analysys mason

Full-fibre access as strategic infrastructure: strengthening public policy for Europe

June 2020

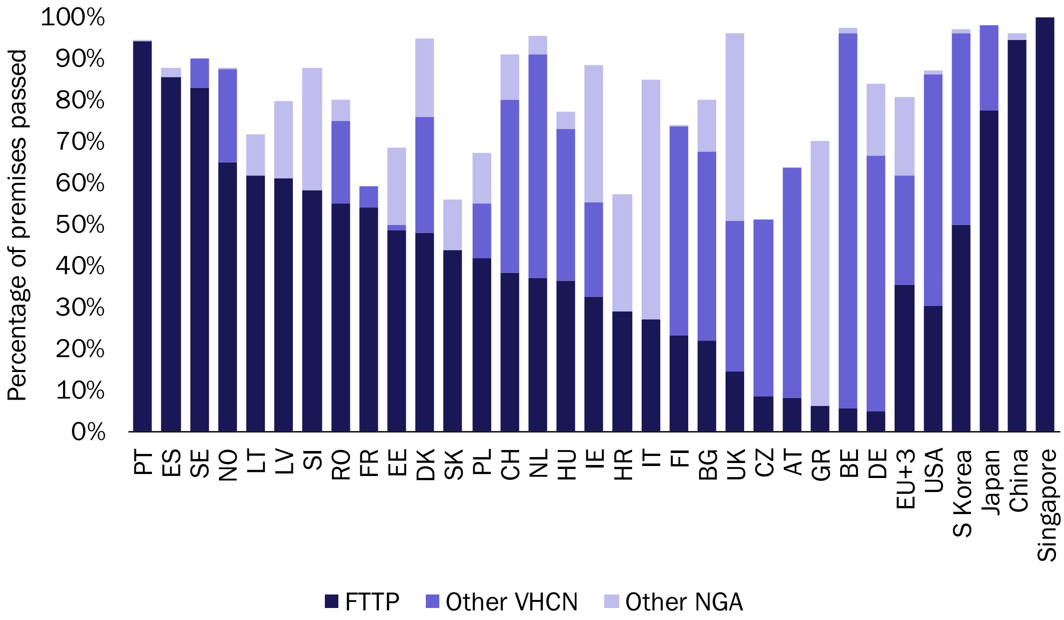
Contents

List of figures

1. Executive summary

The value of ubiquitous high-speed broadband connectivity has been demonstrated in numerous socioeconomic studies.[1] Policy makers agree that there is a need for co-ordinated long-term investment to realise this potential. Most EU countries look set to miss European Commission (EC) targets for fibre access, and to lag behind most benchmark countries. Take-up of FTTP in Europe is now accelerating fast. Looking ahead, European countries need to accelerate the rate at which access networks are being upgraded.

Figure 1.1: Estimated percentage of premises passed by FTTP, other VHCN, and by other NGA network technologies, European plus selected benchmark countries, 2019 [Source: Analysys Mason, 2020]



Copper- and coax-based technologies face performance constraints. New fibre technologies do not require alteration of the existing optical distribution network. FTTP standards have a detailed roadmap and next-generation PON systems are being deployed commercially. Growing numbers of operators are focusing more of their attention on FTTP as capex and opex benefits become more apparent. Moreover, full-fibre networks use less energy than alternatives and fit a green agenda. FTTP networks offer ultra-low latency, which makes them suitable to be used alongside Wi-Fi 6 and 5G (and the eventual successors to these technologies), and to support AI applications. FTTP networks can also be extended to the end-user terminal and IoT devices with passive optical LAN deployments.

Many advanced economies in the Asia–Pacific (APAC) region already have a high level of FTTP coverage. In nearly every case, this has been facilitated by clear and ambitious government policy and consistent regulatory practice. In general, outcomes have been positive in countries where it is treated as 'strategic infrastructure'. For example, in Singapore, government regulation and investment have led to universal FTTP coverage and enviable levels of higher-layer competition. In New Zealand, the Ultra-Fast Broadband (UFB) initiative has

1 An example of such a study is the European Commission (EC) report on the benefits of broadband (http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=1809).

achieved high coverage and take-up in a sparsely populated country. In South Korea, fibre-based broadband strategy dates from 1994 but it is no longer the front-runner in the region. In China, a comprehensive strategy centred around fibre as national infrastructure has resulted in rapid expansion of coverage.

European countries face a heterogeneous set of challenges to achieve good roll-out targets. Post-liberalisation, fixed telecoms has evolved into a connectivity business. European regulation has tended to favour fostering retail competition and low prices over long-term investment. National governments are increasing investment in fibre, but this is unlikely to be enough to achieve targets.

High-quality civic infrastructure is key to rolling out FTTP quickly, but labour costs are high and strict planning laws have delayed FTTP deployment in some European countries. There have been a number of success stories. For example, in Sweden, a ‘village fibre’ approach has ensured fast and reliable FTTP networks across most of the country, despite its geographical challenges. In Spain, high-quality civic infrastructure and effective light-touch regulation have made the country a leader in FTTP in Europe. In France, the national broadband plan introduced efficient operational regulation, which improved the speed of deployment.

However, in other countries, experience has been more mixed. In Italy, uncertainty over future ownership has proved to be an issue. In the UK, commercial enthusiasm for FTTP may disguise future problems with respect to the potentially inefficient nature of multiple discrete investments. In Germany, the government is ambitious, but progress is slow to date.

New approaches are emerging, assisted by positive government-led policy, in particular, those that recognise the importance of fibre as national infrastructure and lower or remove barriers to deployment. Any government policy to promote full-fibre networks will contain specific practical measures to lower or remove barriers to commercial deployment, and provide loan funding or subsidies where necessary. Effective wayleave law is an important means of facilitating FTTP deployments. Infrastructure sharing reduces costs and improves speed of deployment. ‘Pre-installing’ fibre-optic cables in new real-estate developments assists the roll-out of the last mile. New technologies can improve the efficiency of Optical Distribution Network (ODN) deployment. Accelerating the rate at which copper and coax can be released is also important.

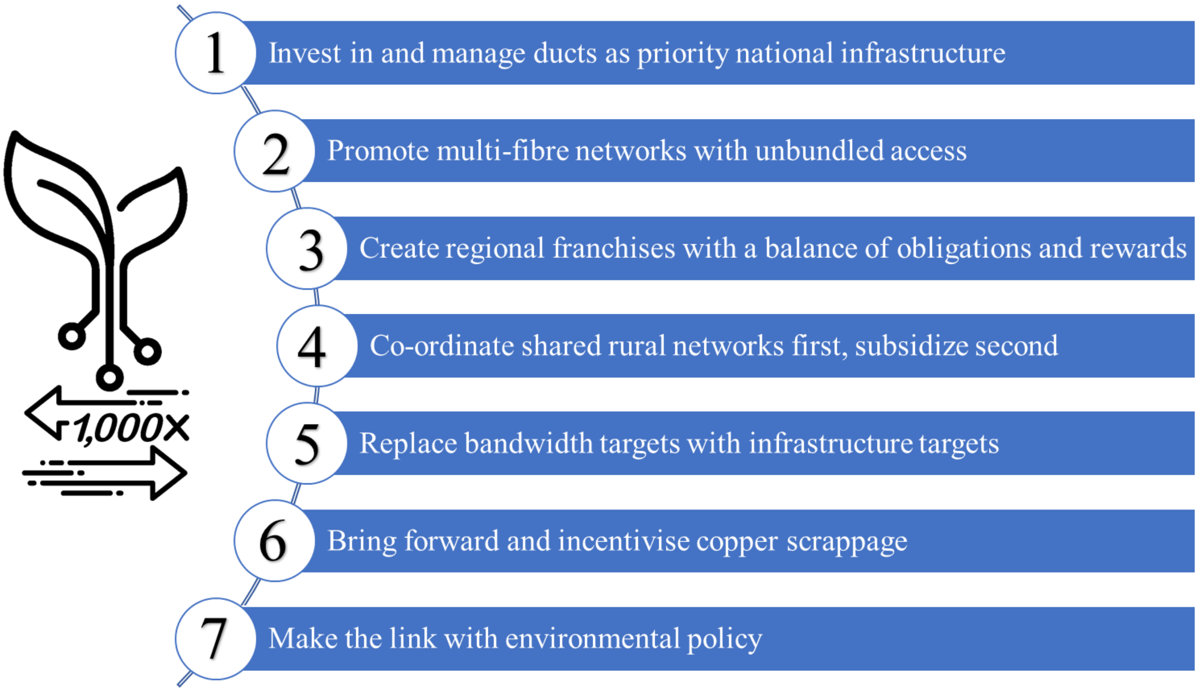
Enabling the conditions for flourishing competition-driven innovation and service improvement is where public money is best spent, and it is to this end that policy should be directed. A more dirigiste approach is required. In general, policy should treat fibre as infrastructure and should encourage a diversity of vendors, operating companies and services.

Policy should encourage options for access at as low a layer as is feasible. This means a preference for physical infrastructure access or dark fibre access. Public money, where required, should be spent enabling low layer access. As an alternative to duct build, policy should encourage or mandate the building of networks with end-to-end multi-fibre. Governments should impose stricter and more forward-looking building regulation, where this has not already been done and take measures to combat the shortage in skilled workforce required for the mass deployment of fibre. Governments should also consider tax incentives on fibre network build and on fibre customer connections. A copper scrappage scheme with a guaranteed price for scrap should also be considered.

A relentless focus on getting the right kind of infrastructure deployed rather than on bandwidth targets is the right approach.

Finally, there should be joined-up thinking between telecoms/ICT and environmental policy.

Figure 1.2: Seven key recommendations for policy [Source: Analysys Mason, 2020]



2. Introduction

This report has been commissioned by Huawei to describe the current status of, and case for, extending coverage of full-fibre access networks in Europe, the challenges involved in extending that coverage, international best practice, and the need for a coherent and positive set of policies to deliver these high-performance networks for the decades to come.

Throughout this report, Europe is taken to mean the EU27 plus Norway, Switzerland and the UK.

Full-fibre networks go by several names, so it is important to get definitions clear from the outset. In its simplest form, full-fibre means an optical distribution network (ODN) in which fibre runs all the way to an optical network unit (ONU) at the subscriber's premises (a house, an apartment, a business premises etc.). This can be referred to as fibre to the premises (FTTP), or, more colloquially, fibre to the home (FTTH). Importantly, this definition excludes fibre to the building (FTTB) where fibre enters a multi-tenant building but is distributed over a non-optical infrastructure (for example, LAN cabling, copper cabling, coaxial cables). Full-fibre networks can extend beyond the simple FTTP case, where each premises has one ONU, to include scenarios where the ODN extends inside individual homes, apartments and offices: this includes fibre to the room (FTTR), fibre to the desk (FTTD) and fibre to the machine (FTTM).

Full-fibre networks include passive optical network (PON) and point-to-point (PTP) architecture. These are discussed in chapter 4. Over 95% of FTTP is based on PON, but some operators prefer PTP, which is more prevalent than PON in a handful of countries.

In this report, we also use the term next-generation access (NGA). In practice, this is used to refer to any technology capable of delivering over 30Mbit/s downstream.

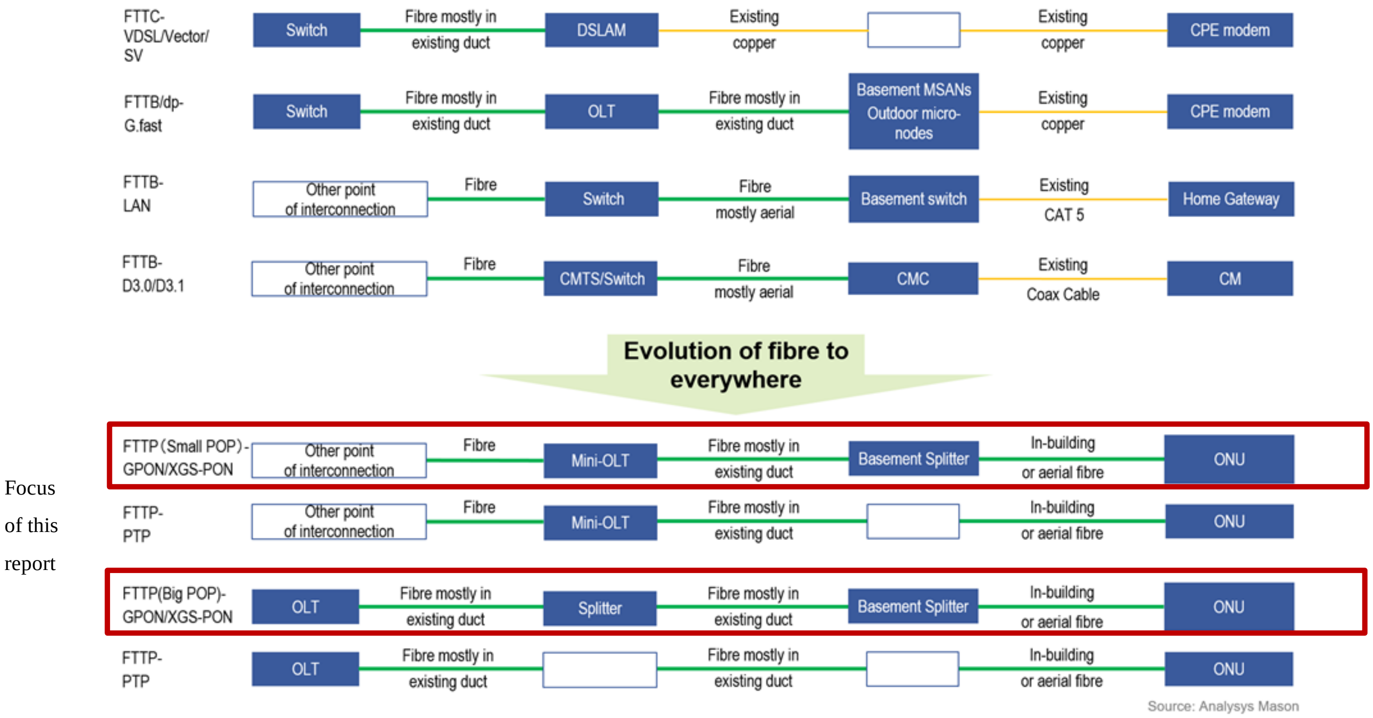
A summary of technical definitions is given in the figures below.

Figure 2.1: Definitions used in this report

Term		Definition
FTTx	FTTC/copper	Fibre runs to the cabinet and the remaining sub-loop carries VDSL or G.fast.
	FTTB/LAN	Fibre runs to a building. Signals are distributed via a switch and over CAT-5 Ethernet or Wi-Fi.
	FTTB/dp/copper	Fibre runs to a node in the building, and the remaining copper carries VDSL or G.fast signals from a DSLAM or distribution point unit (DPU) installed in the node. This category also covers FTTdp (fibre to the distribution point) architecture in other geotypes, where a micronode containing a mini-DSLAM or DPU is installed serving a final copper line or lines.
	FTTP	Includes all broadband deployments in which fibre runs all the way to or inside of the subscriber's premises. FTTP includes passive optical network (PON) and point-to-point (PTP) architecture and includes broadband fibre connections to business sites. However, it does not include uncontended dedicated fibre leased lines. FTTP is often informally referred to as FTTH, or as full-fibre broadband.
DOCSIS3.0+		Includes DOCSIS3.0 and equivalent or successor technologies.
NGA		The sum of FTTx and cable DOCSIS3.0+.
VHCN		Very high capacity network. A full-fibre network, or a network providing similar performance to the current technologies deployed on a full-fibre network. (In this respect, VHCN is synonymous with the target proposed by the EC's strategic objective for 2025: access to internet connectivity offering a downlink of at least 100Mbit/s, upgradable to gigabit speeds.
Premises passed		For a network to pass a premises, the subscriber must be able to get a connection within 30 days without the need for a substantial new network build.
Connections		Active internet access connections. Unactivated lines are not counted.

Source: Analysys Mason

Figure 2.2: Overview of FTTx network topologies and elements



Acronyms

DSLAM: Digital Subscriber Line Access Multiplexer

MSAN: Multi-Service Access Node

GPON: Gigabit Passive Optical Network

XGS-PON: 10G Up and Down Symmetrical PON

PTP: Point-To-Point

ODN: Optical Distribution Network

OLT: Optical Line Terminal

ONU: Optical Network Unit

The rest of this report comprises seven chapters as follows:

- Chapter 3 describes the current situation in Europe regarding coverage and demand for fibre-based broadband relative to current EC and national targets and international benchmarks.
- Chapter 4 takes a closer look at the advantages of fibre-optic technology compared to copper alternatives, with particular focus on its long-term advantages, not only in terms of performance but also in terms of cost and environmental impact. This chapter is relatively technical; readers less interested in a detailed discussion of the advantages of full-fibre technology may prefer to skip this chapter.
- Chapter 5 considers the approaches taken in four APAC countries that have resulted in good coverage of full-fibre networks.
- Chapter 6 describes the Europe-specific challenges involved in deploying fibre-based access in Europe.
- Chapter 7 focuses on six key European markets, starting with those where policy approaches have proved successful, and moving on to countries where a positive outcome is less certain.
- Chapter 8 considers a number of specific policies to accelerate the deployment of fibre-based broadband in Europe.
- Chapter 9 summarises the key conclusions of the report and makes recommendations for national governments and regulators in Europe.

3. Broadband development in Europe

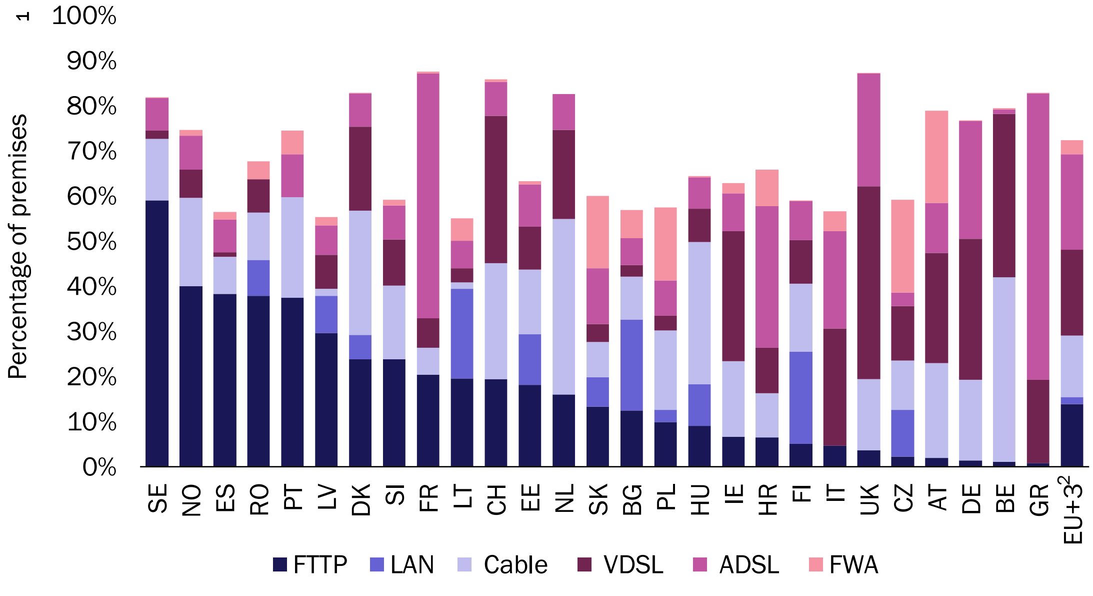
The first part of this chapter analyses current fibre access coverage across European countries and assesses the likelihood of their meeting the latest EC coverage targets on time. The second part looks at take-up rates and demand.

3.1 Most EU countries look set to miss EC targets for fibre access, and to lag behind most benchmark countries

Fixed broadband (FBB) is the workhorse of the internet, carrying about 90% of all traffic in Europe. 4G and 5G mobile networks grab more attention, but fixed networks do most of the work; the average FBB connection carries over 200GB per month, whereas the average mobile network connection carries about 5GB. Traffic is growing rapidly on both fixed and mobile networks, and there is no evidence that mobile is substituting fixed.

FBB penetration in Europe is high overall, but it is unevenly spread (see Figure 3.1). Total FBB, NGA and FTTP penetrations vary significantly across Europe, and are not necessarily correlated – for example, Greece has a high FBB penetration of 82.7% of premises, but it has the lowest FTTP penetration, at under 1%.

Figure 3.1: Estimated fixed broadband penetration of total premises, by technology in European countries[2], 2019 [Source: Analysys Mason, 2020]



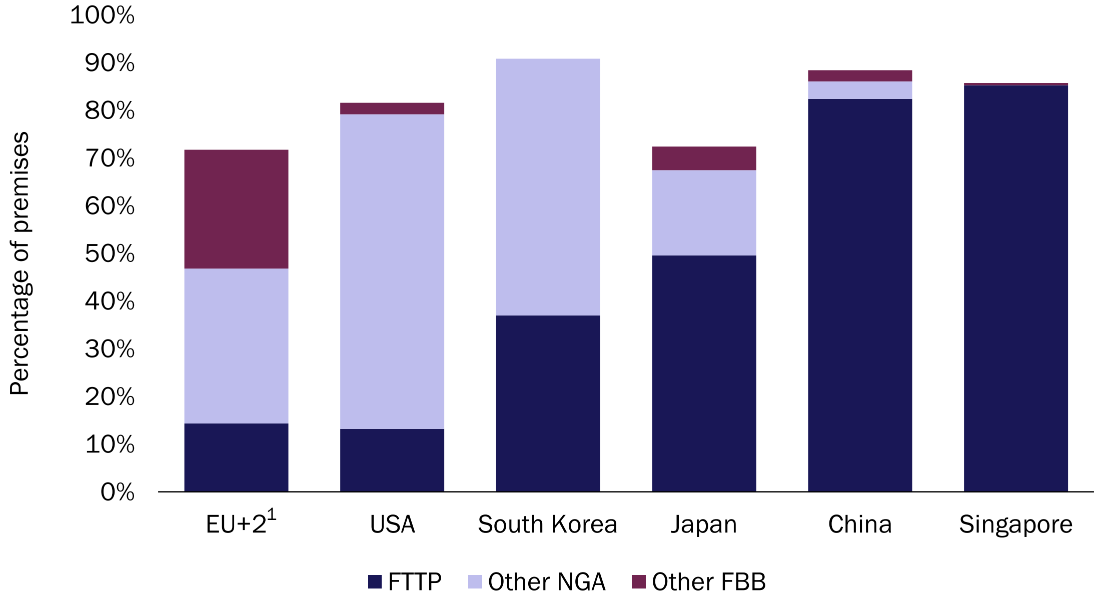
Source: Analysys Mason

Figure 3.2 shows the FBB penetration of Europe compared with the benchmark countries of China, Japan, Singapore, South Korea and the USA. Europe is doing marginally better than the USA, but it is lagging behind the Asian early movers in FTTP penetration at 14.4%. In addition, Europe has the lowest overall FBB penetration (at 71.7%, narrowly behind Japan), and the lowest NGA penetration (46.8%). This corresponds to a

2 The EU, plus Norway, Switzerland and UK. Excludes Luxembourg, Cyprus and Malta.

proportion of non-NGA connections of 34.7%, whereas this category constitutes approximately 25% of FBB lines worldwide.

