with the availability of longer review periods (outlined in section 2), this would signal a long-term commitment to support infrastructure investment.

4.2.3 Unrestricted access to ducts and poles for all purposes

241. A key requirement of 5G networks will be the increase in fibre needed for mobile backhaul. The backhaul links for small cells, for example, will need to be high speed and high capacity, to match the capacity of 5G radio networks. It is important that mobile operators and infrastructure providers have access to the key inputs for network densification, including sufficient fibre backhaul capacity.

242. As noted above, access to Openreach's duct and pole network will be an essential tool to ensure that industry can deploy cost-effective backhaul services that can scale to meet the demands of 5G networks. France and Spain, for example, require operators with significant market power to provide access to their ducting networks for the purposes of deploying fibre networks, including for mobile backhaul.[111]

243. Ofcom has prescribed duct and pole access (the regulated product is known as Physical Infrastructure Access or 'PIA') as an ex ante remedy in the market for Wholesale Local Access.[112] Under this remedy, the right of access to Openreach ducts and poles is restricted to networks used primarily to deliver broadband to small offices and homes.[113]

244. Ofcom should consider removing these restrictions on use as soon as possible, so that DPA can be used to support fibre networks for mobile backhaul. In line with the recommendations in section 2.5, where DPA is not available or of sufficient quality, the Government would also like Ofcom to assess the merits of alternative effective backstop remedies, including dark fibre access.

245. The Government has received a range of evidence from industry on the case for a viable, cost-effective dark fibre access remedy on Openreach for mobile backhaul. The Government encourages Ofcom to consider the merits of this regulatory option.

246. As noted in section 2.5 of this Review, greater use should also be made of other multi-utility infrastructure where possible, to support the cost-effective deployment of fibre for mobile backhaul. The Communications (Access to Infrastructure) Regulations 2016 provide a framework for this, but evidence suggests that the market is not yet making extensive use of these regulations. As mentioned in section 2.5, the Government intends to review these Regulations in 2019.

5: NEXT STEPS

Next Steps

247. This document sets out a national, long-term strategy for digital connectivity. Building the infrastructure across the country to support world-class connectivity is a significant undertaking. Government, regulator and industry must work together to make it happen. We will create the supportive market and policy conditions. We will look to industry to attract the necessary capital, roll out the infrastructure and promote take-up.

248. The strategy sets out a package of policy measures that the Government will take forward in the short-term. These are summarised in the following pages. There has been a long history of cooperation with the Devolved Administrations, especially in the rollout of superfast broadband, that we intend to continue. We recognise that some of these issues will be devolved or linked to devolved strategies, for example, issues concerned with planning or any changes to building regulations. We will continue to work closely with the devolved administrations in taking this forward.

249. We will shortly publish consultations on legislative changes to streamline wayleaves and mandate fibre in new builds. The Government will keep planning regulations under review and continue to work with the sector to promote take-up of the wide range of planning reforms brought forward, and to understand where the current planning regime could further support the deployment of digital infrastructure.

250. The EU's new directive for electronic communications – the EECC – is currently under negotiation. It is likely to be adopted by the EU shortly. If adopted, we are minded to implement, where appropriate, the substantive provisions in UK law, on the basis that it would support the UK's domestic policy objectives. This will enable the extension of market review periods to five years and provide mechanisms to aid fibre network roll out in certain areas.

251. The Government will pursue an 'outside in' strategy to support deployment of full fibre to the commercially most difficult to reach premises, likely to be around 10% of the total (approximately 3 million premises). We will use competitive tenders to award contracts for these areas to commercial operators, in order to minimise any public subsidy requirements and ensure fairly priced services. The Government has already identified around £200 million within the existing Superfast programme that can further the delivery of full fibre networks. The Government will determine the longer-term options for funding rural connectivity as part of the forthcoming Spending Review process.

252. The conclusions of the Review will also form the basis of the Government's Statement of Strategic Priorities to Ofcom, setting out the strategic objectives and outcomes that the regulator should have regard to in the exercise of its regulatory functions. In particular, the Statement will emphasise the importance of promoting investment as the key to achieving UK's connectivity ambitions.

253. The delivery of this national broadband strategy is a core part of the UK's Industrial Strategy and is of fundamental importance to the country's future global competitiveness. We will, therefore, monitor progress on an annual basis and undertake a full review of the strategy's impact after three years. At this point, we will consider all additional measures to ensure the strategy is on track, including actions, if necessary, in those parts of the country that have not benefited from competitive deployment, but where operators could reasonably have been expected to have deployed fibre networks over this period. The Government will consider the more widespread use of 'competition for the market' mechanisms to ensure the roll out of fibre networks in those parts of the country.

Summary of FTIR recommendations

Full fibre connectivity

Reducing costs and barriers to deployment

- The Government will consult on new legislation to reform existing wayleaves arrangements – to provide a 'right to entry' for communications providers – and ensure full fibre connections to new build developments.
- The Government will streamline the permits regime and introduce best practice and guidance toolkit for street works.

Promoting market entry and expansion for new network operators

- The Government will continue to work with Ofcom to ensure that Openreach cooperates fully with DPA requirements to open up its passive infrastructure. If the evidence shows that this remedy is not being implemented properly, the Government will consider all options with Ofcom to ensure compliance.
- Where ducts and poles are not available or ineffective, the Government will encourage Ofcom to consider other options to enable market entry by alternative networks, including dark fibre access.
- The Government will carry out a review of Communications (Access to Infrastructure) Regulations 2016 by 2019 to assess if there are improvements that could be made to further boost investment in infrastructure.
- Ofcom should work collaboratively with other regulators to ensure that multi-utility passive sharing opportunities are explored, and barriers addressed.
- The Government will continue to build on the successes of existing programmes to stimulate demand for fibre services, including actively considering full fibre solutions when purchasing government services.