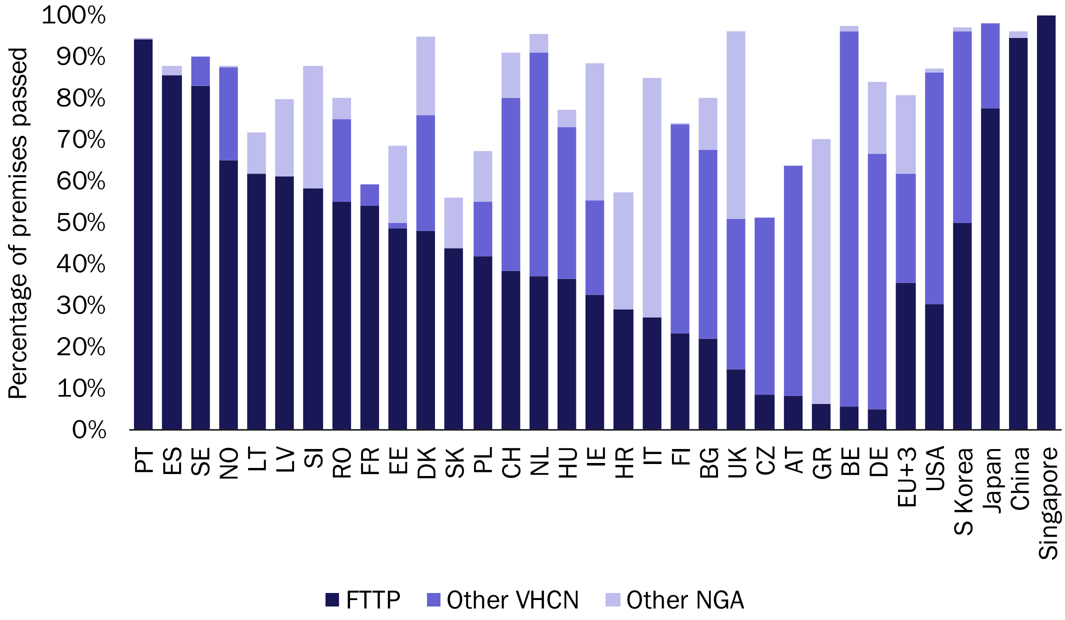
Figure 3.2: Estimated fixed broadband penetration of total premises by technology, Europe and selected benchmark countries, 2019



Source: Analysys Mason

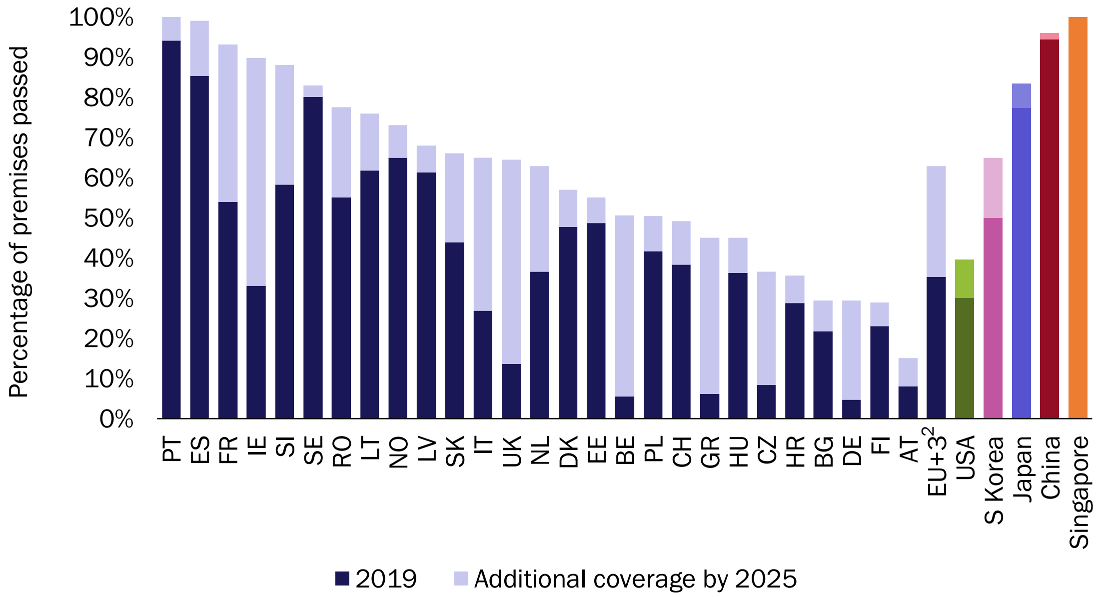
Figure 3.3 shows the coverage of FTTP, other VHCN (cable and FTTB/LAN) and other NGA (FTTC/VDSL, G.fast) technologies in European and benchmark countries, expressed as the percentage of premises passed. Coverage varies greatly in Europe. Some countries are doing well, with Portugal, Spain and Sweden exceeding the full-fibre coverage of Japan and South Korea. Others are doing poorly, with 6 countries (including the UK) with FTTP coverage below 15%, and 5 countries (including the largest, Germany) below 10%. As a whole, Europe is at 35.3%, a little ahead of the USA (30.1%), but significantly behind the benchmark early movers.

Figure 3.3: Estimated percentage of premises passed by FTTP, other VHCN, and by other NGA network technologies, European plus selected benchmark countries, 2019 [Source: Analysys Mason, 2020]



Decent if unspectacular growth in European FTTP coverage can be expected until 2025, although the level of growth is not expected to be even across European countries (see Figure 3.4). These forecasts are based on Analysys Mason's analysis of operators' plans and projections, and on expected regulatory developments. Coverage is expected to exceed 70% in 11 countries by 2025. Coverage in Spain and Portugal is expected to be close to universal, and in France, Ireland and Sweden is expected to exceed 90%. However, coverage in 6 countries, including Germany, is expected to be less than 40%. We expect overall European coverage to reach 64.4% by the end of 2025.

Figure 3.4: Estimated percentage of premises passed by FTTP, European plus selected benchmark countries, 2025



Source: Analysys Mason

At the current rate of progress, it is likely that Europe will continue to lag behind most international benchmark countries in terms of FTTP coverage and six European countries (including the largest, Germany) will have coverage below that of even the USA.

3.2 The EU's European Gigabit Society objectives and 2016 Communication on Connectivity set ambitious targets for fibre access

The EC has defined two sets of targets for internet connectivity that member states should aim to achieve by 2020 and 2025.[3] The 'Europe 2020 Strategy'[4] sets objectives for the growth of the EU by 2020 and consists of seven pillars, one of which is the Digital Agenda for Europe (DAE).[5] The DAE proposes to use the potential of ICT to ensure the economic and social growth of the EU countries.

In 2016, the EC's analysis of trends in technology and demand indicated that provision of many products, services and applications will only be sustainable where optical fibre networks are deployed up to a fixed or wireless access point close to the end user. This resulted in the adoption of a strategy on 'Connectivity for a European Gigabit Society' (EGS), addressing the availability and take-up of very high-capacity networks (VHCN) by 2025.

The EC's strategic objectives for 2025 from the 2016 report include the following.

- Gigabit connectivity for all main socio-economic drivers such as schools, transport hubs and main providers of public services as well as digitally intensive enterprises.
- All European households, rural or urban, will have access to internet connectivity offering a downlink of at least 100Mbit/s, upgradable to gigabit speeds.
- Access to, and take-up of, very high-capacity connectivity as a regulatory objective.
- Regulators to map network investment intentions, and enable public authorities to seek investors in underserved areas.
- Predictable regulatory conditions to promote co-investment and wholesale-only business models, facilitating deployment of VHCN deeper into suburban and rural areas.

However, the DAE and EGS targets are not legally binding. This is one of the reasons why EU countries have developed their own national broadband plan targets that are sometimes not fully aligned with the DAE and EGS targets.

National broadband plans (NBPs) aim to make broadband coverage available across a country/region by focusing on areas that are deemed to be uneconomic. These plans must legally comply with EU broadband state-aid guidelines.[6] One of the key principles of state-aid guidelines is technology neutrality,[7] which means the selection of technology is agnostic as long as the solution meets the specifications. There is no single,

---

3 https://ec.europa.eu/digital-single-market/en/broadband-strategy-policy

4 https://ec.europa.eu/digital-single-market/en/europe-2020-strategy

5 The other six pillars are: enterprise environment, innovative Europe, education and training, labour market and employment, social inclusion, and environmental sustainability.

6 https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2013:025:0001:0026:EN:PDF

7 Paragraph 78(e) of https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2013:025:0001:0026:EN:PDF

comprehensive solution – different technology solutions will be best in different contexts. The main criterion is that the solution meets the project specifications that are state-aid compliant.

Solutions proposed for NBP projects have predominantly focused on FTTx.[8] This could be explained to some extent by the fact that fixed incumbent network operators won procurement competitions for a large share of the NBP projects in EU countries, and these operators have traditionally deployed fibre and copper cables. There are limited examples of instances where fixed wireless access (FWA) solutions have been granted subsidies in state-aid areas (one such example is Open Fibre in Italy).

However, we observe that national policies show a general preference for FTTP deployments as a means of achieving VHCN coverage targets. Some EU countries explicitly mention fibre in their NBPs; others implicitly express a preference for FTTP.

Some examples of NBPs are shown in Figure 3.5.

Figure 3.5: National broadband plans in the six largest European countries [Source: Analysys Mason, 2020]

Country	FTTP deployment target	Spend
France	By 2022, essentially all parts of the country will have access to FTTP with speeds of at least 30Mbit/s, and >100Mbit/s in most areas.[9]	Public and private investments amounting to EUR20 billion.[10]
Germany	Develop a gigabit network, with a preference for FTTP.	A public financing requirement of EUR10 to 12 billion.[11]
Italy	By 2020, develop an NGA network able to provide speeds up to 100Mbit/s to at least 85% of households, with a preference for FTTP in urban areas.[12]	A state-aid budget of EUR4 billion has been made available.
Poland	By 2020, all households will have access to speeds of at least 30Mbit/s, with 50% coverage with speeds of 100Mbit/s.[13]	The government has dedicated around EUR1 billion to broadband upgrades.[14]
Spain	The policy (PEBA300×100[15]) aims to achieve 95% fibre coverage by 2021.	Allocated EUR525 million for the period 2018–2021.[16]
UK	Deploy gigabit-capable broadband to the most remote 20% of locations by 2025 according to an "outside-in" approach.	Allocated GBP5 billion (EUR6 billion).[16]

8 FTTx includes fibre to the cabinet (FTTC), fibre to the building (FTTB) and fibre to the premises (FTTP)

9 https://www.amenagement-numerique.gouv.fr/fr/garantir-du-tres-haut-debit-tous-2022

10 https://ec.europa.eu/digital-single-market/en/country-information-france

11 https://ec.europa.eu/digital-single-market/en/country-information-germany

12 http://www.infratelitalia.it/wp-content/uploads/2015/03/Strategy.pdf

13 https://www.gov.pl/web/cyfryzacja/narodowy-plan-szerokopasmowy

14 https://ec.europa.eu/digital-single-market/en/country-information-poland

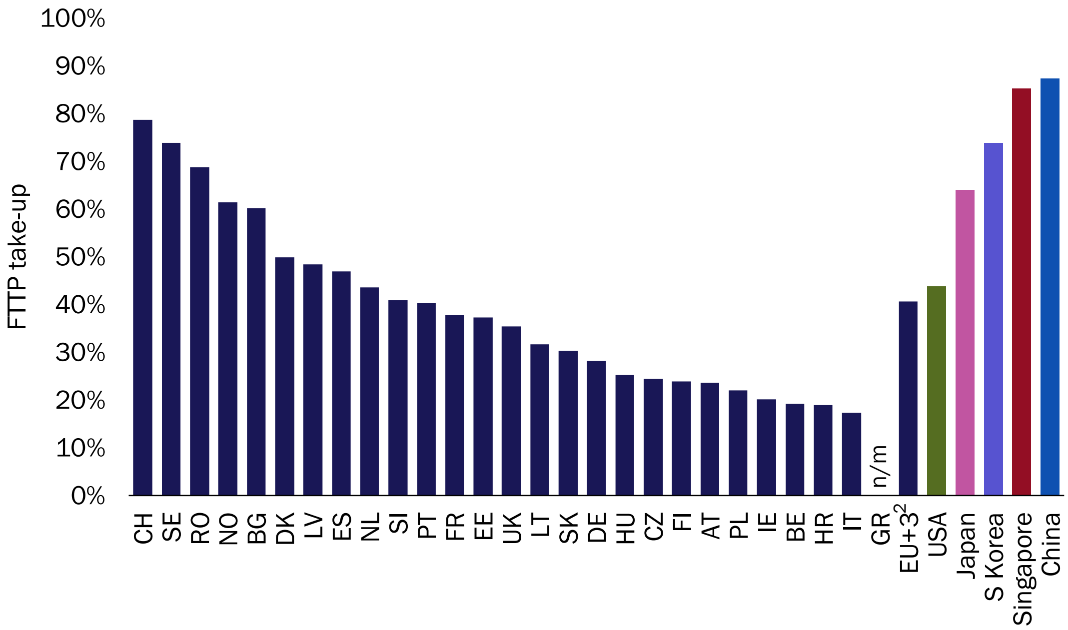
15 https://www.mincotur.gob.es/en-us/GabinetePrensa/NotasPrensa/2018/Paginas/ElGobiernopresentaelPlan300x100parallevarfibraa300Mbitsatodoslosn%C3%BAcleosdepoblaci%C3%B3ndeEspa%C3%B1a.aspx

16 https://opticalconnectionsnews.com/2018/03/spain-green-lights-e525-million-fibre-expansion/

3.3 Take-up of FTTP in Europe is accelerating

The days when FTTP was thought of as a 'nice-to-have' service with limited real demand are long gone in many parts of the world, including some European countries. End users in some countries would not accept anything less. Figure 3.6 shows the take-up of FTTP (in the areas where it is available) in European and benchmark countries in 2019.

Figure 3.6: FTTP take-up (active connections over premises passed), European and selected benchmark countries, 2019 [Source: Analysys Mason, 2020]



Note: Excludes Greece due to the low number of premises passed.

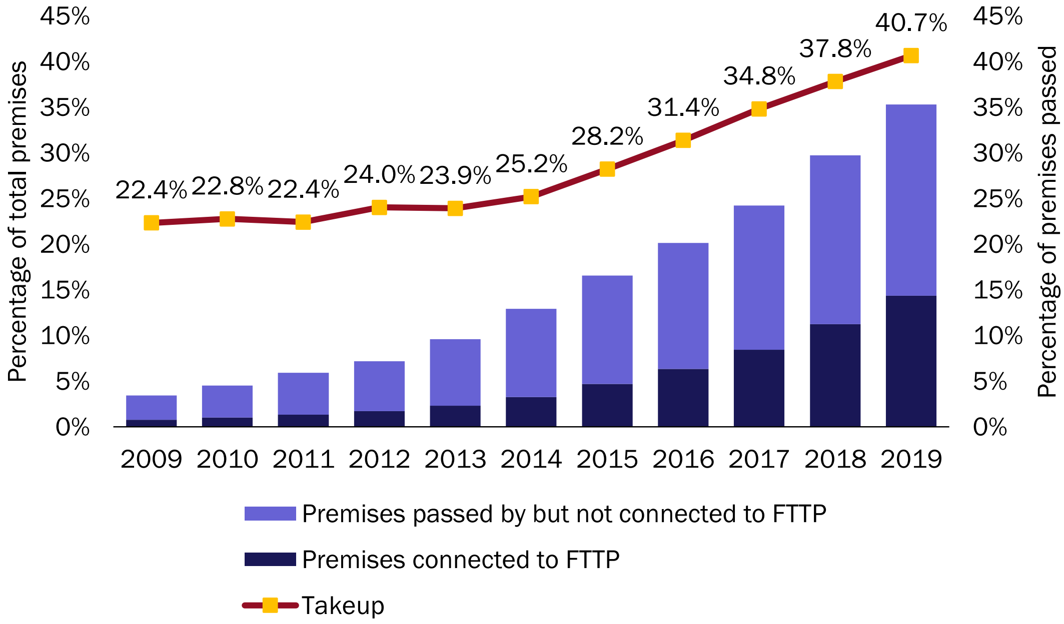
Unsurprisingly, FTTP take-up tends to be higher in countries or in areas of countries in which FTTP has been longer established, and in which coverage of intermediate technologies (such as FTTC/VDSL) is low or non-existent. Take-up rates are high in the Asian early-mover countries and some high-coverage European countries including Sweden and Norway.

Take-up is generally lower in European countries than in the Asian benchmark countries owing to higher coverage of alternative NGA technologies. European operators facing limited competition from other operators' FTTP have tended to preserve a price premium (wholesale or retail) for FTTP over legacy technologies, whereas in markets where competition is stronger entry level FTTP carries little or no price premium, boosting take-up rates. The larger European fibre operators also face a raft of pro-competition regulation and consumer-protection regulation that slows their ability to migrate wholesale and retail customers off copper networks. The total European take-up rate of approximately 41% is good given these factors and its late arrival in this region.

The European Commission's 2016 public consultation on the need for internet speed and quality beyond 2020 and for measures to fulfil these needs by 2025 revealed clear expectations for the quality of service of fixed internet connectivity to improve by 2025, especially regarding downlink speed. More than half (59%) of respondents to the EC survey thought they would need fixed download speeds above 1Gbit/s in 2025; only 8% thought they would need download speeds below 100Mbit/s in 2025.[18]

Figure 3.7 shows how coverage and take-up of FTTP has increased in Europe since 2009. Of note is the steady growth in take-up beginning around 2014. This demonstrates robust demand as the communications needs of consumers and businesses develop in the modern digital economy. High take-up rates in mature, well-covered countries such as Sweden (70%) would indicate that the current upward trend in take-up will not slow down any time soon. Importantly, in countries with well-established FTTP, we see an emerging trend of declining cable broadband take-up, and in a few instances cable operators are already migrating their services to FTTP. In Singapore, that process has reached a conclusion: all broadband subscriptions are on FTTP.

Figure 3.7: Coverage and take-up in Europe, 2009–2019 [Source: Analysys Mason, 2020]



There are pockets of exceptionally high demand in Europe, and these deserve an explanation. In some countries and regions there has been little investment in intermediate broadband solutions, and therefore many households and businesses are faced with FTTP as the sole available upgrade from ADSL2+, which supports only up to 24Mbit/s, or even basic ADSL, which supports only up to 8Mbit/s. Naturally, take-up is strong in these areas. In some rural parts of Norway, where there are few alternatives to FTTP, take-up can be more than 80%.

3.4 Unmatched and future-oriented service capability is just one aspect of demand

The main drivers of this high level of demand, other than alternative supply constraints, are service capability, and reliability/predictability. Increasingly, particularly in markets with strong infrastructure competition, low prices drive demand.

17 https://www.gov.uk/guidance/building-digital-uk

18 https://ec.europa.eu/digital-single-market/en/news/full-synopsis-report-public-consultation-needs-internet-speed-and-quality-beyond-2020

Consumer service capability

The low latency offered by FTTP already offers a competitive advantage in online gaming. FTTP will also enable the development of residential use cases that have not been viable on legacy networks. These include entertainment technologies such as 4K and 8K video, as well as online and cloud-based VR/AR video and gaming, which has high requirements for resolution and frame rate.

8K TV sets have recently become available to consumers. Sceptics argue that the improvement in rendering 8K improvement is imperceptible, but 8K is more than simply a higher intensity of pixels: it incorporates a higher range of colour, a higher frame rate and hence improved capability for zoom or slow-motion. Indeed, 8K is more than passive consumption of video; interestingly, it has recently made its way into mobile handsets, allowing for example, users to live stream their own video to OTT services.

There are variants of 8K, and different codecs that determine the streaming bandwidth of 8K. Moreover, the complexity of the moving images will create different levels of bandwidth demand. At its most basic, however, using the most bandwidth-efficient commonly used codec (HEVC), 8K requires a 40Mbit/s stream, meaning with a suitable overhead, a bare minimum 50Mbit/s internet access service, assuming that nobody else is using it for other applications. A higher frame rate for a premium sports experience requires double that. 5G networks can burst to these speeds and well above, but will not be able typically to deliver these bandwidths reliably indoors, especially on the uplink.

Immersive VR creates demand for even higher bandwidth. For example, a 6-degrees-of-freedom 4K-type experience could demand high hundreds of Mbit/s or low hundreds of gigabytes per hour. One of the huge advantages of reliable FTTP-type speeds is that the whole range of perspectives in immersive VR could be streamed simultaneously so that the user moves between these perspectives instantly rather than having constantly to request the network for a new angle. This can reduce delay and jitter greatly, improving the end-user experience.

The ability to harness massive bandwidth to do away with complex and expensive means of achieving network efficiency will in the long run be a key differentiator for full-fibre access networks. They deliver a better user experience, and they also create simplicity by making efficiency unnecessary. Typically, adapting an application to the limitations of a network is an additional overhead for developers, and service providers will not want to pay a network operator for a guaranteed service, even if net-neutrality legislation allowed them to do so. In an entirely positive sense, full-fibre networks are gloriously inefficient, a huge open, net-neutral playground of an opportunity for consumer-oriented developers.

FTTP will also enable further development of the internet of things (IoT) in the home, such as enhancing the capabilities of smart meters to provide more-detailed reporting and real-time adjustments. However, the relevance of specific high-bandwidth services that are currently available or in development (such as 8K video) is expected to be relatively minor compared with the importance of FTTP as long-term infrastructure.

Business service capability

Business demands for the advantages provided by full-fibre networks will also be significant. As in the residential environment, the high bandwidth and reliability offered will be important in offices, permitting faster upload and download of files and more reliable access to SaaS and cloud-based software. The low latency of full-fibre networks can provide new opportunities for remote work. FTTP also provides greater security than copper networks due to the lack of electromagnetic emission from the optical fibres. The dynamic symmetry offered by fibre networks allows the flexible configuration of up- and down-stream bandwidth depending on business requirements. FTTP may also facilitate the adoption of holographic and AR-based video conferencing.

Demand for FTTP is also supported by numerous use cases within different industry verticals. Many of these applications are related to developing the IoT, with the high bandwidth, security and reliability provided by full-fibre networks allowing the transfer of large amounts of data.

- In manufacturing, FTTP could provide support for industrial IoT based on Wi-Fi 6, or local backhaul for use cases based on 5G. As Section 4.6 describes, the simple FTTP topology can be extended deep into industrial or campus sites and serve as the local area network.

- In the public sector, FTTP will accelerate the development of 'smart cities', by enabling the application of IoT technology to utilities and services in public spaces, including street lighting, energy, waste and water management, transportation and assisted living.

- In retail, full-fibre networks will improve the quality of AR/VR to enable the adoption of these technologies in online shopping.

- In education, FTTP will enable enhanced digital learning, allowing many students at the same premises to download large amounts of educational content from the internet. Through improvements in VR/AR technology, FTTP will enable virtual learning in the form of Immersive Virtual Learning Environments (IVLEs) and virtual field trips. It will also allow students to download higher-quality educational content including taught courses from home, facilitating remote learning.

- In healthcare, the higher bandwidths provided by FTTP will permit more detailed remote patient monitoring using smart sensors. More reliable connections together with more rapid transmission of large amounts of data will enable remote video consultation and surgery, as well as remote AI-supported diagnosis. This will be particularly valuable in times of major public health crises.

In all sectors, reliable, fast, low-latency and symmetrical FTTP access greatly facilitates the utility and user-experience of cloud access. FTTP is key to enabling small and medium-sized enterprises (SMEs) and public sector sites such as schools to eliminate servers, dedicated IT resources and ultimately unnecessary cost.

It is expected that full-fibre networks will become, and continue to be, the standard fixed access technology for at least the next few decades. In addition to the use cases mentioned above, it is probable that other technologies, applications and services will be invented, which will benefit from FTTP well into the future. This highlights the importance of FTTP as a long-term investment.

Reliability and predictability

The above are all promising use cases for FTTP in the form of enhanced consumer services and industrial applications. We do not know how popular any of them will be. A great deal of the demand for FTTP currently comes from and will probably continue to come from something different from service provision and specific applications. End users want reliability coupled with speed: not as a guaranteed service for a premium price and perhaps attached only to certain applications that are bundled in, but as a basic 'best-efforts' requirement. End users do not want 'up to xMbit/s' depending on signal attenuation or number of concurrent users on the network; they want an ultra-high-speed connection and no conditions attached.

An Analysys Mason 2018 survey of 8000 fixed broadband users indicated that in Europe and the USA end-users take reliability to mean 'delivering on speed', and that speed and reliability (in equal measure) have a greater impact on intention to churn than price, value -added services or even the quality of customer service.[19] End users increasingly want their access providers to be high-quality utilities, not multi-service providers. Therefore it seems reasonable to assume that they will in future expect low latency, but will not on the whole be prepared to pay extra for it. In this respect, their expectations may well be met: no network operator will charge for guaranteed low latency when the next offers it as standard.

At the time of writing, Europe is facing the Covid-19 pandemic. A high proportion of the workforce will have to work from home. Remote working ideally requires a corporate-LAN-type experience, whether it is cloud-based, or simply based on access to VPNs. A combination of high uplink speed and low latency will help this. In the longer run, the Covid-19 experience might stimulate demand for an ultra-reliable and overprovisioned fat pipe for all eventualities rather than a 'good enough' connection that is geared to consumer entertainment applications.

Affordability

A final driver of demand is affordability. Entry-level FTTP frequently commands a similar price to, and sometimes even a lower price than, copper-based legacy alternatives. Obviously a better service at a lower price is a winning formula. This phenomenon can occur for the following reasons:

- For an incumbent operator the cost of running parallel copper or coax networks is wasteful, so once the investment in the FTTP network has been made, network owners are highly incentivised to convert as many premises passed as possible. Entry-level 100Mbit/s FTTP from Telia Sweden for example has a retail list price 22% lower than its 60Mbit/s VDSL.

- Where competition between FTTP plays occurs at an infrastructure level, or if it occurs through Layer 1 unbundling, prices can be driven down, and price differentiation based on speed tends to erode or disappear completely. For example, Free in France charges no more for services based on unbundled fibre than on unbundled copper, and it offers just one speed on fibre: 1Gbit/s. Salt, which uses unbundled access to several utility FTTP networks, has simultaneously the cheapest and fastest (10Gbit/s) broadband offer in Switzerland, and like Free, offers only one speed tier.

- Where alternative operator FTTP has been built to compete against incumbent FTTC, basic wholesale and/or retail prices are often lower than those on the FTTC network: in fact, the business model succeeds only when they are. The lifetime value of an FTTP customer is very high and there is plenty of long-term potential to add services and increase revenue, and even perhaps simply to raise prices longer-term. For operators the sacrifice of some revenue per line now appears a good trade-off for high utilisation and/or a platform for additional monetisation.

This raises the legitimate question as to whether end users are ever willing to pay a premium for ultrafast services. One 2016 report found that a majority of national regulatory authorities reported a lack of demand and an unwillingness to pay (more) for ultrafast services (FTTP or not).[20] This may be the case in some countries where infrastructure build has been slow. It is possible to conjecture that the period of stagnation in the conversion of premises passed into subscribers in Figure 3.7 above corresponds to the older business model of treating FTTP as a premium service. In many other countries, perhaps the majority now, citing consumer unwillingness to pay a premium may still be technically true, but it may be an inappropriate or anachronistic

19 Analysys Mason *Connected Consumer Survey 2018: fixed broadband retention and satisfaction in Europe and the USA*. Available at www.analysysmason.com/Research/Content/Reports/Fixed-broadband-Europe-USA-RDMB0.

20 BEREC, Challenges and drivers for NGA rollout and infrastructure competition, BoR (16) 171, 14. Ee https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/6488-berec-report-challenges-and-drivers-of-nga-rollout-and-infrastructure-competition.

view of market trends. Proactive and reactive roll-outs of FTTP, especially where wholesale-focused, have business models that do not depend on a premium. They have longer paybacks, and lean far more heavily on utilisation and opex efficiency than on near-term revenue per line.

3.5 Europe needs to accelerate the rate at which access networks are being upgraded to fibre

Europe is lagging behind the important international benchmark countries in FTTP deployments, and if current trends continue, it will remain behind by 2025. Full-fibre coverage in Europe is not as low as it is in the USA, but Europe has a lower penetration of NGA technology, largely due to the high penetration of DOCSIS3.0+ in the USA. A significant proportion of broadband lines in Europe are legacy copper, including in large countries such as Germany and the UK.

The situation in large parts of Europe stands in stark contrast to the situation many Asia–Pacific countries, where FTTP already constitutes the bulk of fixed broadband infrastructure. FTTP roll-out is booming across emerging economies – in Latin America, in South and Southeast Asia – and fixed broadband take-up, mainly on FTTP, shows very strong growth rates. Indeed most hitherto mobile-only operators in emerging economies recognise the opportunities that come from fibre investment, and their new fixed businesses are their growth areas. Between 2013 and 2019, the number of mobile subscriptions worldwide grew 21% while the number of fixed broadband subscriptions – over half of which are already full-fibre – grew 58%.

As a result, the situation for consumers and businesses in Europe is poor; large parts of Europe could end up with worse outcomes not only than technologically advanced economies like China and Japan, but than many much lower-income countries. Ultimately, it is the European consumer or business end user that ends up suffering from a late fibre deployment.

There are numerous significant sources of demand for FTTP, and more generally gigabit-capable, networks. However, FTTP uniquely provides the combination of high speed, reliability and low latency that the home and office environments demand. Full-fibre networks also provide an opportunity to enable the adoption or unleash the full potential of emerging applications such as AR/VR and IoT. There is demand for these technologies from numerous industries including education, healthcare and utilities, as well as from consumers and businesses more generally, and there will undoubtedly be new popular and useful applications and use-cases developed within the expected asset-life of full-fibre networks. Dense full-fibre networks are a key to unleashing the full power of 5G, so the mobile user also has a stake in FTTP being more widely and rapidly deployed.

Government NGA roll-out policies in Europe have generally been favourable towards FTTP, but this has not yet yielded results comparable with those of the Asian early movers. So far, fibre roll-outs have been largely commercially driven. In order for Europe to meet the connectivity demands of its consumers and businesses, and for it to match the results seen in other advanced economies, it will be necessary to accelerate investment in optical networks within the next few years. This report aims to show why full-fibre networks are important, why they are the right option for future digital communication needs, and what practically can be done to break down barriers to accelerated investment.

4. Full-fibre: the network architecture for the future

As discussed in the previous chapter, many European countries are likely to fall short of current EC targets for VHCN access. This chapter compares full-fibre fibre networks to alternatives involving copper and coax. This chapter is relatively technical; readers less interested in a detailed discussion of the advantages of full-fibre technology may prefer to skip this chapter.

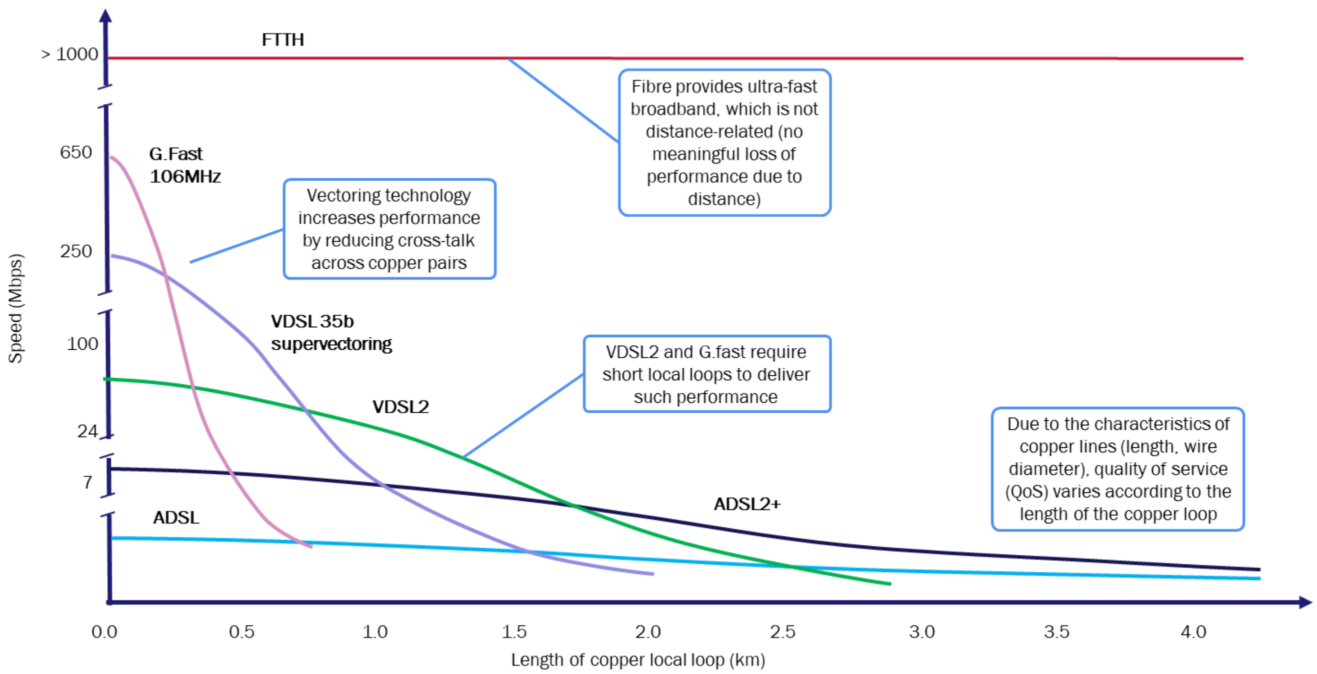
4.1 Copper- and coax-based technologies face constraints

Copper and cable networks (coax) have a number of fundamental limitations that constrain their performance. A fundamental limitation is that copper and cable networks suffer from attenuation, so the speeds that can be offered decrease as distance increases. In contrast, fibre technologies provide a significantly improved range: for example, GPON's range is around 20km, and with higher-speed fibre standard even greater. Cable and copper networks are also limited by the frequencies that can be used over each. The frequencies used on copper networks can be increased, but this introduces greater attenuation concerns and only shorter copper loops can be used for newer copper technologies that can provide the fastest speeds like G.fast. Today's cable broadband networks use separate frequencies to transmit data on the downstream and upstream, and this has led to particular capacity constraints on the upstream. Moreover, there are also concerns that the frequencies being used by cable networks are simply insufficient to meet capacity and peak speed needs.

Copper

Copper acceleration technologies have evolved in recent years to provide higher bandwidths at generally shorter loop lengths (see Figure 4.1).

Figure 4.1: Loop length and downlink capacity, copper broadband technologies [Source: Analysys Mason, 2020]



ADSL networks were traditionally deployed from operators' central offices, and the development of VDSL enabled operators to extend the frequencies used for data transmission over the copper lines, typically up to 17MHz and less commonly to 30MHz. This allowed operators to provide higher bandwidths, typically with either FTTC or FTTB architecture. However, VDSL networks were still constrained by the mutual interference, or cross talk, between copper lines in the same binder. The development of VDSL vectoring allowed operators to cancel this crosstalk and deliver higher data rates.

The most recently available copper acceleration technologies are VDSL35b supervectoring and G.fast. VDSL35b supervectoring builds on the work of previous VDSL iterations, but extends the frequencies used to a maximum of 35MHz, up from the previous maximum of 30MHz, and also implements cross talk cancellation. VDSL35b was designed largely to use with FTTC deployments. Telekom Deutschland in Germany is using VDSL35b supervectoring to offer downstream speeds of only up to 250Mbit/s.

G.fast can also deliver high data rates over copper. G.fast allows 106MHz or 212MHz frequencies to be used for data transmission over the copper network and because of these high frequencies is particularly well suited to deployment over very short copper loops. The technology was initially envisaged to be deployed in conjunction with FTTdp point roll-outs where fibre is rolled out to points between street cabinets and subscriber premises but it has also been used with FTTC roll-outs. G.fast is likely to struggle to provide aggregate (i.e. downstream + upstream) gigabit speeds even when using 212MHz frequencies, and maximum speeds will be even lower with G.fast 106MHz. Test results from Germany show that G.fast using frequencies from 19MHz to 212MHz would not be able to provide gigabit downstream speeds even at loop lengths of 50m, although such speeds would in theory be possible on 50m loops if frequencies from 2MHz to 212MHz were being used. There is however a difference between laboratory environments and real-life environments, where a combination of decades-old degraded copper, cross-talk between cables and multiple unused in-building telephone sockets combine to mean that laboratory speeds will never be matched.

There are further question marks around the completeness of standards for copper acceleration technologies. The first volume of the recommendation for the G.mgfast ITU project was scheduled to be completed in January 2020. G.mgfast (also known as XG-fast), which could use frequencies up to 424MHz or 848MHz, aims to provide aggregate downstream and upstream bitrates of 10Gbit/s over in-building copper and coaxial cabling. This is still lower than the aggregate 20Gbit/s available commercially on XGS-PON networks today. As of the end of 2019, G.mgfast was supported by only one chipset vendor, and no equipment vendor has planned investment.

There are also difficulties with multiple operators offering VDSL35b supervectoring or G.fast. If multiple operators try to use VDSL35b supervectoring or G.fast from the same node then it may not be possible to cancel the crosstalk between the lines used by the different operators, at least if the operators are using equipment from different vendors. This might then entail deploying VDSL35b without vectoring which would have a negative impact on performance. Such constraints do not exist in scenarios where multiple operators deploy FTTP to the same premises.

Cable

Cable technologies will struggle to meet current and future speed demands from end users. Today's cable networks mostly use the DOCSIS 3.0 standard. The most recent version of the DOCSIS standard is DOCSIS 3.1, which was initially specified in 2013, and which promised bandwidths of up to 10Gbit/s downstream and up to 1Gbit/s upstream. However, not only are these bandwidths shared but there are significant challenges in being able to deliver these maximum capacity figures. For example, the downstream frequencies on the cable network can only be allocated to either DOCSIS 3.0 or DOCSIS 3.1 but not both at the same time, which means there will need to be a lengthy migration process before all downstream frequency resources can be dedicated to DOCSIS 3.1.

Moreover, the capacity that DOCSIS 3.1 cable networks can provide is constrained by the frequencies being used. If cable operators try to boost DOCSIS 3.1 capacity by extending the frequencies used on the downstream and/or upstream, this will have cost and time-to-market implications because it may necessitate the replacement of active components and possibly also passive components in the field. In order to further improve capacity alongside a DOCSIS 3.1 deployment, operators could also aim to bring fibre deeper into the network and deploy distributed architecture such as remote PHY.[21] However, this represents a significant change in network architecture for cable operators while raising costs and increasing time to market.

A further challenge for cable networks is that standards work is incomplete. DOCSIS 4.0 promises symmetrical downstream and upstream speeds of 10Gbit/s thanks to the dynamic sharing of all frequencies for both downstream and upstream transmission. DOCSIS 4.0 would also allow frequencies of up to 1.8GHz to be used, an increase from the previous maximum of 1.2GHz with DOCSIS 3.1. However, the DOCSIS 4.0 specification was only scheduled to be completed by CableLabs in early 2020, which has implications for how quickly operators will be able to deploy the technology in the field.

For new networks, many cable operators have started to deploy full-fibre networks (for example Virgin Media in the UK), and a few, largely outside Europe, have even started to replace existing coaxial cable plant with fibre (for example, Altice USA). Cable broadband subscriber numbers have started to decline, especially in countries with good FTTP coverage (for example in Spain and Switzerland) and cable operators there have incentives to switch to fibre either by converting their own plant, or by using an independent wholesaler.

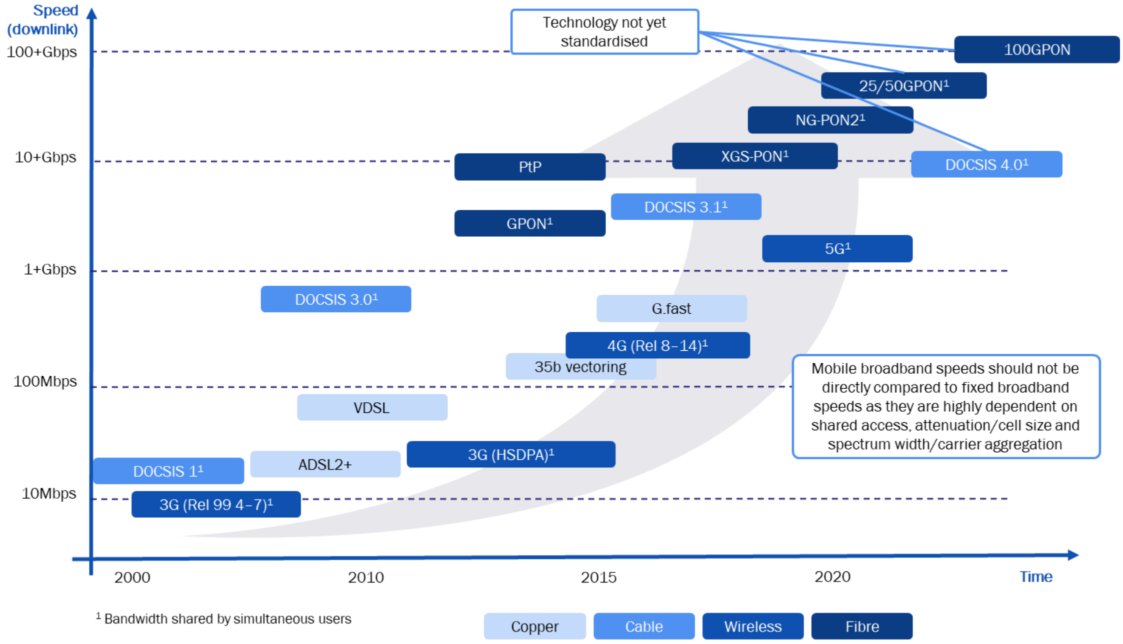
Downstream and upstream speeds are a key component of fixed broadband performance, but stakeholders also need to take the importance of latencies into account as interest in latency-sensitive applications grows. FTTP deployments offer significantly lower latency than copper acceleration technologies and cable. For example, today’s XGS-PON deployments can deliver latency of less than 600µs (compared to 600µs for GPON), which is considerably better than the 10ms that can be delivered over DOCSIS 3.1 cable networks. DOCSIS 3.1 has improved latencies from the 100ms seen with DOCSIS 3.0, but there is still a considerable gap compared to the latencies that FTTP networks can provide. Moreover, there is uncertainty around the latencies that DOCSIS 4.0 could deliver, which adds to the risk of operators investing in cable networks.

4.2 FTTP standards have a detailed roadmap and next-generation PON systems are being deployed commercially

Copper and cable networks suffer from performance limitations, and standards roadmaps for these technologies are uncertain in some cases. However, FTTP is already able to offer symmetrical 10Gbit/s speeds (see Figure 4.2) and there is a clear roadmap for new standards. The roadmap for 25Gbit/s and 50Gbit/s PONs is clear, and has commitment from the largest vendors such as Huawei and Nokia (including pilot demos with operators). The supply chain for higher-speed PON is also rapidly maturing.

21 Remote PHY involves moving the physical layer of the cable network from its traditional centralised location at the headend to distributed locations at the network edge. Remote PHY systems have the potential to allow cable networks to deliver improved capacity.

Figure 4.2: Evolution of copper, cable wireless and fibre bandwidths [Source: Analysys Mason, 2020]



GPON's capacity of 2.5Gbit/s downstream and 1.25Gbit/s upstream has enabled many operators worldwide to launch gigabit FTTP retail offers. This is already a differentiator from cable and, in particular, copper networks. GPON adequately serves most consumer needs. However, operators are also commercially deploying next-generation PON technologies, which can provide shared capacity of up to 10Gbit/s and 10Gbit/s downstream. Some operators may look for a simple marketing differentiator, some may be anticipating future demand, and some may go straight to 10Gbit/s technology in order to save capex on GPON.