Stable and long-term regulation that incentivises competitive network investment

- The Government's overarching strategic priority is to promote efficient competition and investment in world-class digital networks. The Government's view is that promoting investment should be prioritised over interventions to further reduce retail prices in the near term, recognising these longer-term benefits.
- The Government has identified a set of outcomes with a view to achieving this strategic priority:

    - The Government believes that a move to longer, five year review periods could provide greater regulatory stability and promote investment.
    - The Government would encourage Ofcom to publish guidance that clearly sets out the approach and information it will use in determining a 'fair bet' return.
    - The Government's view is that regulatory forbearance is considered by Ofcom in developing its regulatory approach to incentivise the roll out of full fibre networks.
    - The Government's view is the regulatory framework should provide reassurance that the interests of consumers are safeguarded as fibre markets become more competitive.
    - For areas where there is actual or prospective effective competition between networks, Government would not anticipate the need for regulation. For other areas, we would expect the regulatory model for to evolve over time as networks are established. If market power emerges, regulated access (including price controls) may be needed to address competition concerns. These detailed regulatory decisions will be for Ofcom to take.
- For areas where there may not be commercial investment, even when commercially viable:
    - The Government will consider using 'competition for the market' mechanisms to secure deployment, including new powers under the EECC.
    - The Government will discuss with BT and Ofcom how transparency measures might be introduced.
- The Government is determined to work with Ofcom, communication providers, and other key stakeholders such as consumer groups to improve overall customer service in telecoms, drive up standards and ensure that the consumer environment supports our full fibre ambitions. The Government will be considering the responses to the Consumer Green Paper that consultation and what further steps it needs to take to ensure that consumer markets, including the telecoms market, work for all, both now and in the future.

Ensuring world class connectivity for all

- The Government will pursue an 'outside in' strategy to support deployment of full fibre to the commercially most difficult to reach premises, likely to be around 10% of the total (approximately 3 million premises), starting at the same time as the market deploying to commercially viable areas.
- We will use competitive tenders to award contracts for these areas to commercial operators, in order to minimise any public subsidy requirements and ensure fairly priced services.
- The Government has already identified around £200 million within the existing Superfast Programme that can further the delivery of full fibre networks.
- The Government will also ensure that programmes delivered through the National Productivity Investment Fund (NPIF) are consistent with the objective of deployment of full fibre across the country.
- The Government and Ofcom will consider further how our ambitions for fibre deployment can complement existing programmes including the roll out of the broadband Universal Service Obligation (USO) from 2020 to maximise investment in full fibre.
- The Government will determine the longer-term options for funding rural connectivity as part of the forthcoming Spending Review process.

Supporting the timely switchover to new full fibre networks

- Switchover should be led by industry, working closely with Ofcom and Government. The Government will set up a mechanism with Ofcom and industry to plan switchover.
- Switchover should meet a number of clear policy conditions:
  - Plans support a timely switchover;
  - Efficient, so that switchover is smooth with minimal consumer disruption;
  - Transparent, so that customers have the information they need to make informed choices and clearly signalled via notice periods so operators have certainty;
  - Consistent, with existing regulatory and consumer obligations;
  - Pro-competitive, so processes are in place to support easy switching between networks; and
  - A fair deal for consumers and adequate safeguards for vulnerable customers.
- Ofcom will continue to have a role in ensuring that switching processes are easy and reliable for consumers, where customers switch between ISPs on different fibre networks.

Legal separation of Openreach from BT

- The Government wants legal separation to be completed as soon as possible and for Openreach to address all outstanding actions, particularly the transfer of staff from BT to Openreach.
- The Government will consider all additional measures if BT Group fails to deliver its commitments and regulatory obligations and if Openreach does not deliver on its purpose of investing in way that responds to the needs of its downstream customers.

A world leader in 5G

Make it easier and cheaper to deploy mobile infrastructure

- The Government recognises the need to keep planning regulation under review and will continue to work with the sector to promote take-up of the wide range of planning reforms brought forward and to understand where the current planning regime could further support the deployment of digital infrastructure.
- The Government, as a major landlord in the UK, will open up its own estate to support the deployment of mobile infrastructure wherever possible.
- The Government will consider undertaking a formal review of the ECC reforms to assess their impact in 2019.
- The Government will work with industry to understand their concerns and explore whether there are additional ways to support collaboration between utility providers and communications providers to deliver connections to energy infrastructure in as timely and cost-effective manner as possible.
- The Government's new Local Connectivity Group – bringing together local areas, industry and landowners – will publish best practice guidelines relating to the deployment of digital infrastructure at the local level by the end of the year.

Supporting infrastructure models that promote competition and investment in network densification and extension

- The Government would like to see all future concession awards giving greater priority to the proposed investment plans and quality of the mobile infrastructure provision of the bidders.
- The Government intends to use the 5G Testbeds and Trials programme to trial a range of infrastructure models.
- The Government's new Local Connectivity Group will help to develop best practice in awarding concessions.

Stimulating demand and new use cases through the 5G Testbeds and Trials Programme

- The Government's £200 million 5G Testbeds and Trials programme will fund projects to explore different connectivity solutions and business models for 5G.
- The next phase of the Programme will be a major urban connected community project.

Securing a diverse set of innovative 5G services through spectrum policy

- The Government wants Ofcom to complete the award of the remaining 5G spectrum bands of 700 MHz and 3.6 – 3.8 GHz in a timely manner.
- The Government would like Ofcom to assess the feasibility and costs and benefits of potential flexible licensing models as part of its planned release of spectrum in the 3.6 – 3.8 and 3.8 – 4.2 GHz bands.
- The Government will ask Ofcom to report on the utilisation of spectrum in mobile bands.
- The Government would like Ofcom to provide clarity that leasing of mobile spectrum is not prohibited, to promote greater liquidity in the spectrum trading market.

Convergence of networks and markets

- The Government's view is that the policy and regulatory framework should be sufficiently flexible and forward-looking to reflect the growing convergence between fixed and mobile networks and services. This could be achieved through:
- Removing practical obstacles or barriers to converged networks;
- Recognising convergence and considering access network requirements holistically, through unified market reviews; and
- Allowing operators to benefit from unrestricted usage of Openreach's passive infrastructure for the provision of mobile backhaul services.
- Government would like network operators and mobile operators, working with local authorities and other relevant parties, to engage on the likely locations for 5G cell sites, for the purpose of ensuring that fibre networks can be future-proofed.
- Government will ensure that existing programmes, in particular 5G Testbeds and Trials and LFFN, promote investments that recognise convergence, and use the new Local Connectivity Group to share information from these programmes more widely.

Glossary of Terms

Term	Definition
3G	Third generation of mobile systems. Provides high-speed data transmission and supporting multimedia applications such as full-motion video, video-conferencing and Internet access.
4G	Fourth generation mobile phone standards and technology. Provides faster mobile data speeds than the 3G standards that it succeeds.
5G	The term used to describe the next generation of wireless networks beyond 4G LTE mobile networks. 5G is expected to deliver faster data rates and better user experience. Technical standards are still under development and are likely to include both an evolution of existing and new radio technologies.
5G Testbeds and Trials programme	A programme that coordinates the development of 5G services and applications through a series of trials, which contribute to the development of the 5G ecosystem across the UK.
Anchor Tenant	A situation where an operator makes a commercial agreement with a user who will guarantee a minimum amount of use on their network.
Artificial Intelligence	The simulation of human intelligence processes by machines, especially computer systems.
Broadband Delivery UK (BDUK)	A Government agency established to monitor subsidised roll out of broadband networks.
Business Rates	Business rates (or non-domestic rates) are taxes charged on the occupation of non-domestic property (for example, offices and shops) in the UK. This includes telecoms networks.
Communications Providers (CPs)	A person who provides an Electronic Communications Network or provides an Electronic Communications Service.
Communications (Access to Infrastructure) Regulations 2016	Regulations to allow access to existing infrastructure on fair and reasonable terms. Implemented in domestic law via the EU Directive on measures to reduce the cost of deploying high-speed electronic communications networks. Sometimes referred to as 'the 2016 Regulations'.
Convergence	This can refer to both network convergence – the convergence of wireless and fixed networks – and service convergence – the provision of fixed, mobile and content services from the same provider.
Dark Fibre	Optical fibre already deployed (e.g. in ducts) but not in use or 'unlit'.

Term	Definition
Digital Economy Act 2017	An Act of Parliament which addresses issues relating to electronic communications services, made into law in April 2017.
Digital Infrastructure Investment Fund (DIIF)	A £400 million fund launched by HM Treasury, to be at least matched by private sector investors, designed to catalyse investment in full fibre networks.
Data Over Cable Service Interface Specification (DOCSIS)	A technology which allows high-bandwidth data transfer to an existing cable TV (CATV) system, primarily used by Virgin Media.
Duct and Pole Access (DPA)	Access to underground ducts and telegraph poles, used to assist in network deployment.
Ex Ante Regulation	'Before the event' market intervention by a regulatory body, including measures such as pricing regulation and placing obligations on a provider or providers to offer wholesale products.
Ex Post Regulation	'After the event' regulatory tools such as competition law, arbitration and penalty processes.
European Electronic Communications Code (EECC)	The EECC is a European directive setting out current rules for telecoms. The EECC will replace the following four existing telecoms directives: Framework, Access, Authorisation and Universal Service.
Exchange	A building which houses electronic equipment that connects telephone calls. Backhaul links from a content provider are terminated here to connect access links to end users.
Fair Bet Principle	An Ofcom concept in which an investment is a 'fair bet' if, at the time of investment, expected return is equal to the cost of capital. This means that, in order to ensure that an investment is a fair bet, the firm should be allowed to enjoy 'upside' returns when demand turns out to be high (i.e. allow returns higher than the cost of capital) to balance the fact that the firm will earn returns below the cost of capital if demand turns out to be low.
Fibre Backhaul	The part of the communications network which connects a local exchange or base station to the CP's core network.
Fibre to the Basement (FTTB)	Access network using optical fibre to provide the connection between the exchange and the basement of a multi-dwelling unit. An internal cable then distributes the service to the users premises.
Fibre to the Cabinet (FTTC)	Access network consisting of optical fibre extending from the exchange to the street cabinet. The street cabinet is usually located only a few hundred metres to the subscribers' premises. The remaining segment of the access network from the cabinet to the customer is usually by copper phone lines but could use another technology, such as wireless.