Roll-outs of the asymmetric XG-PON (10Gbit/s downlink and 1Gbit/s uplink) were limited, but interest has picked up significantly with the development of the XGS-PON standard, which provides symmetrical 10Gbit/s speeds. XGS-PON was standardised by the ITU in 2016. The IEEE has an alternative set of standards for PON, including the 10Gbit/s 10GEPON, which has also been deployed commercially, for example in South Korea. Equipment built to this set of standards has been deployed mainly in Asia, and has seen little traction in Europe, where the ITU standards are almost invariably the ones used.

Many operators that have upgraded to XGS-PON have done so by cutting the fibre in front of the OLT over to a so-called 'combo' or 'universal' OLTs. These operate as regular GPON now but are XGS-PON ready, meaning that an operator has only to swap out the transceivers to deliver XGS-PON functionality. Some operators deploying XGS-PON are looking for benefits beyond broadband. Faster network technology can also deliver enterprise services and small-cell mobile transport services, and by delivering these over the same PON network it can save the cost of building out those networks separately. Yet others may be looking to XGS-PON to deliver services deep into a factory or a campus environment (see below Figure 4.3).

FTTP operators also have the option to deploy NGPON2, which includes TWDM PON and WDM PON. TWDM PON, which was standardised by the ITU in 2015, can provide the equivalent of up to four XG-PON or four XGS-PON overlay systems within a single PON network. It does this by allocating a separate wavelength on the fibre to each of the systems. Altice and Verizon appear to be the only two operators deploying TWDM PON in any volume while there is growing interest in XGS-PON roll-outs. WDM PON was also standardised as part of NGPON2 in 2015. TWDM PON offers the possibility to use, flexibly and dynamically, separate wavelengths for separate functions (for example, residential broadband, enterprise connections and mobile transport) or for separate retail service providers, but there is a trade-off between the expense of tuneable lasers and the additional value that TWDM brings.

There is more commercial interest in extending the bandwidth of fixed wavelength PON technologies. The future roadmap for FTTP could include solutions that offer 25Gbit/s capacity. For EPON operators, which are largely found in China, Japan and South Korea, the IEEE 25G/50G-EPON standard was scheduled to be completed at the end of 2019. There is also ongoing work to develop 50GPON – the ITU began the standardisation process for this technology in February 2018 and is expected to complete it in the first half of 2020. The technology would provide 50Gbit/s of capacity over a single wavelength. The target timeline for commercial deployments of the technology is 2025. Figure 4.3 demonstrates some of the features of different FTTP technologies.

Figure 4.3: Selected PON technologies [Source: Analysys Mason, 2020]

	GPON	XG-PON1	XGS-PON	TWDM-PON	50GPON
Downstream peak rate (Gbit/s)	2.5	10	10	n×10	50
Upstream peak rate (Gbit/s)	1.25	2.5	10	n×2.5 or n×10	50
Reach (km)	<20	<20	<40	<40	<40
Standardised	Yes	Yes	Yes	Yes	Expected in 1H 2020

Note: n refers to the number of wavelengths being used in a TWDM-PON system. Today's commercial TWDM-PON systems use four wavelengths. n×2.5 refers to when the TWDM-PON system is using XGPON1, n×10 refers to when the TWDM-PON system is using XGS-PON.

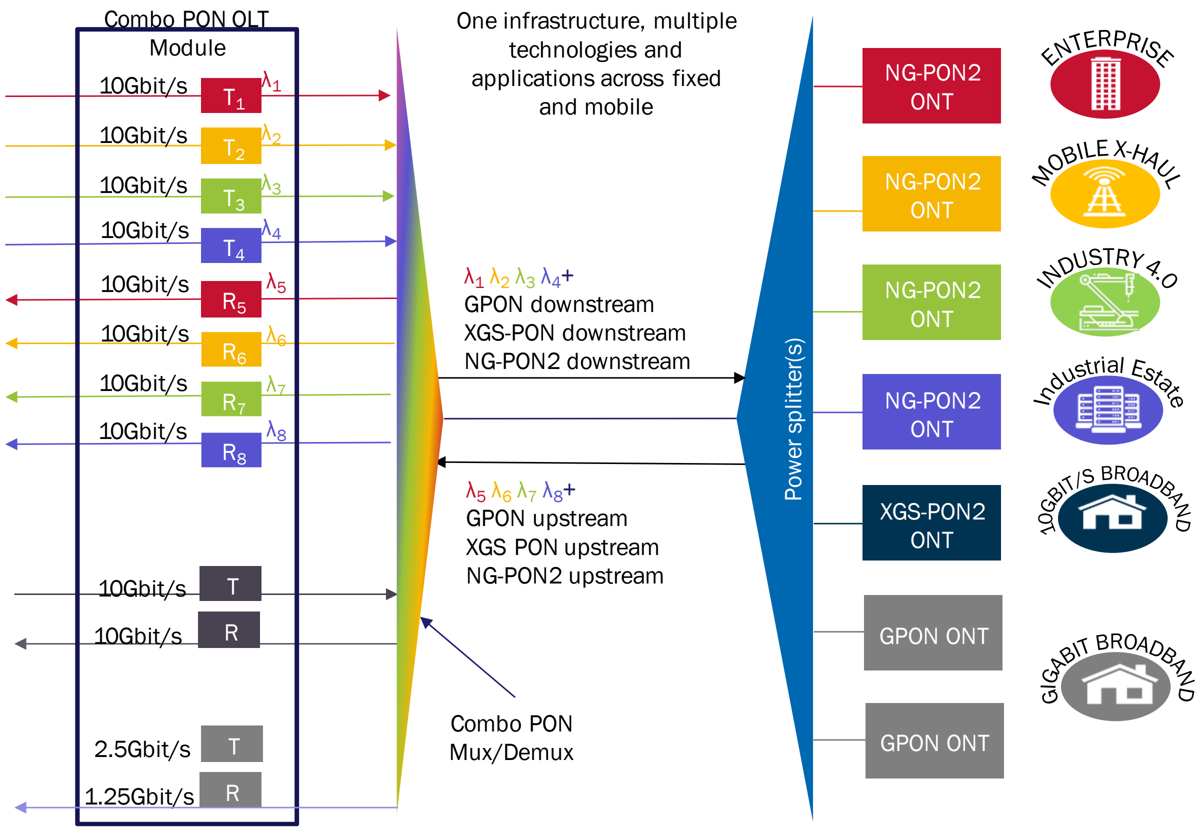
These potential future speeds put FTTP well ahead of what copper and cable networks will be able to provide.

Importantly, all of these **new fibre technologies do not require alteration of the existing optical distribution network**, considerably simplifying the roadmap for their deployment. This is a hugely important differentiator compared to copper and cable networks. For example, if an operator that has deployed G.fast also has VDSL in the same area, then the frequencies being used by VDSL, typically 17MHz, 30MHz or 35MHz, will not be available for G.fast, which will limit G.fast end-user bandwidths. As discussed above, DOCSIS 3.1 can use the same frequencies on the upstream as DOCSIS 3.0, but it cannot do so on the downstream, which again places significant constraints on end-user downstream bandwidths.

In fact, all the ITU standardised technologies can coexist on the same physical fibre without implications for the bandwidths that each technology can provide. This serves to smooth the migration process to next-generation FTTP technologies (see Figure 4.4). Hence capacity upgrades on fibre, when and as they become necessary, will be two orders of magnitude per Mbit/s less than previous upgrades of broadband, and an order of magnitude less than for any competing medium.

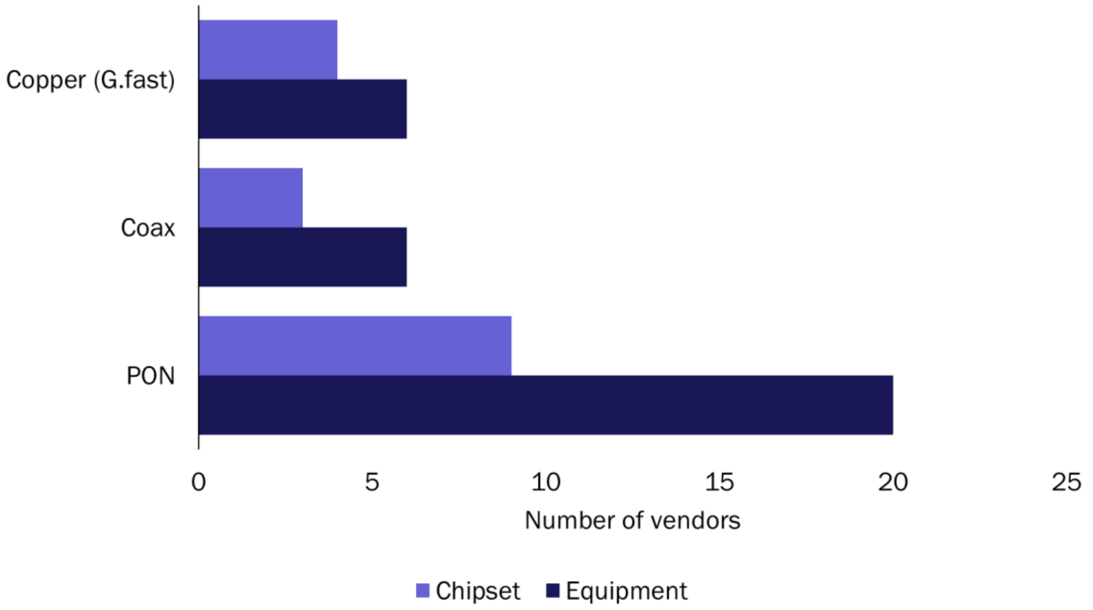
An optical distribution network has a book asset-life of 30 years (its actual asset-life will probably be longer) and will be used for multiple technology generations. Therefore, it is important to think of the passive optical distribution network – the fibre itself – not as a technology, but as national infrastructure on which all of the most advanced and capable network technologies of the coming decades can be placed. It is therefore of national strategic importance; therefore any call for public investment is not simply another call on public funds to help bridge a digital divide for yet another bandwidth target. This is not always fully grasped by policy makers.

Figure 4.4: Example of aggregation of different PON technologies on the same PON network [Source: Analysys Mason, 2020]



The contrast between the copper and cable ecosystems on the one hand and the fibre ecosystem on the other is demonstrated by the number of players that are active in each. The PON equipment vendor and chipset ecosystems are vibrant and home to a significant number of players, which will help to drive innovation in the future while continuing to support operators' existing deployments. A number of major equipment vendors including Huawei and Nokia are focusing investment on 50G-PON and 25G-PON, and also for the future, 100G-PON. The copper and cable ecosystems tend to have fewer equipment and chipset vendors, which has cost implications for operators and leaves question marks around future support for operators (see Figure 4.5).

Figure 4.5: Number of vendors in the copper (G.fast), coax and PON equipment and chipset ecosystems, December 2019 [Source: Analysys Mason, 2020]



4.3 Growing numbers of operators are focusing more of their attention on FTTP as capex and opex benefits become more apparent

Operators worldwide are beginning to realise that continuous incremental improvements in copper and cable technologies will not save money or be sustainable in the long term. In many cases, perhaps most, the argument for FTTP is simple: a competitor is building FTTP and offering it at a low price, so anything other than FTTP is out of the question. But even where that competitive pressure does not exist, the total cost of accelerating the legacy network can be high.

Copper

Copper acceleration technologies (technologies faster than VDSL2) have struggled to make a significant impact on the market: both VDSL35b supervectoring and G.fast have failed to generate many large-scale deployments. VDSL35b supervectoring is being used by Deutsche Telekom in Germany and some of its other subsidiaries in Europe (notably Greece) and G.fast has been deployed by Swisscom and Openreach, although the latter has already refocused away from G.fast to FTTP.

A much more pronounced trend is that operators that initially focused their attention on FTTC–VDSL roll-outs are now seeking to upgrade these networks to FTTP. Examples of such operators include eir in Ireland, Openreach in the UK, Proximus in Belgium, Telecom Italia, Siminn in Iceland, and Bell and Telus in Canada.

The growing trend of migration from FTTC to FTTP reflects a decline in interest in fibre-to-the-distribution point (FTTdp) and FTTB architecture. In theory, such architecture would be well suited to G.fast deployments, because it is optimised for environments with very short copper loops.

However, a number of challenges have made it difficult for operators to focus on FTTdp and FTTB architecture. Not all countries have legacy distribution points where the copper cables can be accessed. In such cases, if operators want to use an FTTdp architecture they may be required to construct a chamber to place the distribution point unit and this could easily cost a few thousand dollars. It is noteworthy that Swisscom, which has rolled out some FTTdp, has access to legacy manholes where it can access the copper lines.

Another challenge is that some legacy distribution points may also serve a very low number of premises, which pushes up costs per premises passed because it necessitates fibre being rolled out closer to end-user premises and because it pushes up the cost per port of the active equipment. It is certainly conceivable that G.fast costs per premises passed could significantly exceed those of FTTP when G.fast is deployed to very small nodes. In theory, G.fast allows the end user to self-install, as with other xDSL technologies, but this cost advantage is negated if the cost per premises passed is actually higher than that for FTTP. Hence it is likely to be preferable for operators to choose the lower costs per premises passed of FTTP compared to G.fast with FTTdp or FTTB. This is because FTTP upfront costs will be lower and the lower connection costs for G.fast will be contingent on the operator achieving significant take-up rates, which implies that G.fast is a riskier deployment option.

For greenfield deployments copper cabling is still often deployed for backwards compatibility reasons, but copper cabling itself is actually more expensive than fibre cabling.

Cable

Cable operators that are upgrading to DOCSIS 3.1, or in future DOCSIS 4.0, will also face significant cost hurdles. For example, if cable operators wish to implement DOCSIS 3.1 alongside an extension of the upstream frequencies to 204MHz then amplifiers may need to be replaced. Extending the upstream path to 204MHz could also introduce costly logistical challenges centred on the possible need to replace legacy set-top boxes as well as the need to manage possible interference with aeronautical systems. In addition, if downstream frequencies are to be extended then both active and passive components in the field may need to be replaced. The large number of passive components in the field means that if these are to be replaced operators might need 3 to 5 years to complete the upgrade. As with copper acceleration technologies, repeated incremental network upgrades have the potential to increase overall capex compared to a single investment in a full-fibre physical plant.

Copper and cable networks have significant capex challenges that are difficult to resolve, but FTTP is benefiting from the cost advantages brought about by large-scale deployments. Widespread FTTP deployments have helped to bring down the cost of OLTs and optical network terminals (ONTs) through the exploitation of economies of scale. New optical distribution network solutions can also serve to reduce the time taken to both pass a premises with fibre and to connect it. These innovations reduce the amount of manpower required for fibre roll-outs and so result in lower capex.

Cable and copper technologies also face major disadvantages compared with FTTP in terms of opex. Fault rates on FTTP networks are lower than on other networks: Telefónica has noted that fault rates on fibre are at half the level of those on copper. Compared to copper cables, fibre-optic cables are also thinner and lighter in weight. Fibre withstands more pull pressure than copper and is less prone to damage and breakage, which can also help to reduce maintenance opex. Unlike copper and coax, fibre is noise proof and not susceptible to electro-magnetic interference. PON signals are native digital, whereas on copper or coax all signals are in electromagnetic waves. Copper cabling has a scrap value, whereas fibre cabling has none, and theft of copper cabling is another factor pushing up copper-related costs in some regions.

Annual operations and maintenance spending per mile of outside plant could be around USD18 for cable networks compared to just USD2 for fibre networks. Copper networks are also costly to maintain, which is driving operators to start the process of decommissioning them. In 2013, Verizon estimated that it spent more than USD200 million per year on maintaining its copper network in areas where it had overbuilt its legacy network with FTTP. Over time, the cost challenges around maintaining copper and cable networks are likely to worsen as more operators decommission these networks and it becomes harder for the operators continuing to support them to find the necessary equipment and workforce to do so. It is worth noting that the burden of regulation relating to the decommissioning of legacy networks and the migration of customers to new networks varies greatly between jurisdictions and this means that some countries will experience the benefits of migration to full-fibre sooner than others.

4.4 Full-fibre networks use less energy than alternatives and fit a green agenda

FTTP-based broadband uses less energy than wireline alternatives. For indoor mobile, it makes environmental sense to move to greener fibre and low-power indoor wireless.

- Because of the passive nature of PON FTTP networks, there are opex savings compared to copper and cable networks, which rely on powered active equipment in the field, such as DSLAMs in street cabinets and coaxial cable network amplifiers. PONs have no powered equipment in the field.
- Furthermore, moving to a full-fibre network and decommissioning the copper network allows operators to consolidate their central offices, again reducing energy consumption.
- In addition, energy consumption per line from central office equipment for both GPON and XGS-PON roll-outs is only around a tenth of that for the copper acceleration technologies VDSL2 and G.fast and for DOCSIS 3.1. A significant contribution to that lower cost is that optical equipment requires no cooling.

Overall, the potential for an operator to reduce its energy consumption from the migration to FTTP is considerable. For example, Telefónica has noted that it has achieved absolute energy savings of about 60% by decommissioning copper networks and shifting to FTTP GPON.

However, seen from an overall environmental perspective, any comparison of the energy consumption of different technologies also needs to take into account energy usage by end-user devices. On a broad level, FTTP GPON home gateways fare well from an energy consumption perspective compared to copper acceleration technologies and DOCSIS 3.0 cable customer premises equipment (CPE), although XGS-PON or NGPON2 CPE have somewhat higher levels of power consumption. The European Union has a Code of Conduct on Energy Consumption of Broadband Equipment that applies to both when devices are idle and on. The permitted maximum values for 2018 are shown in Figure 4.6.

Figure 4.6: Power values for home gateway central functions plus WAN interface, 2018 [Source: European Union Code of Conduct on Energy Consumption of Broadband Equipment]

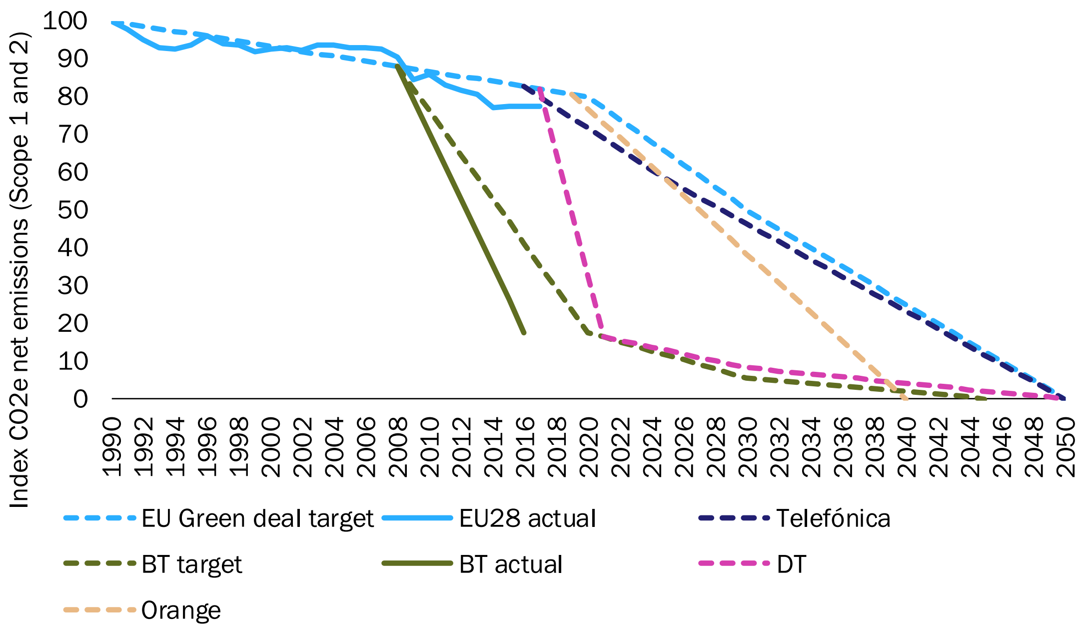
Technology	Idle state (Watts)	On state (Watts)
GPON	3.0	3.3
XGS-PON or NG-PON2	3.5	6.0
DOCSIS 3.0 (basic configuration)	5.2	5.7
G.fast	3.2	3.9
VDSL2 35b	3.8	4.4
VDSL2 (not including 30a or 35b profiles)	3.0	3.7
ADSL2+	2.0	2.4

Using fixed wireless technology to deliver high hundreds of megabits per second, or even potentially gigabits per second, directly into residential and business sites is generally more energy-intensive, especially in cases that utilise millimetre wave frequencies to deliver gigabit or near-gigabit speeds. Even where it is possible to use indoor mmWave CPE, the energy levels required may be extremely high in order to maintain a 1Gbit/s connection. The maximum permitted power level for such indoor CPE in the USA is 55dBm, which is the equivalent of around 300W; this would add significantly to end users' energy bills.

Notwithstanding its superior performance, a combination of full-fibre and low-power-mode Wi-Fi 6 represents a more efficient and a greener way to connect wirelessly in the indoor environment than mobile.

The energy efficiency of full-fibre is important in its own right, but it is given a spur because governmental bodies are placing increasing emphasis on green targets to combat climate change. The EU's Green Deal targets aim to raise the share of renewable energy to 100% by 2050. There is also a target to reduce greenhouse gas (CO_2e) emissions by 50–55% by 2030 compared to their level in 1990. A further proposed target aims to increase this reduction to 100% by 2050. Operators often have their own targets to reduce CO_2e emissions, which can be seen alongside the EU's targets in Figure 4.7.

Figure 4.7: Selected Scope 1 and 2 CO_2e emissions targets and EU 2030 targets [Source: Analysys Mason, 2019]



Note: The baseline for each target has been plotted against the implied value in that year of the EU target.

European operators' Scope 1 and 2 CO2e emissions fell by about 9% in 2018 over 2017, whereas total energy consumption rose 5%.[22] Many operators have switched their energy contracts to renewable suppliers, but more sure-fire and direct ways to help to reduce carbon emissions are to reduce energy consumption and direct emissions from property and plant. A switch to full-fibre networks achieves both of these ends.

[22] ETNO Sate of Digital Communications 2020: https://etno.eu/library/reports/90-state-of-digi-2020.html

4.5 FTTP networks offer ultra-low latency which makes them suitable to be used alongside Wi-Fi 6 and 5G

FTTP also offers important advantages when considering the implications of advances in wireless technologies. Both Wi-Fi 6 and 5G promise significantly lower latencies compared to legacy wireless technologies but these improvements in latencies will be negated if fixed access networks and mobile backhaul and fronthaul are unable to also provide low latencies. Fibre roll-outs can help to avert this threat.