Term	Definition
Fibre to the Premises (FTTP), or Full Fibre	An access network using optical fibre network to provide the connection between the local exchange and the end users' houses or business premises. The optical fibre may be point-to-point – a dedicated fibre connection for each home – or may use a shared infrastructure such as GPON (Gigabit passive optical network).
Fixed Wireless Access (FWA)	Internet access provided over the airwaves using cellular network technology, rather than a physical connection through traditional fibre or copper wiring.
GHz	Gigahertz – a unit of frequency of 1 billion cycles per second.
Gigabit Broadband Voucher Scheme (GBVS)	The GBVS is being delivered by the Local Full Fibre Networks programme. The scheme offers vouchers worth up to £3,000 for small businesses and £500 for residents in a group project to offset the installation cost of a gigabit-capable broadband connection.
Gigabit connectivity/speeds	A broadband connection of at least 1 Gbps/1,000 Mbps.
Hybrid Fibre Coax (HFC)	An access network technology comparable to fibre to the cabinet (FTTC) where the connection between the exchange and the cabinet is by fibre optic cable and then the connection between the cabinet and the home was by coaxial cable amplified to maintain signal strength and quality.
Industrial Strategy	The Government's Industrial Strategy – published in November 2017 – which sets out the Government's plan to create an economy that boosts productivity and earning power throughout the UK.
Internet Service Providers (ISPs)	A retail service provider who provides access to internet services.
Latency	The time it takes for data to travel to a data centre server and back.
Local Full Fibre Networks programme (LFFN)	The Local Full Fibre Networks programme is a Government initiative designed to address market lag in the deployment of FTTP by stimulating commercial investment in full fibre networks across the UK.
Long Term Evolution (LTE)	Long Term Evolution is a standard for communication of high-speed data for mobile phones and data terminals. The term 4G is generally used to refer to mobile broadband services delivered using mobile technologies, including Long Term Evolution and WiMAX.
Macro Cell	A macro cell provides wide-area radio coverage infrastructure for a mobile network. The antennas for macro cells are mounted on ground-based masts, rooftops and other existing structures.
MHz	Megahertz – a unit of frequency of 1 million cycles per second.

Term	Definition
Mobile Backhaul	In a mobile network, backhaul is the connection between a given mobile site (e.g. a base station) and the core network.
Mobile Broadband	Various types of wireless, high speed internet access provided through a cellular network.
Mobile Network Operator	A provider of wireless communications services that owns or controls all the elements necessary to provide services to an end user including radio spectrum, wireless core network infrastructure and backhaul infrastructure.
Mobile Virtual Network Operators (MVNOs)	A mobile service provider which does not own the network infrastructure over which it provides a service, but which uses the infrastructure of a Mobile Network Operator to provide its services.
National Productivity Investment Fund (NPIF)	A £740 million fund, announced at Autumn Statement 2016, designed to boost productivity, in areas such as transport, housing, digital communications and research and development.
Network Slicing	Network slicing is a form of virtual network architecture which allows for parts of a network – with predefined specifications and quality of service – to be available for different purposes and/or users. Network operators can thereby provide dedicated virtual networks to different customers over a common network.
New Radio	5G New Radio refers to the specification of the radio transmission between mobile transmitters and receivers which will be required for 5G. This could provide increased data capacity and faster speeds by using wider spectrum bandwidths.
Physical Infrastructure Access (PIA)	Openreach's regulated duct and pole access product.
Premises	A house or building used for residential or business purposes within a postcode area.
Small Cell	An overarching term for low-powered radio access nodes that help provide service to both indoor and outdoor areas.
Spectrum	The descriptor of the range of electromagnetic frequencies which can be modulated to carry information.
Superfast Broadband	A broadband connection that can support a download speed of 24 Mbps or greater (EU 30 Mbps).
Supply Chain	Widely interpreted as being multi-tiered and being both upstream (supply) (i.e. between the organisation and the organisation's suppliers or suppliers' suppliers) and downstream (demand) (i.e. between the organisation and its market).

Term	Definition
Statement of Strategic Priorities (SSP) for Ofcom	As described in Clause 98 of the Digital Economy Act 2017, the SSP will set out the Government's strategic priorities for Ofcom in telecommunications, the management of radio spectrum, and postal services. Under the legislation Ofcom must have regard to the Statement when carrying out its regulatory functions.
Ultrafast Broadband	A broadband connection that can support a download speed of 100 Mbps or greater.
Universal Service Obligation (USO)	A legal right established by UK Government for everyone to access high speed fixed broadband (10 Mbps download, 1 Mbps upload) if they do not have it, subject to a cost threshold.
Wayleave	An agreement between a landowner and utility provider landowner allowing access to land for the installation of infrastructure or equipment.
Wi-Fi	Short-range wireless technology using any type of 802.11 standards such as 802.11b or 802.11a. These technologies allow an over-the-air connection between a wireless client and an access point, or between two wireless clients.
WiMax	A wireless data transfer technology usually longer range than Wi-Fi.

Endnotes

1 Ofcom (2018), 'Connected Nations Spring Update' https://www.ofcom.org.uk/__data/assets/pdf_file/0017/113543/Connected-Nations-update-Spring-2018.pdf

2 Ofcom (2017), 'International Communications Market Report https://www.ofcom.org.uk/__data/assets/pdf_file/0032/108896/icmr-2017.pdf

3 Full fibre target set out by Chancellor 22 May https://www.gov.uk/government/speeches/chancellor-speech-cbi-annual-dinner-2018. 5G target based on Conservative manifesto commitment. https://s3-eu-west-1.amazonaws.com/2017-manifestos/Conservative+Manifesto+2017.pdf

4 BEIS (2018), 'Industrial Strategy' https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

5 This is an estimate of total deployment capex (undiscounted) under a competitive model (i.e. with network competition). This excludes connection costs and operating expenses over the lifetime of the network.

6 National Infrastructure Commission (2018). 'National Infrastructure Assessment' www.nic.org.uk/publications/national-infrastructure-assessment-2018/

7 We have commissioned analysis from Frontier Economics to model the economics of fibre roll out in the UK and analyse the impacts of different interventions. The report and the findings can be found at Annex A.

8 Our analysis suggests that three network areas could be up to 60%, driven largely by deployment costs.

9 Ofcom (2018), 'Wholesale Local Access Market Review – Statement' https://www.ofcom.org.uk/__data/assets/pdf_file/0020/112475/wla-statement-vol-1.pdf

10 Long Term Evolution (LTE) – a standard for communication of high-speed data for mobile phones and data terminals. The term 4G is generally used to refer to mobile broadband services delivered using mobile technologies, including Long Term Evolution and WiMAX.

WiFi – Short-range wireless technology using any type of 802.11 standards such as 802.11b or 802.11a. These technologies allow an over-the-air connection between a wireless client and an access point, or between two wireless clients.

New Radio – refers to the specification of the radio transmission between mobile transmitters and receivers which will be required for 5G. This could provide increased data capacity and faster speeds by using wider spectrum bandwidths.

11 Network Slicing – a form of virtual network architecture which allows for parts of a network – with predefined specifications and quality of service – to be available for different purposes and/or users. Network operators can thereby provide dedicated virtual networks to different customers over a common network.

12 This is this the present discounted value after taking account of the costs of building, operating and maintaining full fibre networks compared with continuing to operate and maintain the existing copper network.

13 Frontier Economics (2017), 'Future Benefits of Broadband Networks' https://www.nic.org.uk/wp-content/uploads/Benefits-analysis.pdf and Tactics/Prism (2017), 'Costs for Digital Communications Infrastructures https://www.nic.org.uk/wp-content/uploads/Cost-analysis.pdf

14 The estimated benefits include only the benefits to consumers from being able to access new innovative services and cost savings in the delivery of public services. There is no allowance for wider economic benefits associated with productivity improvements, greater scope for innovation, enhanced labour force participation, or 'externality' impacts related to improved health, wellbeing, inclusion or environmental benefits.

15 Ofcom (2018), 'The economic impact of broadband' https://www.ofcom.org.uk/research-and-data/telecoms-research/broadband-research/economic-impact-broadband

16 Regeneris (2018), 'The Economic Impact of Full Fibre Infrastructure in 100 UK Towns and Cities' https://cityfibre-electricstudiolt.netdna-ssl.com/wp-content/uploads/2018/03/The-Economic-Impact-of-Full-Fibre-Infrastructure-in-100-UK-Towns-and-Cities-12.03.18.pdf

17 Based on Openreach's KPIs, there were a total of 3.2 million faults on Openreach's 25 million copper lines, from Ofcom (2016), 'Initial conclusions from the Strategic Review of Digital Communications' https://www.ofcom.org.uk/__data/assets/pdf_file/0016/50416/dcr-statement.pdf

18 DCMS (2017), 'A 5G Strategy for the UK' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597421/07.03.17_5G_strategy_-_for_publication.pdf** ; DCMS (2017), 'An Update to the 5G Strategy for the UK' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/677598/Next_Generation_Mobile_Technologies__An_Update_to_the_5G_Strategy_for_the_UK_Final_Version_with_Citation.pdf** ; Deloitte (2018), 'The Impacts of Mobile Broadband and 5G – A Literature Review for DCMS' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/714112/The_impacts_of_mobile_broadband_and_5G.pdf**

19 European Commission (2016), 'Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe' **https://ec.europa.eu/digital-single-market/en/news/5g-deployment-could-bring-millions-jobs-and-billions-euros-benefits-study-finds**

20 Digital Catapult (2018), '5G Nation: The UK 5G Ecosystem 2018' **https://www.digicatapult.org.uk/news-and-views/publication/5g-nation**

21 Deloitte (2018), 'The impacts of mobile broadband and 5G. A literature review' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/714112/The_impacts_of_mobile_broadband_and_5G.pdf**

22 DCMS (2017), 'Future Telecoms Infrastructure Review – Call for Evidence' **https://www.gov.uk/government/consultations/future-telecoms-infrastructure-review-call-for-evidence**

23 We received a total of 59 responses as part of the Call for Evidence, as well as additional evidence. These are published alongside this Review.

24 We have worked with consultants Frontier Economics to model the underlying market dynamics, and with NERA to develop case studies on international comparisons. All sources are in the supporting annexes to this document.

25 Ofcom (2017), 'The Communications Market Report' **https://www.ofcom.org.uk/__data/assets/pdf_file/0017/105074/cmr-2017-uk.pdf**

26 General network access obligations require BT, amongst other things, to offer network access on reasonable request, not to unduly discriminate, and to provide an Equivalence of Inputs (i.e. BT provides the same services to all telecoms providers including to its own downstream operations). See Ofcom (2018), Wholesale Line Access Market Review: Statement, Volume 1, Table 6.1 and paragraph 6.89.

27 As per Ofcom's Fixed Access Market Review (2010)

28 See Ofcom's Wholesale Line Access Statement (2017)

29 Frontier Economics analysis in Annex A.

30 Tactics/Prism (2017), 'Costs for Digital Communications Infrastructures' **https://www.nic.org.uk/wp-content/uploads/Cost-analysis.pdf**

31 Ofcom (2018), 'Connected Nations Spring Update' **https://www.ofcom.org.uk/__data/assets/pdf_file/0017/113543/Connected-Nations-update-Spring-2018.pdf**

32 Our analysis has been informed by studies undertaken by Frontier Economics, NERA and evidence submitted as part of the public Call for Evidence.

33 A copy of the NERA report can be found at Annex B

34 European Commission (2018), 'Broadband Coverage in Europe 2017' **https://ec.europa.eu/digital-single-market/en/news/study-broadband-coverage-europe-2017**

35 VDSL (Very high bitrate DSL): An upgrade to ADSL technology which allows for very fast internet access over copper lines. It is likely to be the technology which will be used in FTTC deployments.