As 5G roll-outs gather pace, over time there are likely to be growing numbers of virtual RAN deployments. These reduce costs by centralising processing functions (potentially in the cloud) and by reducing the complexity of the equipment deployed out in the RAN. If the higher frequencies typically being used by 5G and growing data traffic lead to a need for significant cell densification, then virtual RAN will be needed to control the interference between cell sites. Virtual RAN deployments can also help to maximise the commercial benefits of 5G by allowing operators to deploy end-to-end network slicing. Virtual RANs have a number of potential configurations, but what they all have in common is a requirement for far higher levels of transport bandwidth. Unlike with conventional mobile backhaul, so-called mid- and front-haul transport bandwidth requirements grow not with the level of traffic, but with the increased radio frequency bandwidth and the number of antennas in antenna arrays. XGS-PON can handle today's conventional backhaul, but even more bandwidth will be required in the near future. Moreover, fronthaul connections would require something like maximum 250µs latency, which would be only really possible with fibre.

A further driver for FTTP is the growing number of consumer and enterprise applications that require very low latency levels. Advanced virtual reality, which might involve the use of Wi-Fi 6 in a consumer's home, might require round trip latency of less than 10ms, which would be challenging for non-fibre access networks. Online cloud gaming could also have stringent latency demands of less than 15ms. The lower latencies that FTTP can provide could also open up new opportunities for differentiation in the consumer market. Some FTTP service providers have started to provide packages targeted at gamers, which offer guaranteed latencies to specified gaming servers. If the latencies promised are not achieved, then end users can receive compensation.

Fibre is also likely to be required to deliver on the promise of 5G in industrial applications. Smart manufacturing applications (both machine control and machine analysis) could have even more stringent latency requirements than in the consumer market. This could mean that latencies of as low as 1ms would be required, which would necessitate the use of fibre, where required in conjunction with low-latency wireless networks.

With or without a wireless edge (Wi-Fi 6 or 7, 5G or 6G), all optical networks deliver on ultra-low latency for immersive video conferencing and tele-education. Where remote human control of body movement is essential, as in tele-medicine, fibre becomes a necessary and sufficient condition for ultra-low latencies, whether the near and remote machines are connected directly by fibre or they use a wireless edge. Visual response time is about 10ms, but a tactile response time is lower still, certainly below 5ms.

The development of a single physical fibre infrastructure that is capable of providing residential and business FTTP connections as well as mobile backhaul and fronthaul also has significant cost and energy consumption advantages. The development of such an infrastructure removes the need for wasteful duplication with separate networks. Integrated fixed and mobile operators that roll out fibre for fixed broadband access networks and also use this asset for the densification of their cellular networks have the potential to offer an enhanced mobile data experience that could also deliver revenue benefits while ensuring that network costs do not spiral as traffic grows.

In contrast, operators that rely purely on cellular networks to provide both mobile data and residential broadband FWA connections may find it difficult to compete effectively in the fixed broadband market. They will face increasing costs as the need for cellular network technology upgrades, more spectrum or cellular network densification becomes more apparent.

4.6 FTTP networks can be extended to the end-user terminal with passive optical LAN deployments

FTTP also offers the advantage of extensibility because passive optical LAN deployment can extend fibre to the room in residential premises, fibre to the desktop and access points in office environments, fibre to the electronic classroom whiteboard, fibre to the medical device, fibre to the factory machinefibre and fibre to the shopfloor in industrial environments. Passive optical LANs could be integrated with FTTP roll-outs, for example, in residential environments operators could deploy low-power budget mini PON devices. Such devices include an ONT to terminate the fibre signal coming into the home as well as an integrated mini OLT to then distribute the signal across the passive optical LAN to edge optical network units (ONUs).

Passive optical LAN deployments hold a number of advantages over traditional copper-based LAN deployments. Part of the advantage of fibre LAN deployments is that they provide high bandwidths that are scalable over time. GPON passive optical LAN deployments can deliver up to 2.5Gbit/s downstream speeds to end users and this figure can easily be increased as next-generation PON technologies can deliver at least 10Gbit/s downstream capacity. These high speeds could be advantageous in office and industrial environments where the use of cloud applications is growing. Furthermore, fibre LAN deployments can benefit from the low latencies that fibre can provide, which could be important in office environments as well as for industrial applications. Fibre LANs could also deliver benefits to enterprises because they provide opportunities to offer service level agreements (SLAs) for cloud services that stretch all the way to the desktop.

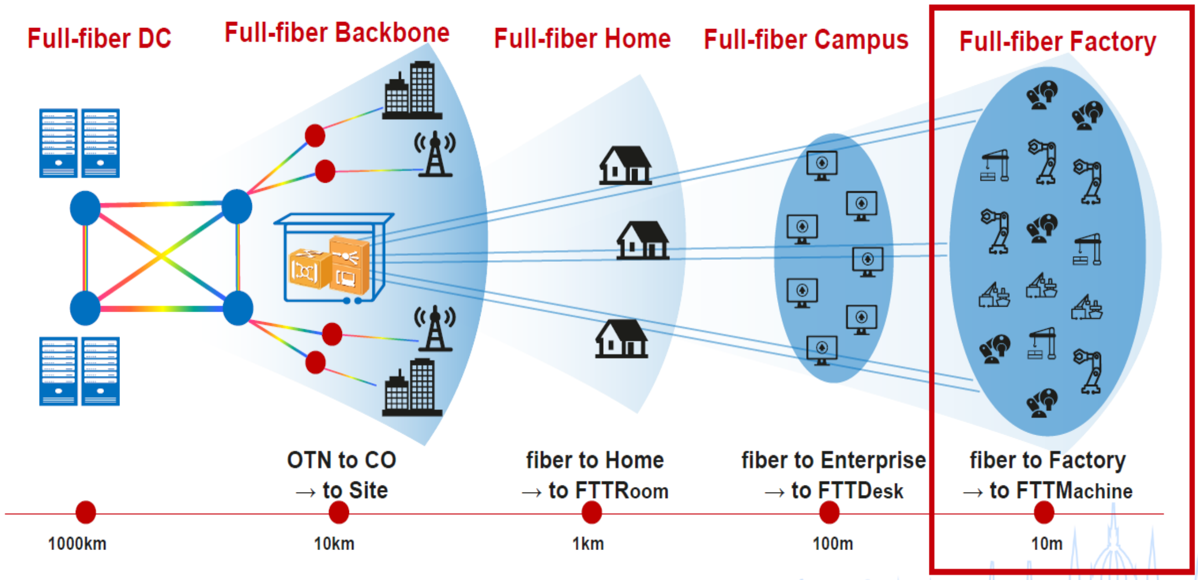
Passive optical LAN deployments also offer the potential to deliver reduced opex and capex. Passive optical LAN roll-outs are not as widely deployed as traditional Cat5/6 LANs, but they are based on mature PON fibre technologies that are already rolled out to hundreds of millions of homes and businesses worldwide, which means they enjoy the cost-related benefits of a mature ecosystem. Another cost-related benefit of deploying passive optical LANs is that the upgrade to a next-generation PON passive optical LAN would not entail replacing the existing fibre cabling or the existing centralised access node. Even where the enterprise has point-to-point fibre-based LAN, a passive optical LAN has significant cost and space advantages because of its passive point-to-multipoint architecture.

Passive optical LANs can reduce opex by cutting energy consumption because they do not require any active devices between the OLT and ONT nor do they require any cooling. This is a significant difference from traditional LAN switch configurations. In these traditional LANs, active aggregation switches are deployed between the central switch and the end user, and these switches need cooling, which increases the energy requirement. In larger business environments, traditional LAN equipment needs to be housed in a separate room. Passive optical LANs can help to free up office space because only passive splitters, which do not need cooling and are smaller than traditional LAN aggregation switches, are needed between the OLT and the point where the fibre terminates.

A further cost-related benefit of passive optical LANs is that they decrease capex because copper LAN cables are much larger in size. In a traditional copper LAN, however, cabling is point to point, and may need constant labour-intensive reconfiguring. Passive optical LANs offer flexibility in that they allow point-to-multi-point cabling, so a separate fibre cable need not be deployed between each end point and the OLT.

Full-fibre local networks, whether passive optical LAN or switched optical PTP technology, provide the best possible infrastructure to support future industrial applications, in particular the industrial internet of things and, more broadly, new industrial processes, commonly referred to as Industry 4.0, including industrial applications of artificial intelligence and scientific computing. Examples of this type of use case include machines that predict failure and trigger maintenance processes automatically, and self-organised logistics that react to unexpected changes in production. The advantages of end-to-end fibre within business premises over copper Cat5/6 are similar to those in the wide area, namely high bandwidth, low latency, high reliability, adaptability to multiple protocols and lower costs, and flexibility over a distance of up to 40km.

Figure 4.8: Extending full-fibre connectivity into the business premises [Source: Huawei, 2020]



4.7 Fixed wireless access (FWA) can work as a fast remedy to some digital divide challenges

The launch of 5G networks starting in late 2019 has triggered interest in the potential of 5G networks to serve as a complement to full-fibre fixed networks, that is in fixed wireless mode, especially in rural areas.

Mobile networks remain a shared medium, and performance also depends on the distance from the base station and on the physical and built environment. 5G typically utilises higher frequencies than earlier generations, which means lower propagation characteristics, making them more difficult to use with indoor CPE. Operators can reserve spectrum for FWA to help to preserve QoS, and in the future they will be able to create discrete slices optimising resources for FWA and mobile. Nevertheless, operators have to balance their total spectrum resources between mobile and FWA, and this entails a trade-off between shared cost and lower performance.

From a technology perspective, 5G FWA falls into two distinct types, depending on the spectrum used.

- **C-band (3.4GHz-3.8GHz):** this kind of deployment will typically be on current mobile macrocells, which lowers the cost. Many early 5G launches using this spectrum included FWA services. These services have so far been marketed at speeds from 50–500Mbit/s downlink. Higher-speed tiers may become more difficult to maintain as the subscriber base grows. Most FWA networks using this spectrum band are TDD, and this, as well as power constraints on end-user devices, mean that uplink speed is significantly lower than the downlink.

- **Millimetre wave (26-28GHz and 39GHz):** this kind of deployment uses high-capacity high-frequency bands that also require smaller radius cells. These would typically be placed at an inter-site distance of 400m on utility poles or similar. This makes using mmWave a more expensive option than C-band. Typical downlink speeds could potentially reach over 1Gbit/s, but this will depend on having line-of-sight, and in most cases adequate access will require outdoor antennas and a wired connection through the building wall. Uplink speeds will be much lower. Verizon has had a commercial service for more than 1 year and currently markets it as 'typically 300Mbit/s'.

Unlike copper and cable technologies, 5G standardisation has a long roadmap. The 5G ecosystem is also very powerful and benefits from huge economies of scale, which drive down costs. However, in pure capacity terms, 5G is likely always to be many years behind PON technologies. As it uses ever-higher frequencies for gigabit-type access, and the amount of additional backhaul fibre increases, any cost advantage over FTTP will tend to erode. Even when less expensive in capex terms, wireless technologies will always have higher opex than FTTP, and they will be less energy-efficient, especially at higher frequencies.

FTTP is the ideal option because of performance and long-term total cost of ownership. Regimes such as the French government are committed to 100% fibre coverage, but many will face competing demands on budget, and will accept that 100% FTTP coverage is not immediately viable. For those governments with such budgetary constraints or for those wanting to have a faster remedy to address their digital gap challenges, there will be a case for using public money to subsidise 5G FWA as a work-around in some of the least populous areas where the economics of FTTP are most challenging. Overall, for wide-area coverage on macrocell infrastructure, the capability of 5G FWA means that high-speed connectivity can be provided at a lower cost than FTTP in some circumstances, particularly where there are 'clusters' of demand in rural areas.[23]

[23] https://www.analysysmason.com/Research/Content/White-papers/broadband-challenges-opportunities/

5. Full-fibre networks as strategic infrastructure – examples from the APAC region

The previous chapter found that there is a strong case for prioritising full-fibre access over the alternatives. This chapter looks at international best practice in delivering this objective.

Many advanced economies in the APAC region, already have a high level of FTTP coverage. In nearly every case, this has been facilitated by clear and ambitious government policy and consistent regulatory practice. Those countries with good coverage in Europe have also benefitted from clear and well-executed policy. On the other hand, FTTP roll-outs have been late to get going in several developed countries, including the USA, as well as key European markets such as Germany and the UK. FTTP commercial activity has increased in the UK in the last 24 months, and Germany in the last 6 months, and this is to be welcomed, but without firm policy direction this commercial enthusiasm carries its own risks.

In general, outcomes have been positive in countries where it is treated as 'strategic infrastructure'. It is worth unpacking what that means.

- First, it is strategic, a matter of national economic importance, not because every country can be a digital leader, but often only because no country can afford to be left behind in an increasingly interconnected and digital world.

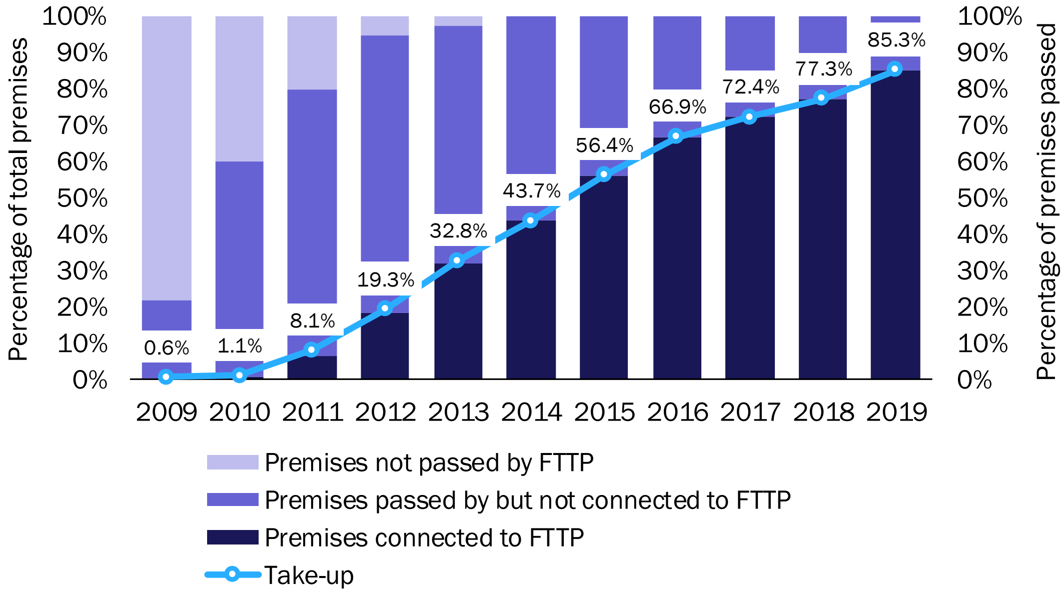
- Second, it is infrastructure, not technology *per se*, but the underpinning of future communications technologies and the whole digital economy that relies on these. Policy that sees fibre as infrastructure is not, therefore, the same as a policy that seeks to even up fixed broadband access speeds across a digital divide. The key difference is that an infrastructure policy would see full-fibre networks as a strategic necessity for, say, half a century, whereas a broadband technology policy would see fibre and/or its current quasi-substitutes as a necessity for the next 10 years at most, or until expectations have outgrown the original target.

In this chapter, we examine successful broadband policies in several countries, beginning with examples from Singapore, New Zealand, South Korea and China.

5.1 Case study: Singapore. Government regulation and investment have led to universal FTTP coverage and enviable levels of higher-layer competition

The roll-out of Singapore's Next Generation Nationwide Broadband Network (Next Gen NBN) began in 2009 and rapidly resulted in universal coverage of FTTP. Multiple internet service providers offer FTTP plans from 100Mbit/s to 10Gbit/s. Being a city state with a high population density, Singapore is not burdened by some of the challenges that face full-fibre deployments in many other countries. Nevertheless, the positive results and the speed with which they were obtained make the case of Singapore an instructive one in urban fibre roll-out policy. Figure 5.1 illustrates how coverage and take-up of FTTP have expanded in Singapore.

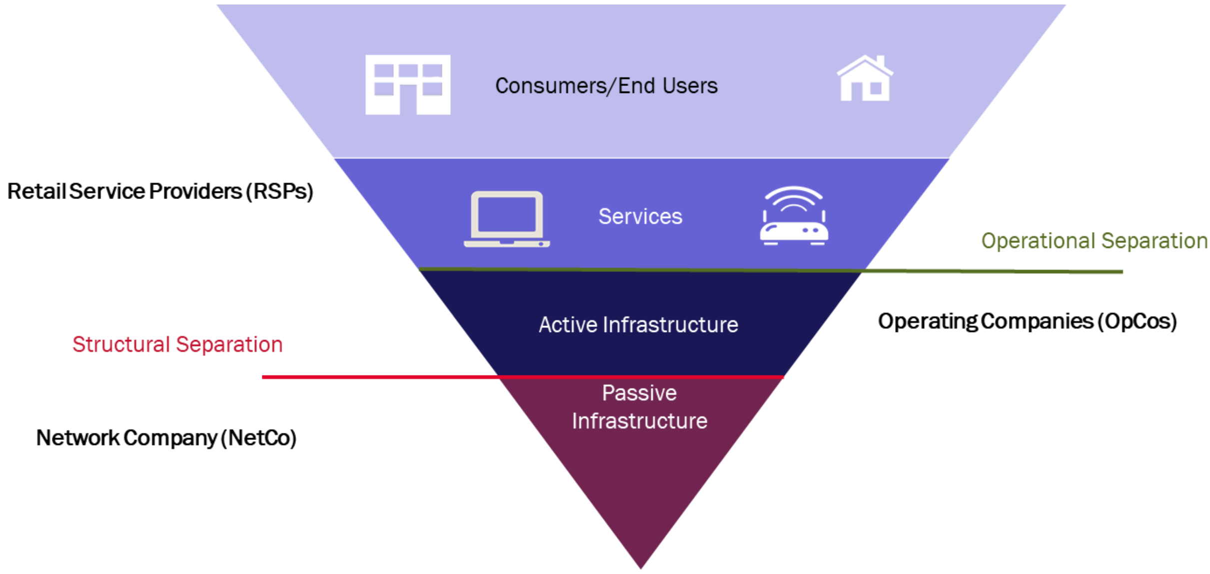
Figure 5.1: Percentage of premises passed by and connected to FTTP in Singapore, 2009–2019



Source: Analysys Mason

Singapore recognised the strategic importance of full-fibre networks as long-term national infrastructure, enabling the country's digital economy to expand and providing the means for significant economic growth. The government responded to the requirement for network upgrades with public investment in the passive layer and a coherent roll-out strategy. The policy mandates a three-layer 'open access' industry structure, separating responsibility for the passive infrastructure, active infrastructure and provision of retail services. This policy is intended to encourage competition and allows the regulator to determine the most cost-effective wholesale prices.

Figure 5.2: The Singapore three-layer model [Source: Analysys Mason, IMDA, 2020]



In Singapore, the deployment and operation of the passive and active layers of the network are structurally separate, being carried out by separate entities.[24] A single network company or NetCo, NetLinkTrust, is responsible for the passive network infrastructure (including ducting and dark fibre) and leases its infrastructure, at regulated rates, to active infrastructure companies or OpCos, which are responsible for active network infrastructure (for example, switches and routers). According to NetLinkTrust, 11 active OpCos use the passive network. The OpCos can sell direct to end users, or sell on again to retail service providers. One OpCo, NucleusConnect, a subsidiary of second entrant StarHub, was originally designated as a regulated active wholesaler, and it still has a bitstream reference offer. We understand that the commercially negotiated wholesale agreements have all but displaced the regulated offer, a wholly desirable outcome as the market now has competition between active wholesalers and an uncountable number of retail providers at the service layer.

The government provided funding amounting to SGD750 million (EUR502 million) to NetLinkTrust, to assist in the roll-out of the passive infrastructure.[25] Singapore's high population density provided a convenient environment for rapid deployment, roll-outs were also aided by the presence of existing ducts and manholes. Additionally, the network and operating companies were subject to universal service obligations, and in order to encourage take-up, NetLinkTrust was required to waive all installation fees for building owners when their property was first passed by the network.

[24] www.itu.int/net/wsis/stocktaking/docs/activities/1291981845/Towards%20a%20Next%20Generation%20Connected%20Nation_Singapore.pdf

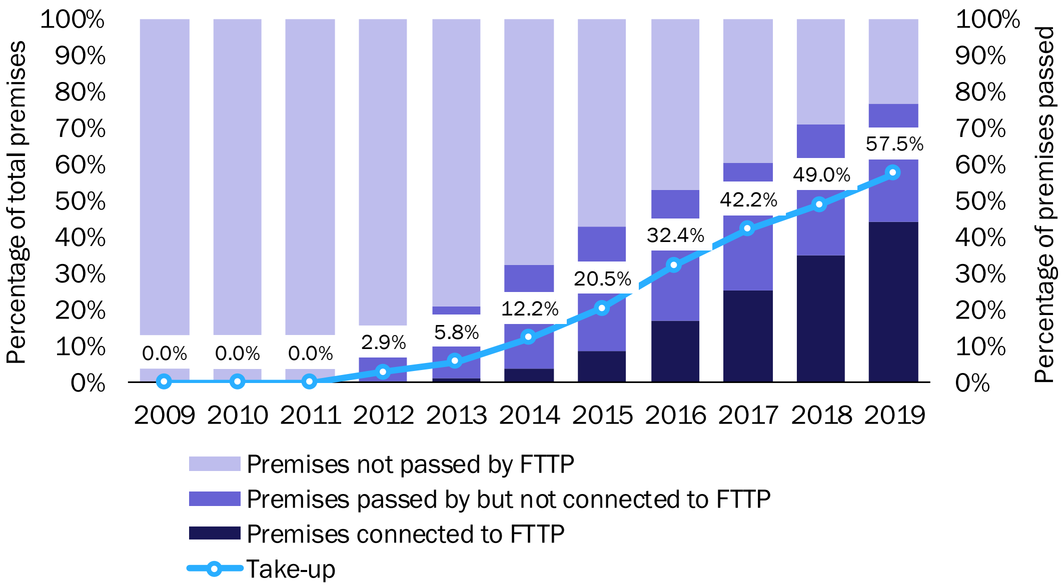
[25] https://www.dbs.com/aics/templatedata/article/generic/data/en/GR/042019/190424_insights_Singapore_telco_sector.xml

5.2 Case study: New Zealand. The Ultra-Fast Broadband (UFB) initiative has achieved high coverage and take-up in a sparsely populated country

Announced in 2009, deployment of New Zealand's full-fibre network under the Ultra-Fast Broadband (UFB) initiative began in 2012, with the initial aim of achieving 75% FTTP coverage by 2019. At 2009, New Zealand had 50% FTTC/VDSL coverage with regulated bitstream wholesale, and one very small cable operator covering only 8% of premises nationally.