36 Nera Report (Annex B) – P5

37 Ofcom (2017), 'Wholesale Local Access Market Review' **https://www.ofcom.org.uk/__data/assets/pdf_file/0021/108381/consultation-wla-competition-superfast-ultrafast-broadband.pdf**

38 This is an estimate of total deployment capex (undiscounted) under a competitive model (i.e. with network competition). This excludes connection costs and operating expenses over the lifetime of the network.

39 Transfer of jurisdiction has not yet been completed in Northern Ireland.

40 Research by Think Broadband and Ofcom indicates that only approximately 30% of new developments are built with full fibre connections.

41 DCMS (2018), A Framework for Fibre: Street Works'
'www.gov.uk/government/publications/framework-for-uk-fibre-delivery-street-works

42 Ofcom (2017), 'Wholesale Local Access Market Review Consultation'
https://www.ofcom.org.uk/__data/assets/pdf_file/0008/101051/duct-pole-access-remedies-consultation.pdf

43 Ofcom (2017), 'Opening up BT's infrastructure for new fibre broadband'
https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2017/duct-pole-access

44 The Ducts and Poles Access remedy, see WLA paragraphs 1.23-1.28,
https://www.ofcom.org.uk/__data/assets/pdf_file/0020/112475/wla-statement-vol-1.pdf

45 **http://www.legislation.gov.uk/uksi/2016/700/pdfs/uksi_20160700_en.pdf** this was transposed through on an EU Directive (on measures to reduce the cost of deploying high-speed electronic communications networks (2014/61/EU)).

46 We note that Openreach is already required to offer dark fibre access in areas of market failure as part of the State aid obligations under its BDUK Superfast Programme Phase 3 contracts.

47 Implementing an EU Directive on measures to reduce the cost of deploying high-speed electronic communications networks (2014/61/EU).

48 Community Broadband Network **http://broadband.coop/tlm**

49 Under the provisions of the Digital Economy Act, the Secretary of State may designate a Statement of Strategic Priorities that sets out the *"strategic priorities of Her Majesty's Government in the United Kingdom [....] and [The statement may, among other things, set out particular outcomes identified with a view to achieving the strategic priorities."*

50 Ofcom (2018), 'Wholesale Local Access Market Review', Volume 1, paragraph 1.49.

51 Until 2016, access obligations in Spain had been limited to services up to 30 Mbps, and in Portugal the regulator decided in 2014 not to impose ex-ante regulation for superfast broadband in areas which had at least two alternative superfast networks and where the incumbent's market share was less than 50%.

52 Ofcom has recognised that *"in time, a greater degree of differentiation in our regulatory approach across the UK is likely to emerge."*

53 Ofcom has actually defined two distinct geographic markets for the WLA product market namely (i) the UK excluding the Hull Area, and (ii) the Hull Area (see recent WLA statement, paragraph 3.3). In the Hull Area the main local access network is operated by KCOM (i.e. not BT). The findings of the WLA apply to all parts of the UK excluding Hull.

54 Ofcom (2017), 'Delivering a more independent Openreach'
https://www.ofcom.org.uk/__data/assets/pdf_file/0035/98855/Openreach-consultation-2017.pdf

55 Based on cost data from NIC cost analysis, and triangulated through other sources including industry evidence.

56 In France, co-investment was predominantly underpinned by regulation (through symmetric access regulations for certain parts of the network like in-building wiring i.e. access obligations on all operators).

57 Article 74 of the draft EECC

58 Rural England (2018), 'Unlocking the digital potential of rural areas across the UK'
https://ruralengland.org/unlocking-the-digital-potential-of-rural-areas-research/

59 DotEcon (2018), 'Deployment of FTTP in Rural Northern Ireland'
https://www.dotecon.com/publications/deployment-of-fttp-in-rural-northern-ireland/

60 This should be consistent with the prevailing State Aid framework.

61 Spanish incumbent Telefonica noted that *"widespread FTTH deployment, IP migration and legacy switch-off are allowing us to reduce failures and improve quality of service, leading to lower maintenance costs and new revenues"*
https://www.telefonica.com/documents/162467/138879215/rdos17t3-transcript.pdf/5198fbd8-b800-cc40-2059-54f605d34724

62 CNMC (2014), 'Economic Report on the Telecommunications and Audiovisual Industry'
https://www.cnmc.es/sites/default/files/1539380_3.pdf

63 In Spain, Telefonica has now begun to switch-off its copper switch-boards, at the rate of around 200 per year, and plan to close 653 by 2020. Telefonica have c.6500 local exchanges, and many will be repurposed.
https://www.telefonica.com/en/web/press-office/-/telefonica-will-shut-down-one-copper-switchboard-a-day-until-2020

64 We note that Hyperoptic offer an entry-level product at £18pm and TalkTalk offer a full fibre product for £25pm (in York) both including installation.

65 Structural separation would require Openreach to be placed under different ownership to BT Group. This is different to legal separation, whereby Openreach is owned by BT Group, but is a distinct company with its own staff and management, together with its own strategy and a legal purpose to serve all of its customers equally.