In 2017, the FTTP target was expanded to 87% of the population, to be completed by 2022. As of the end of 2019, the UFB initiative had achieved 77% coverage, slightly ahead of its target. This is a particularly high figure for a sparsely populated country with a very low proportion of MDUs among the housing stock. Figure 5.3 shows FTTP coverage and take-up in New Zealand in the period 2009–2019.

Figure 5.3: Percentage of premises passed by and connected to FTTP in New Zealand, 2009–2019



Source: Analysys Mason

The UFB initiative was supported by government investment of NZD1.5 billion (EUR950 million), to supplement while "neither discouraging nor substituting for" private sector investment[26], – that is, to support deployment in areas in which the business case is weak. The investment takes the form of an interest-free loan paid to operators to subsidise the network roll-out, to be paid back in 2036. The government expects NZD550 million of the total to be paid back by 2025.

To manage its investment, in 2009 the government created Crown Fibre Holdings (now Crown Infrastructure Partners), a state-owned holding company. In 2011, Crown Fibre Holdings tendered UFB partnership contracts to become so-called local fibre companies (LFCs) whose responsibility was to build and operate FTTP networks. A condition was that these entities should be wholesale-only. In order to be able to participate, the incumbent operator Telecom New Zealand voluntarily structurally separated in late 2011 into the wholesale-only network operator Chorus and the retail provider and MNO Spark. Chorus maintained responsibility for the

[26] https://www.crowninfrastructure.govt.nz/media/4824/invitation-to-participate.pdf

existing copper network nationwide. Responsibility for the greater part of the FTTP roll-out was secured by Chorus. Additionally, about 30% of the deployment was carried out by three other local fibre companies.

The UFB networks were constructed with a PON architecture for residential customers, with point-to-point access available for businesses and other institutions. In addition to its coverage targets, the UFB initiative aimed to provide all businesses, schools and health services with FTTP by 2015. The government has also taken steps to facilitate fibre deployments by streamlining the consent process for installation in shared premises. Operators have provided the option for pre-installation of fibre into newly built real estate developments, to accelerate take-up of the FTTP network.

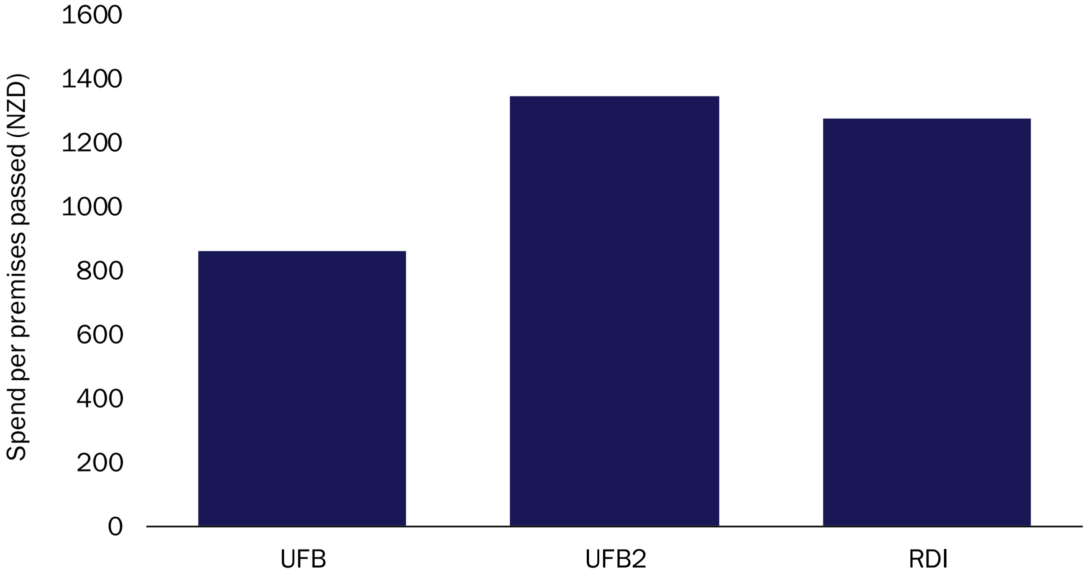
The LFCs were initially mandated to provide Layer 2 bitstream services to ISPs, but it was built into their contracts that they should also offer Layer 1 (fibre unbundling) as of 2020. This obligation, which allows operators to install their own active equipment (with potentially higher speeds than the GPON initially deployed by all of the local fibre companies), provoked some of the LFCs to add next-generation PON technology (XGS-PON and TWDM-PON) to the bitstream options on their networks.

The Rural Broadband Initiative (RBI) aims to provide high-speed broadband access to remote areas in which UFB roll-outs are not planned. Using a mix of technologies, the RBI aims to ensure that 99% of the population has access to broadband with speed of at least 50Mbit/s by 2025, with the remaining 1% having access to at least 10Mbit/s broadband.[27] This initiative has received public funds amounting to NZD430 million.[28] The deployment has been carried out by fixed and mobile operators, including Chorus, which has extended its fixed network into rural locations, and Vodafone, which has built and upgraded cell towers to provide FWA coverage in rural areas. This strategy is cheaper per premises passed than deploying FTTP to the entire population, but it does not provide subscribers in rural areas with the various benefits of a full-fibre network.

[27] https://ufb.org.nz/initial-ultra-fast-broadband-programme-75-complete/

[28] https://www.mbie.govt.nz/science-and-technology/it-communications-and-broadband/fast-broadband/broadband-and-mobile-programmes/

Figure 5.4: Public subsidy per premises passed, New Zealand, UFB, UFB2 and RBI areas [Source: Analysys Mason, 2020]



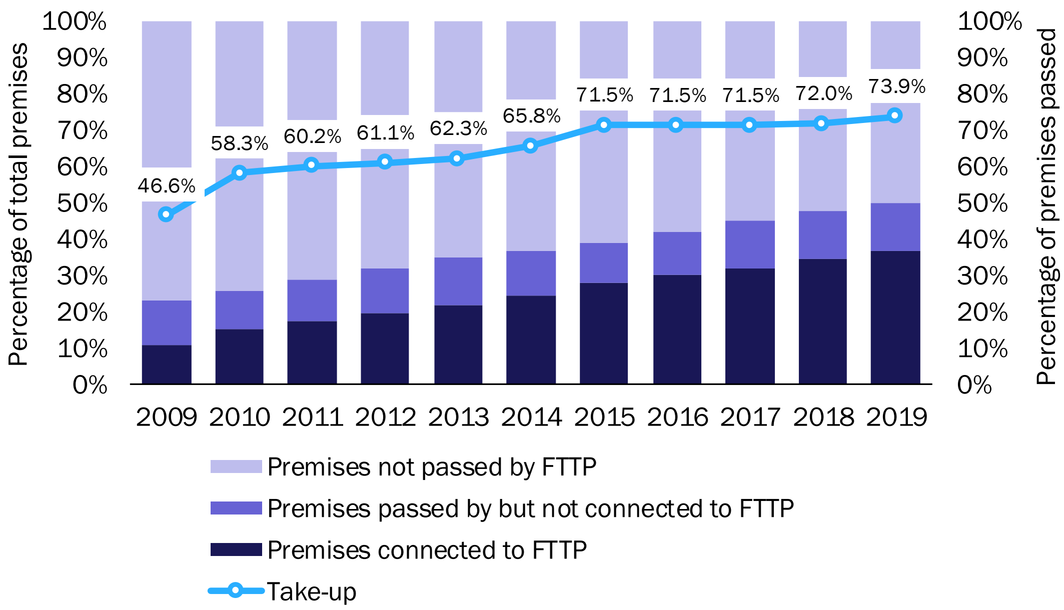
Source: Analysys Mason

Take-up of FTTP has been significantly higher than forecast at the outset of the project, and by the end of 2019 was above 60% of premises passed in most of the larger cities. Usage per connection is also extremely high by global standards, reaching 341GB per month per line on the Chorus FTTP network by June 2019.

5.3 Case study: South Korea. Fibre-based broadband strategy dates from as far back as 1994 but it is no longer the front-runner in the region

Figure 5.5 illustrates how coverage and take-up of FTTP have developed in South Korea in the period 2009–2019. Coverage is still only 50%, although take-up in those covered areas is 75%. A high proportion of South Koreans live in apartment blocks, and most apartment blocks still rely on LAN or cable-TV infrastructure within the building rather than full-fibre access networks. LAN infrastructure can support gigabit speeds but has drawbacks in terms of energy, space and maintenance. A small proportion of apartment blocks rely on a South Korean proprietary copper technology G.hn (branded as GiGA Wire), which is similar in performance to G.fast.

Figure 5.5: Percentage of premises passed by and connected to FTTP in South Korea, 2009–2019



Source: Analysys Mason

South Korea's fibre policy was established as far back as 1994, when the government launched the Korean Information Infrastructure (KII) initiative, with the aim of building a nationwide fibre network. This was carried out in three stages. In the first stage, the government invested KRW18 trillion (EUR17 billion) in constructing a nationwide fibre-optic backbone and metro fibre network. The aim of this was to facilitate operators' offering fibre broadband to government buildings and schools across the country. Following this, the government encouraged operators to expand broadband coverage to homes and businesses, including deployment of fibre in the access layer. This was a public–private joint endeavour, involving public investment in the form of loans of KRW1.4 trillion (EUR1.3 billion) and private investments amounting to KRW11.4 trillion (EUR10.8 billion).[29] The government also incentivised business take-up by applying a tax exemption to small and medium-sized businesses equal to 5% of their investment in broadband. Additionally, the KII initiative conducted research into gigabit network technology, with public and private funding.

The KII programme was followed in 2004 by the Broadband convergence Network (BcN) initiative, and in 2009 by the Ultra Broadband convergence Network (UBcN) initiative, each with the aim of expanding NGA coverage, with a long-term preference for FTTP.[30] In both programmes, as with the second phase of the KII

29 https://www.anacom.pt/render.jsp?categoryId=340674.

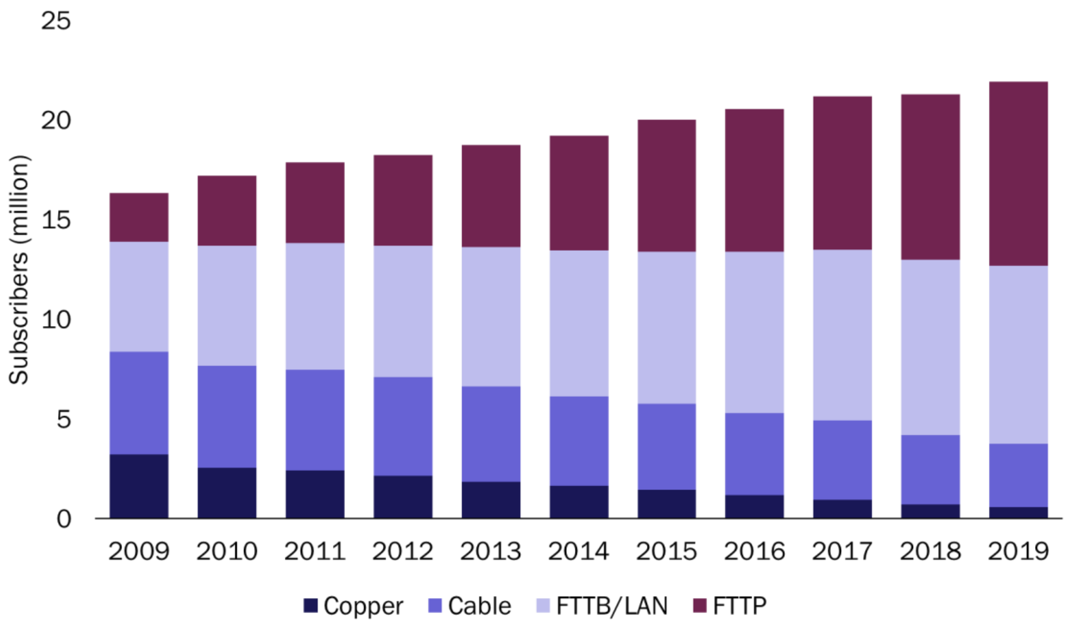
30 https://www.itu.int/dms_pub/itu-r/oth/0A/0E/R0A0E0000380001PDFE.pdf.

initiative, most of the investment came from private sources – for example, while the government contributed KRW1.3 trillion (EUR918 million) to the UBcN initiative, KRW32.8 trillion (EUR23.2 billion) was intended to be contributed by operators. The UBcN initiative aimed to provide download speeds of 1Gbit/s across the country, to be achieved by expanding coverage of FTTP. South Korea's policy has been to use network operators as the primary instruments of network deployment, with only a small proportion of investment in NGA roll-outs coming from public sources, taking the form of low-interest loans and tax subsidies.

Around 97% or 98% of Koreans have access to gigabit speeds, but the policy has not entirely succeeded in pushing universal full-fibre networks. In-building networks have frequently not been upgraded to full-fibre despite the policy preference for this approach. The historical incumbent operator KT started commercialising FTTP with an upgrade of some 1.144 million FTTB lines in 2007. The cost per premises was KRW352 000 (EUR275), which for an indoor-only refit is at the high end of what we would expect. This may serve to explain the reluctance of the main operators to upgrade.

South Korea has approached next-generation broadband as an issue of national importance, but the operators have adopted a somewhat technology-agnostic strategy to fixed broadband. In 2014, KT announced plans to invest KRW4.5 trillion (EUR3.2 billion) to upgrade its residential broadband service to gigabit downlink speeds[31], but this was a multi-technology mix, not a universal evolution to full-fibre. The growth in FTTP coverage and subscribers has been slow and steady, but the national subscriber base demonstrates that South Korea's coverage is a multi-technology mix.

Figure 5.6: Fixed broadband subscribers, South Korea, 2009- 2019 [Source: Analysys Mason, 2020]



However, South Korea continues to lag behind the other early movers in APAC that have prioritised full-fibre networks, including China, Japan and Singapore. This deficit is especially stark given South Korea's early start in NGA and fibre deployments.

---

31 https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Transformation%20of%20Telcos%20in%20the%20Internet%20Era.pdf

There have also been some well-publicised deficiencies in co-ordination between major stakeholders in the fixed telecoms ecosystem. For example, KT blocked internet access to Samsung smart TVs in 2012 on the grounds that they slowed the fixed networks greatly. It is difficult to square this assertion with a properly upgraded fixed network.

The government has introduced various other policies and regulations to encourage the deployment and take-up of high-speed networks. In 1999, the government introduced a system of certification for large residential and commercial buildings based on the downlink broadband speed available in the building, incentivising pre-installation of NGA network infrastructure. In 2003, regulation was introduced requiring KT to offer regulated wholesale access to its fibre network, though the regulation of wholesale prices expired after 2004. In 2009, KT was required to offer wholesale access to ducts built as part of the UBcN programme.

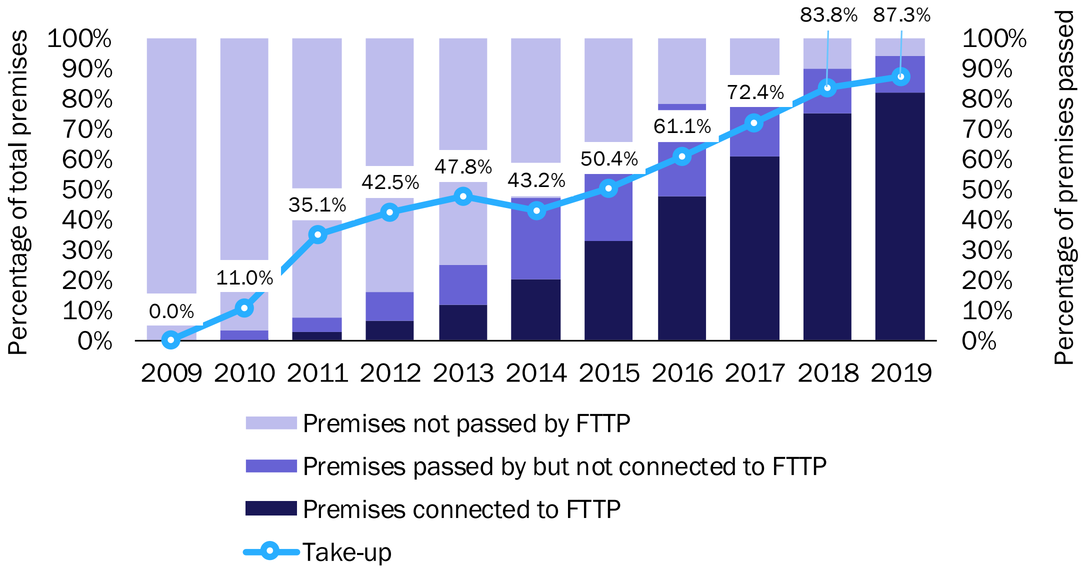
5.4 Case study: China. A comprehensive strategy centred around fibre as national infrastructure has resulted in rapid expansion of coverage

The broadband policy of the Chinese government has been based on the treatment of full-fibre networks as national infrastructure, with FTTP development a fundamental priority in China's national economic strategy. China's digital economy is worth over USD30 trillion, accounting for 34.8% of the country's GDP.[32] As discussed in chapter 3 and mentioned above, the Chinese policy has resulted in very high coverage and take-up of FTTP. Figure 5.7 illustrates how coverage and take-up of FTTP have expanded in China during 2009–2019. The policy has been based on a combination of public investment and tax reductions, pre-installation of fibre in civil works and residential construction projects, and the encouragement of joint network construction and sharing between operators.

The strategy was initially focused on the replacement of legacy copper infrastructure with fibre, and the expansion of NGA coverage (with a preference for FTTP) across the country. Following this, from 2016-2020, optimisation of the fibre network has been the main focus. The approach has also varied between regions. The focus in urban areas in eastern China has been mainly on network upgrades. In rural areas in central and western China, expansion of coverage has been prioritised, with the aim of establishing broadband as a universal service. Additionally, whereas full-fibre roll-outs have been preferred in urban areas, rural deployments have used a mix of technologies in order to facilitate the expansion of broadband coverage. The government has also adopted a more concessional approach in rural areas.

[32] http://www.xinhuanet.com/english/2019-05/06/c_138038007.htm

Figure 5.7: Percentage of premises passed by and connected to FTTP in China, 2009–2019



Source: Analysys Mason

In remote areas, network development is subsidised by the Telecommunications Universal Service Funds. In addition to roll-out costs, operational costs can be subsidised for 6–10 years, depending on location. Deployment and operational costs can be subsidised by up to 50%, with 25% of the costs contributed by the central government and 25% by the local municipality.

Telecoms operators have also been subject to tax reductions. In 2014, value-added tax replaced business tax in the telecoms sector, in order to stimulate fibre network expansion. Broadband services are also taxed at a lower rate than average, with the tax on internet access at 6%, in contrast with the average of 11% for value-added services.

Fibre pre-installation has been essential to the deployment of last-mile FTTP infrastructure. According to codes published by the Chinese government in 2013[33], residential property developers can be required to lay fibre-optic cables in new residential buildings. Deployment of the backbone and aggregation layers of the network have also been carried out in collaboration with other civil infrastructure projects, including construction of electrical power lines, oil pipelines, highways and railways, gas and water pipes and municipal construction. This has resulted in a reduction in the cost of civil work for fibre deployments of 30%.

FTTP deployments in China have also been assisted by unified technical specifications and procedural standards between operators. Passive network elements are standardised, including optical fibre cables, access and distribution terminals and PON installation procedures. Procurement and professional training are also standardised. These measures improve the efficiency of the roll-out of the network.

As discussed previously, the Chinese policy has resulted in high coverage and take-up of FTTP. By 2016, 100% coverage with speeds of 20–100Mbit/s was achieved in urban areas, with 100% coverage of >4Mbit/s in rural areas. As of 2019, 400 million residential subscribers were connected to FTTP, and 50% of households were

[33] The Code for Design of Communications Engineering for Fibre-to-the-Home in Residential Districts and Residential Buildings, and the Code for Construction and Acceptance of Communications Engineering for Fibre-to-the-Home in Residential Districts and Residential Buildings

covered by broadband with speeds of 100Mbit/s, with 1Gbit/s available in some developed areas. The raw FTTP subscriber figures are remarkable, and China now accounts for over half of all FTTP connections worldwide, but the modest speed coverage amply demonstrates that Chinese policy prioritised infrastructure (the construction of the ODN) over bandwidth targets.

6. The challenges for Europe

In this chapter, we look at Europe-specific challenges of full-fibre roll-out.

6.1 Post-liberalisation fixed telecoms has evolved into a connectivity business

It is worth remembering that barely more than 20 years ago, in most European markets, fixed telecoms was a state monopoly that recovered the cost of the network with revenue from long-distance calls priced well above long-run incremental cost.

Cross-subsidy by services has now been removed by pro-competition European regulation, the logic of Internet Protocol (IP) that disaggregates connectivity and service, and competition, both direct and indirect, notably mobile and 'over the top' services. Hence, while there is no limit to the variety of applications, there are no protected sources of additional revenue on fibre – or indeed on any other telecommunications medium – other than the price of internet connectivity itself. For better or worse, fixed telecoms (and arguably mobile too) has evolved into a connectivity business, and there is no umbilical cord between services and connectivity. Practically everything else in the digital sphere inhabits a highly competitive, increasingly globalised, low-cost, world of applications/services and content that telecoms operators have, by and large, failed to capture or, in the case of voice, failed to defend.

Business models for fibre have had to adapt to this reality by recognising that payback comes from geographically extending, at as low a cost as possible, the availability of a very simple set of services to as many players working at higher layers as possible. These simple services are not restricted to broadband: additional value will come from mobile transport and enterprise leased lines. The function of this utility set of services is to maximise utilisation of the network, and to derive steady, fairly low-value but high-margin average revenue per line over longer periods of time. This is the gist of an infrastructure-first approach: it is investment in the highest-quality basics in order to allow diversity and innovation to flourish on top.