66 Ofcom (2018), 'Progress on delivering a more independent Openreach' |**https://www.ofcom.org.uk/__data/assets/pdf_file/0019/114814/openreach-implementation-report-2018.pdf**

67 DCMS (2017), 'Next Generation Mobile Technologies: A 5G Strategy for the UK' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/597421/07.03.17_5G_strategy_-_for_publication.pdf**; DCMS (2017), 'Next Generation Mobile Technologies: An update to the 5G strategy for the UK' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/677598/Next_Generation_Mobile_Technologies__An_Update_to_the_5G_Strategy_for_the_UK_Final_Version_with_Citation.pdf**

68 European Commission (2016), 'Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe' **https://ec.europa.eu/digital-single-market/en/news/5g-deployment-could-bring-millions-jobs-and-billions-euros-benefits-study-finds**

69 Ofcom (2016), 'The Communications Market 2016: 4 – Telecoms and networks' **https://www.ofcom.org.uk/__data/assets/pdf_file/0026/26648/uk_telecoms.pdf**

70 Cornerstone Telecommunications Infrastructure Limited (CTIL) is a joint venture between O2 Telefonica and Vodafone. Mobile Broadband Network Limited (MBNL) is a joint venture between Three and BT EE. Wireless infrastructure providers include Arqiva and Wireless Infrastructure Group, amongst others.

71 LS telcom (2016), '5G Infrastructure Requirements in the UK' **https://www.lstelcom.com/fileadmin/content/marketing/brochures/5G_Infrastructure_requirements_for_the_UK_-_LS_Telcom_report_for_the_NIC.pdf**

72 Ofcom (2018), 'Connected Nations Spring Update' **https://www.ofcom.org.uk/__data/assets/pdf_file/0017/113543/Connected-Nations-update-Spring-2018.pdf**

73 Williamson, B (2018), 'Keeping an eye on the prize – investment in mobile networks to deliver coverage, capacity & the 5G strategy: A reappraisal of recurring spectrum fees' **http://static1.1.sqspcdn.com/static/f/1321365/27899690/1525377757620/Reappraising+recurring+spectrum+fees+May+2018+1.pdf?token=K5Fzz7gxmTAexT0Wp9j3jom%2B0ko%3D**

74 Since 2012 prices have declined by 31% whilst data usage has increased sixfold. Ofcom (2017), 'Pricing trends for communications services in the UK' **https://www.ofcom.org.uk/__data/assets/pdf_file/0028/98605/Pricing-report-2017.pdf**

75 Investment varies widely between countries. In 2013, the leading countries in both measures were Japan and the U.S. The UK is ranked 4th and 7th (in terms of capex to revenue ratio and capex per subscriber respectively) among EU countries, but well behind non-EU countries (Figure 11). WIK Consult (2015), 'Competition & investment: An analysis of the drivers of investment and consumer welfare in mobile telecommunications' **http://www.wik.org/fileadmin/Studien/2015/Competition_and_investment_mobile_telecommunications.pdf**

76 Ofcom (2017), 'The Communications Market Report', Figure 4.1 **https://www.ofcom.org.uk/__data/assets/pdf_file/0017/105074/cmr-2017-uk.pdf**

77 Enders Analysis (2018), 'UK mobile market Q4 2017: Swings, roundabouts, and auctions' **http://www.endersanalysis.com/content/publication/uk-mobile-market-q4-2017-swings-roundabouts-and-auctions**

78 This is the compound annual growth rate. Taken from GSMA (2018), 'The Mobile Economy 2018' **https://www.gsma.com/mobileeconomy/wp-content/uploads/2018/02/The-Mobile-Economy-Global-2018.pdf**

79 Ofcom (2018), 'Results of principal stage of auction for mobile airwaves' **https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2018/results-auction-mobile-airwaves**

80 MNO capex figures compiled by Frontier Economics from annual company reports. Note that capital expenditure covers a range of investments including refreshing and replacing existing assets, adding new capacity as well as introducing new capabilities. In addition, the expenditure will cover not just the radio access networks but also the aggregation and core network and a range of non-network systems.

81 Analysis by Ericsson predicts that operators could potentially grow revenues up to 36% by addressing ten key industry sectors. Ericsson (2018), 'The guide to capturing the 5G industry digitalization business potential' **https://www.ericsson.com/assets/local/narratives/networks/documents/report-bnew-18001324-rev-a-uen.pdf**

82 The amount of mobile data we use continues to grow, increasing by 47% last year. Ofcom (2017), 'Connected Nations Report 2017' **https://www.ofcom.org.uk/__data/assets/pdf_file/0024/108843/summary-report-connected-nations-2017.pdf**. 5G is expected to deliver the ability to connect one million devices per square kilometre. Ofcom (2018), 'Enabling 5G in the UK' **https://www.ofcom.org.uk/__data/assets/pdf_file/0022/111883/enabling-5g-uk.pdf**

83 Our analysis has been informed by Frontier Economics and evidence submitted as part of our Call for Evidence. We have examined the estimated 5G capital expenditure on radio access network infrastructure, and this does not include spectrum or core networks.

84 This is an estimate based on current costs (and assuming no sharing of active equipment). We recognise that industry will incur opex costs in addition to these capex figures. Our estimates are informed by analysis undertaken by Frontier Economics and information received as part of our public Call for Evidence.

85 Estimate based on cost of one small cell and relates to a single operator, as per analysis undertaken by Frontier Economics.