This new, largely wholesale-focused, approach is already emerging in parts of Europe, notably the UK and Germany, and it is largely commercially driven. The principal reasons for the uptick in investment are as follows.

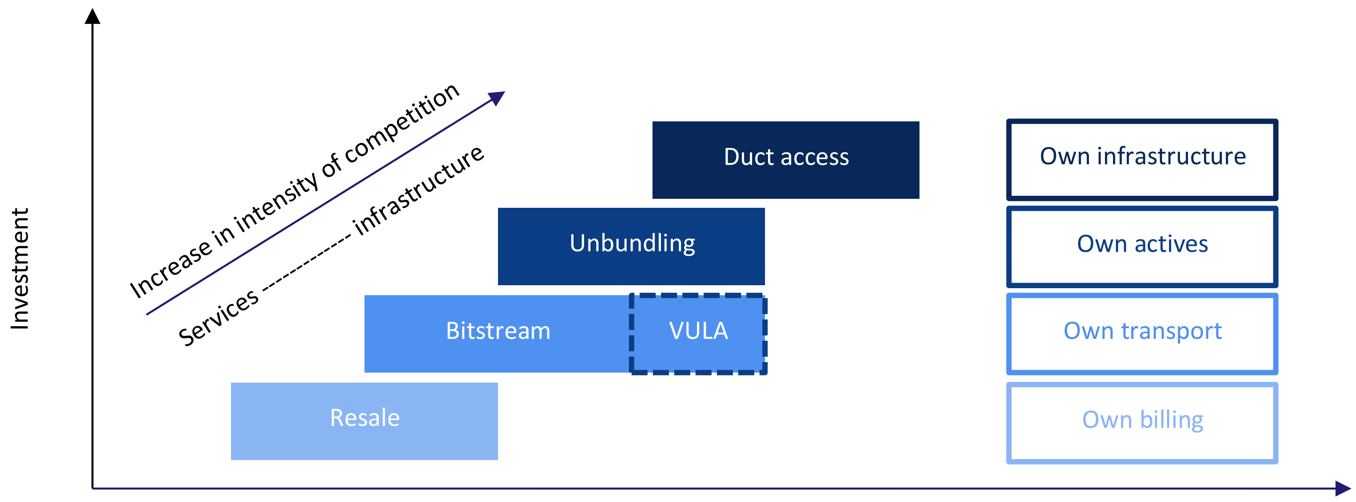
- The demand-side case for FTTP is much more clear-cut than in the past.
- New civil engineering techniques have allowed capex to fall.
- Infrastructure funds are willing to invest in new safe long-term opportunities.
- Electricity utilities have seized the opportunity to re-utilise their own physical infrastructure to deliver FTTP.

What we are seeing is a fracturing and restructuring of the ownership of access networks, and a rise in bilateral co-operation between existing players or between existing player and outside entities. In most cases, this welcome investment has also benefitted from positive policies. It will also be policies that determine whether the investment is carried through in a way that is economically efficient and that benefits Europeans.

6.2 European regulation has tended to favour fostering retail competition and low prices over long-term investment

The level of investment in European fibre has been directly affected by the eCommunications framework established by the EC in 2002. The framework, devised soon after liberalisation in continental Europe, and at a time when the primary uses of the copper network were voice and ADSL, has served effectively to encourage retail competition and to drive down prices, but has largely failed to deliver on the promise of the 'ladder of investment' hypothesis.

Figure 6.1: The 'ladder of investment hypothesis' [Source: Analysys Mason, 2020]



This hypothesis was that if new broadband entrants were given a range of wholesale access options ranging from pure resale, through Layer 3 and 2 bitstream, to copper unbundling and eventually to duct access for their own networks, they would start with the least capitally intensive, and, with scale, gradually bulk up investment to the more capitally intensive options. The final stage would be building their own networks, at which stage, with sufficient competition, the whole panoply of regulation could be replaced or deconstructed.

The 2002 framework was supplemented by EC recommendations on regulated access to next generation access networks in 2010 and by "consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment environment" in 2013.

While it is true that the larger access seekers shifted from resale and bitstream to copper Layer 1 unbundling for ADSL, it is not true that they have been encouraged to go much further. In fact, certain impracticalities associated with Layer 1 unbundling in NGAs (both FTTC/VDSL and FTTP/GPON) pushed regulators to mandate Layer 2 products (virtual unbundled local access or VULA) that emulated as closely as possible unbundling on FTTC and FTTP local loops, while returning control of active network elements to the incumbent.

However, the main reason the 'ladder of investment' hypothesis turned out to be false is that regulation, and especially cost-oriented access, depressed retail prices so much that few were motivated to invest in new networks. Broadband – and indeed all telecoms – in Europe is extremely inexpensive when set against comparable world regions, and it is against this backdrop of consumers expecting to pay very little and of operators being undermotivated to invest that targets for a European gigabit society have to be placed.

The European Electronic Communications Code of 2018 (EECC) is due to be implemented in national laws by the end of 2020 (including it would appear the UK), and shifts towards a somewhat more pro-investment approach. Importantly this allows for some relaxation of regulation where co-investment in fibre (and in 5G) are concerned. It is still uncertain how this new framework will get implemented at a national level.

The absence of EU-style regulation hardly leads to convincingly good outcomes either. In the USA, the level of FTTP (or any telco FTTx) investment has been significantly lower than in Europe taken as a whole, resulting in lower FTTP coverage, continued dominance in fixed broadband by cablecos with few motivations to invest and, currently, no major plans by any of the local access carriers to invest much further in FTTP. Expansion of Verizon's FTTP networks stopped in 2010, and AT&T's recent FTTP build was a sweetener to the FCC for its acquisition of Time Warner. The USA does have federal inter-utility pole and duct attachment regulation, but these have proven extremely difficult to apply without descending into litigious acrimony. Google's attempt to break into FTTP access, Google Fiber, depended on municipal co-operation on access to civic infrastructure, but it must be counted as a commercial failure as it never extended beyond a handful of small cities. Future competition in gigabit access in the USA depends on 5G mmWave fixed wireless, a new and unproven technology with significant performance drawbacks compared to FTTP.

6.3 National governments are increasing investment in fibre, but this is unlikely to be enough to achieve targets

Financing for fibre networks comes from different sources. Private operators have more economic incentive to invest in fibre networks in areas with high population densities, and rural areas are less likely to attract interest. Networks in areas with low population densities are usually sponsored by the government, either directly or through local municipalities. European institutions also provide important sources of funding. EU bodies allocated almost EUR15 billion for the 2014–2020 period to support the development of broadband projects.[34] National governments also provide public funds: the Italian government allocated EUR5 billion to NGA projects as part of its national broadband plan, while the French government contributed EUR3.3 billion to its plan. These figures are allocations and may not correspond to the amounts that have actually been spent.

The level of public funding (as opposed to loans) that would be required to get from the level of FTTP coverage at the end of 2019 to reach 96% coverage is probably in the region of EUR80–EUR120 billion, assuming that private players contribute on average about EUR600 per premises passed.[35] Capital expenditure on European telecoms (fixed and mobile) was about EUR49 billion in 2018, equivalent to a moderately high capital intensity of about 17%. If operators were to bear the additional cost of reaching the European Gigabit Society's 2025 gigabit coverage target, their capital intensity would rise to 23% for a 6-year period, a capex bulge that would not generally be acceptable to shareholders for what is generally regarded as dividend stock.

However, in the past 2 years it has become apparent that with the right business model, investors from outside the traditional telecoms space have shown a willingness to invest in FTTP. This means that at least some of the capex bulge will be absorbed by private players hitherto outside the industry. These private players are mainly pension funds, sovereign wealth funds, infrastructure funds and utilities comfortable with longer payback periods. Several existing operators (for example Altice operations in France and Portugal, Telefonica Spain and Orange France) have created NetCo subsidiaries in which a third party typically takes a 49.99% stake so that the operator maintains operational control. Moreover, several of these funds have taken stakes in alternative FTTP players: for example EQT and OMERS acquiring Deutsche Glasfaser.

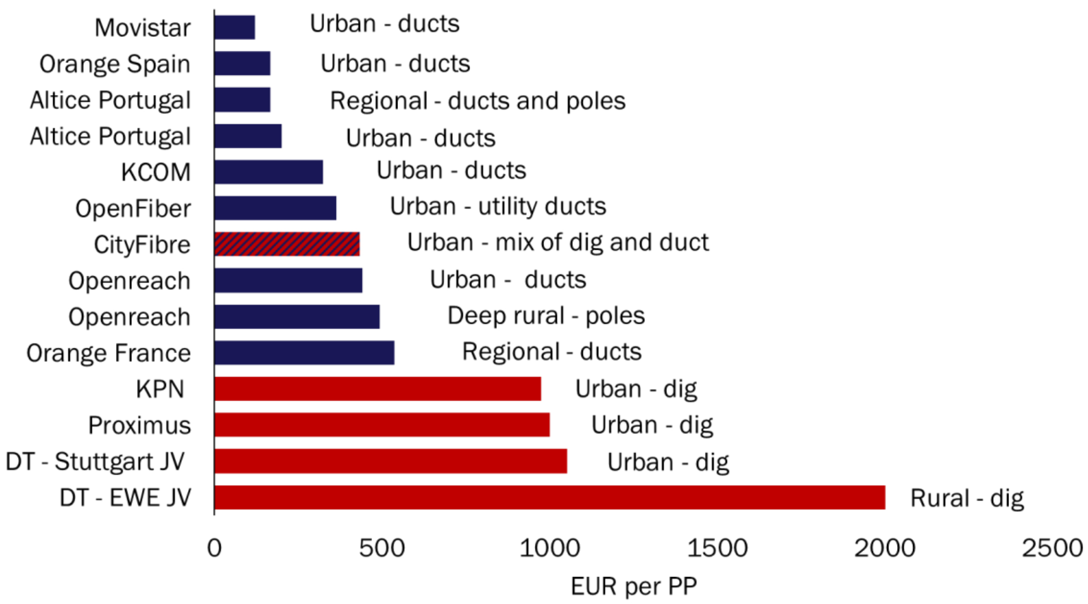
[34] European Commission, "The socio-economic impact of bandwidth", 2013, p. 207.

[35] ETNO, https://etno.eu//downloads/reports/etno%20state%20of%20digital%20communications%20report%202020.pdf

6.4 High-quality civic infrastructure is key to rolling out FTTP quickly

One major reason behind the slow fibre roll-out in some European countries is the absence of suitable physical infrastructure in the legacy copper network that would facilitate swift and low-cost roll-out of fibre. For example, the Telekom network in Germany generally has copper cables directly buried between street cabinets and end-user premises, meaning that any new fibre build requires new digging. This means that in Germany deploying fibre networks involves very high upfront costs. The Netherlands and Belgium also face similar challenges. Real benchmark costs to pass a premises with FTTP show the stark differences. Proximus is expecting about EUR1000 per premises passed in what is the 'easiest' 50% to cover. From KPN's unbundled fibre reference offer it can be deduced that the average cost per premises passed where KPN has rolled out FTTP (the first 30% as of the end of 2019) is about EUR975. Deutsche Telekom has estimated that the total cost for Germany would be EUR60 billion to EUR80 billion, for about 42 million premises, a figure that would tend to suggest the cost for urban Germany is even higher still.

Figure 6.2: Benchmark cost per premises passed, national or incumbent operators [Source: Analysys Mason, 2020]



Regulation is a necessary, but not in itself sufficient, part of the solution to the civic infrastructure problem. The Broadband Cost Reduction Directive of 2014 brought different measures to facilitate broadband roll-out in Europe. The directive covered four main areas.

- Access to existing physical infrastructure (e.g. ducts, poles or masts) including those belonging to energy and other utility companies, for operators willing to deploy high-speed broadband networks.
- Efficient coordination of civil works.
- Faster, simpler and more transparent permit-granting procedures.
- Equipping new buildings and major renovations with high-speed physical infrastructure (e.g. mini-ducts, access points) and access to in-building infrastructure.[36]

[36] https://ec.europa.eu/digital-single-market/en/cost-reduction-measures

The specific implementation by national regulators and by designated telecoms operators varies greatly in its detail or practicability. One of the key reasons behind fast fibre roll-out in Spain and Portugal has been the long-established clear rules regarding the local incumbents' infrastructure sharing obligations.

6.5 Labour costs in Europe are high

In some Western European countries such as Germany and the UK, FTTP roll-out has been slowed down because of high labour costs. Labour costs can account for well over 80% of the total deployment cost, especially when extensive infrastructure works are required. The cost of labour obviously varies across the continent, but it has also varied depending on the moment in economic cycles, and implicitly it varies according to the efficiency of processes (including economies of scale) and the skill level of the workforce. Our understanding is that appropriate field-force labour in the UK would cost about EUR45 per hour, whereas it cost about EUR30 in Spain when FTTP build was initiated during the last financial downturn. The two large markets with the highest FTTP deficit, Germany and the UK, currently have very high levels of employment and suffer some skills shortages, including in civil engineering / construction, a notoriously cyclical industrial sector.

6.6 Strict planning laws have delayed FTTP deployment in some European countries

Most European countries have an aesthetic aversion to aerial deployment, especially in cities. Some copper networks have very little aerial deployment left in them, and new fibre deployment on poles would not be allowed. Regulation in some markets allows for the re-use of existing aerial poles for fibre. In some countries, such as Romania, fibre lines were installed in cities on existing electrical poles and aerially between buildings rather than underground. This facilitated rapid and largely unchecked roll-out; urban Romanians now have some of the fastest and lowest-cost internet access anywhere in the world. Notwithstanding its ugliness, aerial fibre has other drawbacks. Aerial cables are exposed to changes in weather conditions and could hence require higher maintenance costs. Underground ducts are safer and more reliable since they provide full support to the cables. Optical distribution networks are meant to last for decades and an aerial approach may cost more in the long run. In fact, some Romanian local authorities, especially those in historic cities, have moved to create ducts systems after fibre roll-out to improve aesthetics.

7. Full-fibre as strategic infrastructure in Europe

The following three sections describe three successful policy-led examples of FTTP deployment in Europe. The policies adopted in these countries are quite different from one another in many ways, and structural differences in these economies mean that they could not simply be replicated; there is no 'one-size-fits-all'. However, what they do have in common is an emphasis on thinking of fibre as long-life infrastructure rather than as technology. Most tend to treat technology as something that should be allowed to flourish in its own way, and without much direction, on top of the infrastructure. Moreover, all three go some way beyond the ladder of investment thinking by more or less by-passing bitstream access and focusing almost exclusively on Layer 1, co-investment incentives/obligations and Layer 0 duct access as a means to deliver on full-fibre. None is a deregulated commercially-driven free-for-all, but all have focused regulation on where it helps competitive investment rather than stifles it.

7.1 Case study: Sweden. A 'village fibre' approach has ensured fast and reliable FTTP networks across most of the country despite its geographical challenges

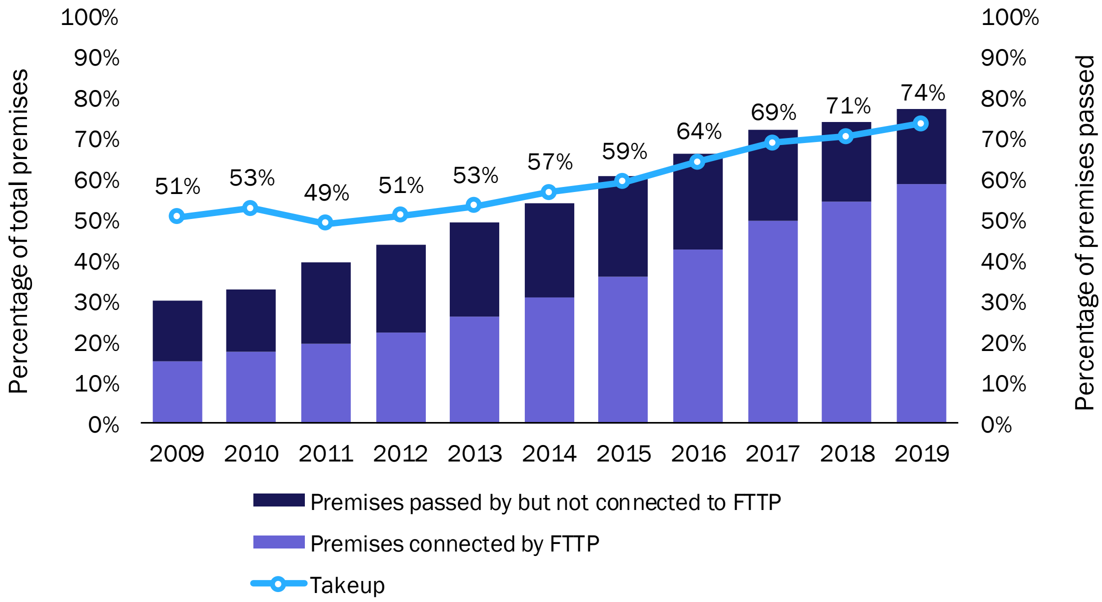
Sweden was one of the first countries in Europe to adopt a nationwide broadband plan. In the 1990s, the government made it a priority to bring fast, reliable internet to all, especially to remote rural areas. Since its inception, the Swedish approach has been focused on infrastructure. The plan ensured that dark fibre was installed near every home; a tax rebate scheme was created so that households could claim 50% of installation costs over SEK8000 for the final connection to the network. The government also provided subsidies to towns with fewer than 3000 inhabitants, to ensure that fibre reached all 289 municipalities.

As of 2019, we estimate that around 80% of total premises in Sweden had been passed by an FTTP network. This puts Sweden in third place in Europe in terms of percentage of premises passed by FTTP, after Portugal and Spain. The main urban centres such as Stockholm and Malmö have extensive coverage (97% and 85% respectively as of 2018 according to the PTS[37]), but one of the main challenges for the country is to tackle the potential 'digital divide' between the cities and the rural areas. To do this, the Swedish government devised a strategy that has been referred to as a 'village fibre' approach[38]. This approach puts local municipalities at the centre of the planning, building and construction of fibre networks.

37 Post and Telecommunications Authority, Sweden

38 OECD (2018). Bridging the Rural Digital Divide. OECD.

Figure 7.1: Percentage of premises passed by and connected to FTTP, Sweden, 2009–2019



Source: Analysys Mason

The Swedish government recognised the potential of FTTP as a driver of economic growth, especially in rural areas. Fast internet connections allow residents in remote areas to gain access to most of the services that are normally available in big population centres, such as schools, libraries and businesses. Moreover, they facilitate company formation and remote working, increasing regional economic growth in the long run.

The impact of broadband on a country's GDP has been the subject of empirical studies. In the case of Sweden, it was estimated that broadband contributed to a GDP increase of 0.12% annually in the period 2002–2016.[39] The study, published by Kotroumpis for Ofcom, includes a broad set of variables, as well as time and country-specfic effects, to better capture the effect of broadband on GDP. The findings establish an important causal relationship between broadband investment and economic growth, which further supports the importance of long-term broadband plans based on fibre. The countries where the effect of broadband on GDP was found to be the strongest include Sweden, South Korea, Japan and Iceland, where the percentage of premises passed by FTTP or FTTB was higher than 60% as of 2019.

One of the factors that sets the Swedish model apart from other community-centred fibre approaches such as the RIP zones[40] in France is the direct involvement of the members of the community. Construction is usually devolved down to local workers or even volunteers. Single dwelling unit households that wish to connect to the network usually have to pay an upfront connection fee of approximately EUR2000[41], hence customers' willingness to contribute directly to the funding of fibre networks is linked to the pace of construction.

39 Koutroumpis, P. (2018). The economic impact of broadband. Ofcom.

40 'Public Initiative Network Zones' where fibre projects are financed and deployed by local governments using public funds.

41 BEREC (2016). Challenges and Drivers of NGA Rollout and Infrastructure Competition.

The Swedish government also provides grants to support community networks, especially in areas with no private operators. Overall, broadband is seen as a utility, and most municipal networks are operator neutral. The SSNF[42] (Swedish City Network Association) defines two types of such networks:[43]

- fully operator-neutral NetCos, which only act as dark fibre providers
- those run by operators that provide wholesale access to retailers and actively manage network infrastructure, offering bitstream access as well as dark fibre.

A small fraction of municipal networks are fully integrated and offer end-user services as well. The SSNF actively promotes the role of municipal networks as wholesale service providers, in order to ensure open and fair competition at the end-user service level. The SSNF networks account for over 50% of FTTP connections in Sweden.[44]

The success of the Swedish approach relies on the focus on infrastructure. The presence of publicly owned networks allowed small ISPs to compete with larger operators, including the incumbent Telia, on an equal level. Service providers can buy wholesale services from the municipal network and offer their internet/pay-TV packages to the end user. This allows them to save money on network deployment and increases competition, brings down cost for the final user and contributes to high take-up. In fact, it is common for Telia, the historical incumbent and biggest operator in the market, to compete with small local service providers on third-party infrastructure in many areas of Sweden.

The largest single municipal network is Stokab[45], which covers the city of Stockholm as well as its surrounding towns. Stokab was established in 1994, and the total cost of build to pass 100% of enterprise areas and 90% of households was EUR540 million. Stokab acts as a dark fibre provider, and also leases out access to its physical infrastructure, including underground ducts. It offers no active access service at higher layers.

The system allows for the NetCo's primary customers, operating companies, to offer their own higher-layer wholesale services to 'thin' retail service providers.