86 Based on Frontier Economics analysis, and HSBC (2018), '5G: What's the use...??' **http://www.gbm.hsbc.com/insights/technology/does-5g-have-a-use**

87 Our analysis has been informed by Frontier Economics, NERA and evidence submitted as part of our Call for Evidence.

88 European Commission (2016), 'Case M.7612 – Hutchison 3G UK / Telefonica UK' **http://ec.europa.eu/competition/mergers/cases/decisions/m7612_6555_3.pdf**

89 A study by Genakos et al. concluded that the average four-to-three merger would be expected to increase investment per operator but that prices would be driven up. Genakos et al. (2015), 'Evaluating Market Consolidation in Mobile Communications' **http://www.cerre.eu/sites/cerre/files/150915_CERRE_Mobile_Consolidation_Report_Final.pdf**

90 Analysis by Frontier Economics found no clear link between investment and competition in three versus four player markets. Frontier Economics (2015), 'Assessing the case for in-country mobile consolidation' **https://www.gsma.com/publicpolicy/wp-content/uploads/2015/05/Assessing_the_case_for_in-country_mobile_consolidation.pdf**; WIK Consult found no linkage between consolidation or higher concentration in mobile markets and an increase in investment. WIK Consult (2015), 'Competition & investment: An analysis of the drivers of investment and consumer welfare in mobile telecommunications' **https://www.ofcom.org.uk/__data/assets/pdf_file/0029/78365/competition_and_investment_mobile.pdf**

91 As part of the Digital Economy Act (2017).

92 DCMS (2016), 'ECC impact assessment' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/524895/ECC_Impact_Assessment.pdf**

93 In response to the Call for Evidence, and in a separate letter jointly sent by the four mobile network operators, the MNOs have suggested that improved access to power and transmission is needed.

94 Evidence submitted to this Review suggested that such models could open up a new investment front since they are likely to be attractive to infrastructure funds given their wholesale-only business models. This is typically long-term patient capital enabling a lower cost of capital than traditional operators, which in turn could help unlock more investment projects.

95 The Code regulates access to land (including buildings), but does not regulate access to infrastructure, recognising the need to encourage and protect investment. This means operators cannot employ the Code to secure rights to use or access infrastructure owned by WIPs (or other operators).

96 Ofcom (2018), 'Enabling 5G in the UK' **https://www.ofcom.org.uk/__data/assets/pdf_file/0022/111883/enabling-5g-uk.pdf**

97 National Infrastructure Commission (2016), 'Connected Future' **https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/577906/CONNECTED_FUTURE_ACCESSIBLE.pdf**

98 Ofcom (2017), 'Improving consumer access to mobile services at 3.6 GHz to 3.8 GHz' **https://www.ofcom.org.uk/__data/assets/pdf_file/0019/107371/Consumer-access-3.6-3.8-GHz.pdf**

99 For example, in a speech to the Dynamic Spectrum Alliance Global Summit, Lord Willetts estimated that only 2% of the UK's landmass is covered with 2.6 GHz 4G spectrum five years after the spectrum was auctioned. Rt. Hon. the Lord Willetts (2018), 'Dynamic Spectrum Access holds the key to turning a growing 'geographic' waste of spectrum into a 5G success story' **http://dynamicspectrumalliance.org/wp-content/uploads/2018/05/Day2-2-1_Keynote_LordWilletts.pdf**

100 National Infrastructure Commission (2016), 'Connected Future' **https://www.gov.uk/government/publications/connected-future**

101 University of Surrey published by Ofcom (2017), 'Response to Ofcom's consultation of 5G' **https://www.ofcom.org.uk/__data/assets/pdf_file/0023/106259/University-of-Surrey-5G-Innovation-Centre.pdf**

102 Analysys Mason recommended DCMS and Ofcom should explore flexible licensing approaches for suitable spectrum to support local 5G service deployment. Analysys Mason (2018), 'Lowering barriers to 5G deployment' **http://www.broadbanduk.org/wp-content/uploads/2018/07/BSG-Report-Lowering-barriers-to-5G-deployment.pdf**

103 Written evidence has been provided to DCMS by (inter alia) Wireless Infrastructure Group, Plum Consulting (on behalf of INCA and UK WISPA), King's College London Department of Informatics, Dense Air, Open Cell and Broadway Partners.

104 This would be subject to the outcome of future auctions.

105 BNetzA (2018), 'President Chamber's decision of 14 May 2018 on the order for and choice of proceedings for the award of spectrum in the 2 GHz and 3.6 GHz bands for mobile/fixed communication networks (MFCN)' **https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/Telecommunications/Companies/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/FrequencyAward2018/20180613_Decision_I_II.pdf?__blob=publicationFile&v=2**

106 Both fixed line networks and mobile networks evolve to comprise a fibre core and transmission element, with wireless connectivity (such as 4G, 5G or Wi-Fi) at the edge to connect to the user.

107 Orange, Free, Altice and Bouygues

108 CNMC (2015), 'Telecommunications and Audiovisual Sector Economic Report' **https://www.cnmc.es/sites/default/files/1539347_1.pdf**

109 Analysys Mason cited a lack of engagement between network providers and local authorities as an issue that will create increasing barriers to 5G as deployment of 5G accelerates. Analysys Mason (2018), 'Lowering barriers to 5G deployment' **http://www.broadbanduk.org/wp-content/uploads/2018/07/BSG-Report-Lowering-barriers-to-5G-deployment.pdf**

110 Ofcom (2017), 'Wholesale Local Access Market Review: Statement -Volume 3' **https://www.ofcom.org.uk/__data/assets/pdf_file/0023/112469/wla-statement-vol-3.pdf**

111 NERA (2018), 'Telecoms Infrastructure International Comparison: A Report for the Department of Digital, Culture, Media and Sport'. This Report can be found at Annex B.

112 Ofcom (2018), 'Wholesale local access market review' **https://www.ofcom.org.uk/consultations-and-statements/category-1/wholesale-local-access-market-review**

113 In its decision, published earlier this year, Ofcom made some changes to the PIA remedy, with the aim of improving take-up of PIA. The remedy now permits 'mixed usage', enabling access seekers to offer both broadband and non-broadband-based (e.g. business) services using PIA, provided the primary purpose of the network deployment remains the delivery of broadband services.