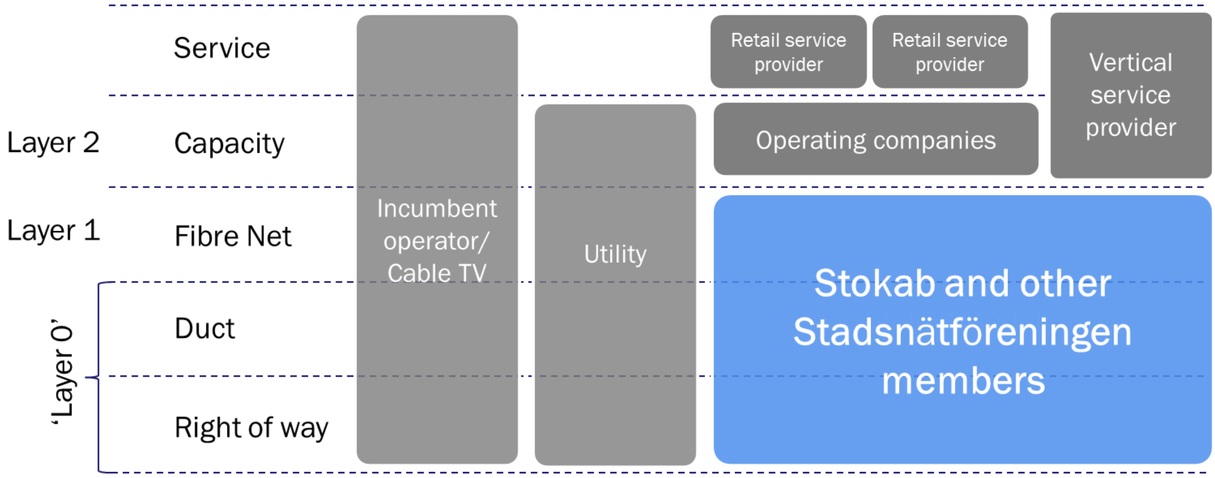
42 Stadnatsforeningen, https://www.ssnf.org/sveriges-stadsnat/vardeniva/

43 OECD (2018). OECD Reviews of Digital Transformation: Going Digital in Sweden. Chapter 2.

44 https://www.ssnf.org/globalassets/in-english/facts-and-statistics/local-fibre-networks-in-sweden.pdf

45 https://www.stokab.se/

Figure 7.2: The Stokab model [Source: Analysys Mason, https://www.stokab.se, 2020]



There are over 100 communications operators and service providers, ranging from big operators such as Tele2 and Telenor to small and specialist providers that only operate in Stockholm. Larger mass-market retail service providers tend also to be operators; at sufficient scale, owner-economics of active equipment kicks in.

The network is heavily overprovisioned with fibres. Some established operator FTTP overbuilding of the Stokab and other SSNF networks has occurred, and some cable-TV networks predate the SSNF networks, but there is clearly a disincentive to overbuild; one of the important aspects of the multi-layer competition landscape in Sweden is that the historical incumbent operator Telia has long been an operator on third-party owned networks. European incumbent operators' use of third-party networks has been relatively rare outside the Nordic region, but we see signs that this resistance is breaking down elsewhere: for example, Telekom Deutschland on Deutsche Glasfaser's networks, and Orange Polska on Nexera's.

The village fibre approach has provided Swedish customers with good services as well as choice in rural areas too. For example, Skellefteå Kraft Fibrenät AB operates a municipal network in the municipality of Skellefteå, in the north-west of Sweden, and passes around 26 000 households.[46] As of January 2020, 10 different operators and service providers, including the incumbent Telia, offered service packages on this network, with monthly prices ranging from SEK249 (EUR 23.56) to SEK999 (EUR94.52).

Since ISPs often do not incur significant construction and operational costs, barriers to entry are low. Hence, end users have access to a wide range of services at different prices. Therefore, the Swedish approach has been widely regarded as successful, allowing fast FTTP roll-out as well as directly promoting the improvement of digital services in the country.

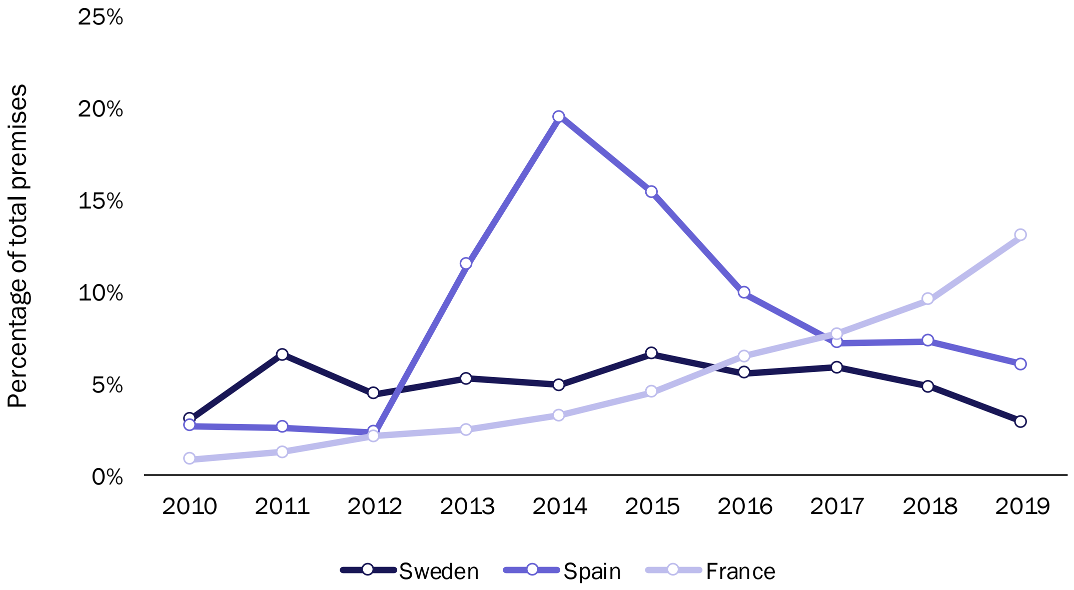
7.2 Case study: Spain. High-quality civic infrastructure and effective light-touch regulation have made the country a leader in FTTP in Europe

The rapid deployment of FTTP in Spain is a case study for effective development of fibre networks. Since 2009, the country went from 0% to 85% of premises passed by FTTP in 2019, the second highest in Europe after Portugal, where the approach has many similarities. Figure 7.3 depicts the rate of FTTP roll-out in Sweden, Spain and France for the period 2010–2019. The rate of FTTP roll-out in Spain was much higher than in the other two countries from 2013 to 2016. The average rate of premises passed in this period has been higher than

46 https://www.skekraft.se/om-oss/verksamhet/bredbandsnatet/

10% per year, with a peak of 20% from 2013 to 2014. 20% coverage in 1 year is about as fast a roll-out has been achieved anywhere in the world. Even China Mobile's roll-out did not quite achieve this peak run-rate.

Figure 7.3: Annual rate of FTTP roll-out in Sweden, Spain and France, 2009–2019



Source: Analysys Mason

In terms of number of premises passed, Spain reached 22 million[47] in 2019, more than the UK, Germany and Italy combined. The success of the Spanish FTTP roll-out was driven by the following set of factors.

- **Clear, wide and fairly modern pre-existing physical infrastructure, such as manholes, ducts and poles, which allowed operators to quickly deploy fibre at low cost.** This was a key factor that allowed Spain to get ahead of other wealthier countries such as the UK and Germany. A similar environment has led to similar, if not better, outcomes in Portugal.

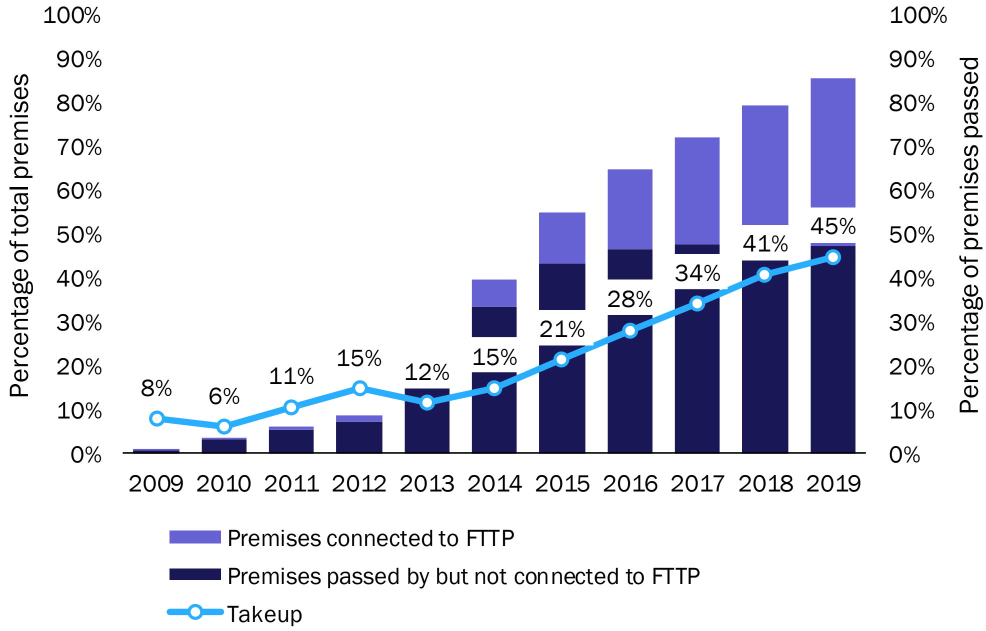
- **Favourable regulatory environment for both the incumbent and its competitors.** Since 2009, Telefónica has been obliged to grant its competitors access to its physical infrastructure (ducts and conduits) at regulated rates, but it has not been obliged to offer fibre unbundling or bitstream (other than a simple 30Mbit/s service). All operators have been obliged to share in-building fibre. Third-party operators are charged a price per metre of duct and per area of duct section.[48] This allowed smaller operators to save money on construction costs while giving Telefónica an incentive to develop its own networks. This initially led to several FTTP players placing their own fibre networks in the duct systems, but has evolved over time into a fairly complex set of commercially negotiated access swaps and other bilateral agreements between major players to provide access to parts of fibre networks. Regulation has subsequently been applied to those areas served by only a Movistar network. Continued momentum in competitive commercial deployment by Orange and Másmóvil in particular means these areas are shrinking in terms of premises passed.

47 Analysys Mason, 2020.

48 Acceso Regulado a las infraestructuras de obra civil de Telefónica (Oferta MarCo), Comisión Nacional de los Mercados y la Competencia, 9/11/2009.

- **Access to low-cost labour.** Spain and Portugal were among the countries that suffered the most from the economic downturn in the late 2000s/early 2010s. While this decreased the overall availability of investment capital, it also meant that a sizeable proportion of the population was seeking employment. Furthermore, since telecoms services have become essential for society in industrialised countries, the telecoms sector is becoming increasingly non-cyclical. Hence, operators had access to cheap labour and enough capital to carry out fibre deployment.

Figure 7.4: Percentage of premises passed by and connected to FTTP in Spain, 2009–2019



Source: Analysys Mason

Take-up in Spain has not always kept up with the speed of FTTP roll-out. This is because the rate of FTTP roll-out has been very high: about 20% of the country's premises were passed by FTTP between 2013 and 2014. Nonetheless, take-up is now on a strong upwards trajectory, and FTTP is displacing cable as well as xDSL.

Operators have used retail fixed–mobile convergence (FMC) (in the form of so-called quadruple plays of internet access, TV, voice and mobile) to drive take-up. It is no coincidence that the four European markets where FMC has been pushed the hardest (i.e. with the greatest subsidy of mobile) are those with the highest level of fibre competition (France, Portugal, Romania and Spain). It is arguable that cross-subsidy of mobile is a consequence of excess FTTP network deployment; converting homes passed to subscribers is of greater importance at this stage than average revenue per line, especially considering the lifetime value of an FTTP subscriber.

Competition has also proved to be beneficial for FTTP deployment in Spain. By 2015, Telefónica had already passed 13.4 million homes with its FTTP network.[49] In order to close the gap with the incumbent, Orange Spain

49 https://www.lightreading.com/gigabit/fttx/telefonicas-fibre-fix/a/d-id/719518

and Vodafone announced ambitious plans for FTTP roll-out in Spain. Orange Spain committed over EUR1.5 billion to FTTP in 2015[50], and signed a network sharing scheme with Vodafone[51] in 2014.

Figure 7.5: Live FTTP networks by operator, Spain [Source: CNMC, 2020]

Operator	Launch year	FTTP premises passed (3Q 2019)	Number of active FTTP lines (3Q 2019)
Telefónica (Movistar)	2008	22.68 million	4.24 million
Orange (incorporating Jazztel, which it acquired in 2015)	2010	14.61 million	3.13 million
Vodafone	2014	3.63 million	1.21 million
Grupo Másmóvil	2015	8.84 million	1.10 million
Others		1.03 million	0.16 million

It is instructive to observe the interplay between market and cable networks. Vodafone's acquisition of Spain's largest cable operator Ono in 2014 initially put the company in a better position to compete with Telefónica[52], but the competitiveness of cable has recently declined compared to FTTP-based players. This may in part be because of deficiencies in the content side of the Vodafone retail offer, or because of the difficulty of competing on price with a higher-opex network. Whatever the reasons, a relative decline in cable broadband has started in some other European countries. Vodafone signalled its intention to spin off its cable network infrastructure in Spain. It probably makes more economic sense for Vodafone to have an FTTP network sharing or wholesale contract than to continue to use cable.

The outlook for FTTP roll-out remains positive despite new regulations. In 2016, the Comisión Nacional de los Mercados y la Competencia (CNMC) implemented important changes to the wholesale broadband agreements approved in 2009. Above all, it established different sharing terms for fibre and copper networks. Telefónica would be obliged to open its fibre network only in those municipalities with little or no competition.

While it has been argued that obliging Telefónica to share its infrastructure, especially its fibre network, could have resulted in a slowdown in fibre roll-out, the evidence suggests otherwise. Since 2016, the total number of premises passed by FTTP increased by approximately 4 million. By comparison, this is almost four times the number of premises passed in Germany since 2010. In fact, Spanish operators have been actively promoting infrastructure and investment sharing agreements, which allowed them to share costs and risks, especially in rural areas.

The central government is supporting fibre roll-outs through the 300x100 Plan. The plan sets the ambitious objective of covering 100% of the population with connections capable of 300Mbit/s. The government allocated EUR525 million to fibre deployment over the 2018–2021 period. Although it is difficult to anticipate whether the 300x100 Plan will be fully achieved, Spain is set to keep its leadership among larger countries in FTTP in Europe. Movistar (Telefónica) expects to switch off copper networks in about 2025. Wireless may play a small role in achieving the 300x100 Plan, but we would expect mid-to high nineties percent coverage of FTTP by that date.

50 https://www.fiercewireless.com/europe/orange-spain-outlines-4g-ftth-investment-ambitions

51 http://otp.investis.com/clients/uk/vodafone1/rns/regulatory-story.aspx?cid=221&newsid=434414

52 https://www.vodafone.com/content/dam/vodcom/files/investors/m%26a/acquisition-of-ono-presentation.pdf

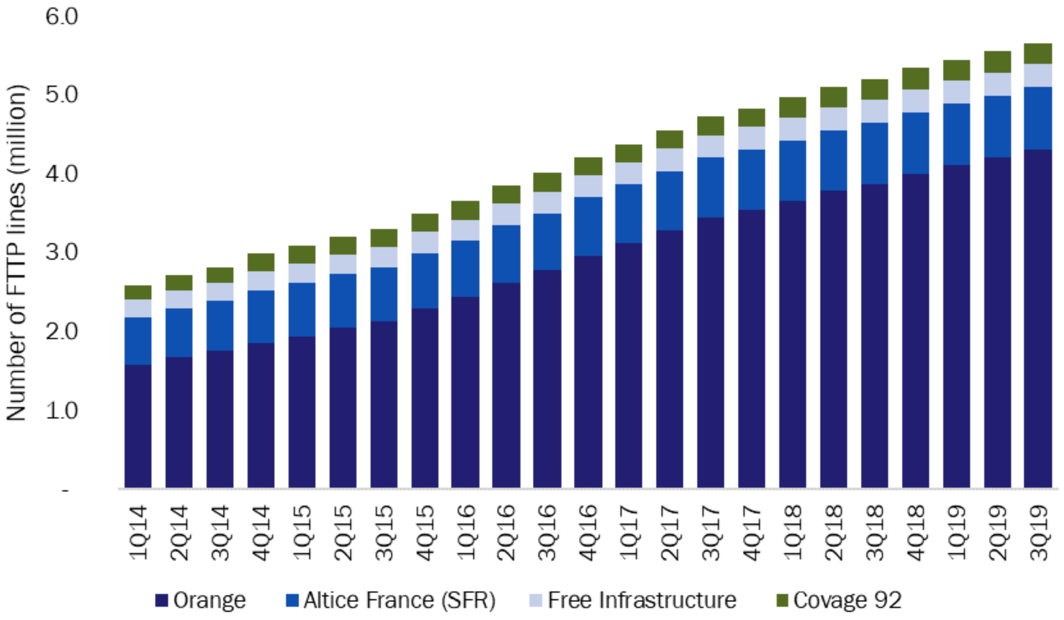
7.3 Case study: France. The national broadband plan introduced efficient operational regulation, which improved confidence in deploying FTTP

Before 2013, FTTP roll-out in France had been relatively slow. As of 2013, only 9.4% of total premises had been covered by an FTTP network. By comparison, 19.7% of total premises had been passed by the same year in Spain. Orange was by far the largest FBB retail service provider, with over 40% of market share[53] and the largest copper-based network. To accelerate the deployment of fibre, the French government devised a detailed national broadband plan. Although it took some years for operators and municipalities to adapt to the new rules, FTTP roll-out has gained traction. From 2017 to 2019, the percentage of premises passed by a fibre network went from 31.4% to 54.0%. The run-rate has actually increased and is now over 1 million premises passed per quarter.

The 'Plan France Très Haut Débit' ('Ultra-Fast Broadband Plan'), published in 2013, aims to achieve 100% coverage of territory with speeds of at least 8Mbit/s by the end of 2020 and over 30Mbit/s by the end of 2022. The government stated in February 2020 that it intended 100% FTTP coverage with no role for wireless. The plan outlines three zones characterised by different types of developments and financing:

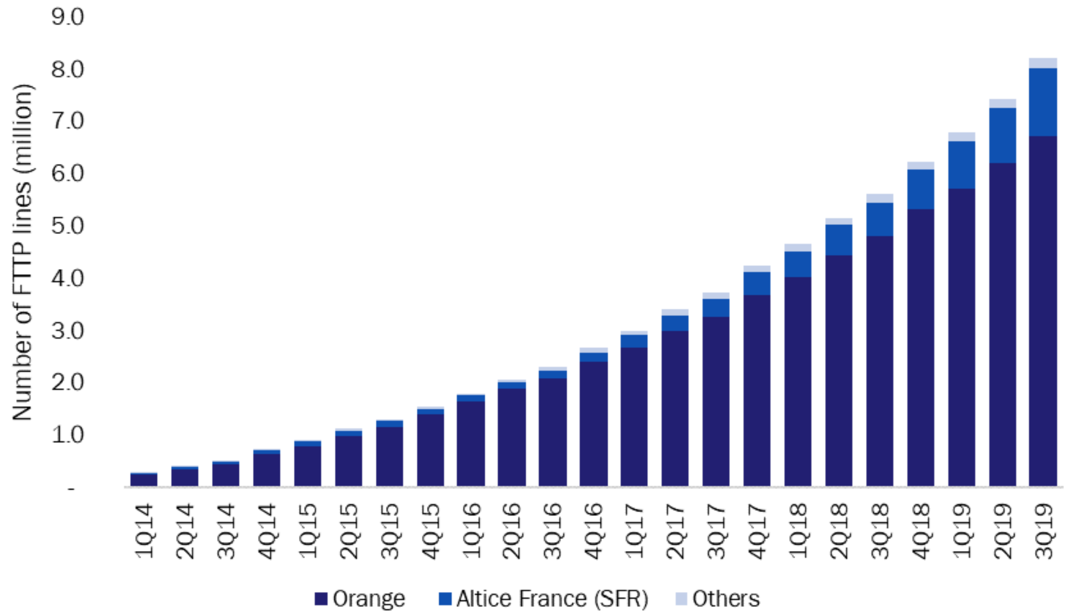
- 'ZTD' ('High-density zones'), where private operators and providers are responsible for deploying their own networks. The ZTDs include 106 municipalities and around 6.4 million residential and business premises.
- 'AMII Zones' ('Call for Investment' zones), for which multiple operators have expressed their interest to jointly deploy and/or finance fibre-optic networks. These are medium-density areas and medium-sized cities.

Figure 7.6: Number of FTTP lines in ZTDs by operator, France [Source: ARCEP, 2020]



53 Analysys Mason, 2020

Figure 7.7: Number of FTTP lines in AMII zones by operator, France [Source: ARCEP, 2020]



The AMII zones include medium-sized cities and their respective hinterlands. This includes around 14 million premises, bringing the total number of premises passed by privately financed projects to 20 million. Two companies, Orange and SFR, expressed their interest to the government in 2011 to develop FTTP networks in 3500 municipalities in AMII zones across France.

- 'RIP Zones' ('Public Initiative Network Zones'), where fibre projects are financed and deployed by local governments using public funds.

About 17 million premises are grouped into the RIP zones, mainly in rural communities and geographically challenging territories. The network construction projects in these areas are generally built according to the guidelines outlined by the 'Plan France Très Haut Débit' (THD) and are financed by local municipalities. This is because, in the around 33 000 municipalities included in these zones, it is not economically viable for private operators to invest. The French government delegated the task of managing these projects to local municipalities instead of co-ordinating operations from Paris.

In addition to these three zones, Appel á Manifestation d'Engagements Locaux (AMEL) zones were created in 2017. These zones included parts of the RIP zones where private operators expressed willingness to roll out FTTP infrastructure without public subsidies. The projects in these areas are still conducted under the supervision of local authorities, and have to meet a set of requirements:

- operators' commitments are binding and enforceable
- operators have to respect the economic equilibrium of public projects that are already launched in neighbouring areas
- operators will have to ensure that the deployment is complete, sufficient and conducted according to a schedule that is consistent with other planned deployments.

ARCEP outlined a symmetric regulatory framework that applies to all operators deploying FTTP networks. This framework varies according to the type of zone in which the network is located.

Figure 7.8: Summary of regulation by area type, France [Source: ARCEP, Analysys Mason, 2020]

	Very dense areas			Less dense areas	
	Outside low-density sub areas		Low-density sub areas	AMII/AMEL areas	RIP areas
Total premises	6.4 million			13.7 million[1]	16.8 million[1]
Parallel networks	Multiple			Single	
Obligation to offer co-investment	× (except for the in-building segment)			✓ (by share of 5% of lines)	
Public subsidies	×			×	✓
Network ownership	Operator			Operator	Local authority
Location of the mutualisation point (PM)	**Large buildings (>12 dwellings)**	**Small buildings (<12 dwellings)**	**Low-density sub areas**	Street cabinet	
	Basement	Street cabinet	Street cabinet		
Minimum number of lines at the PM	–	**100**	**300**	**1000** (300 if the infrastructure operator also offers backhaul services)	
Layer 1 access obligation	Multifibre (between 1 and 4 by client)	Monofibre (multifibre if isolated building)	Monofibre	Monofibre	
Bitstream obligation	×	×	×	×	

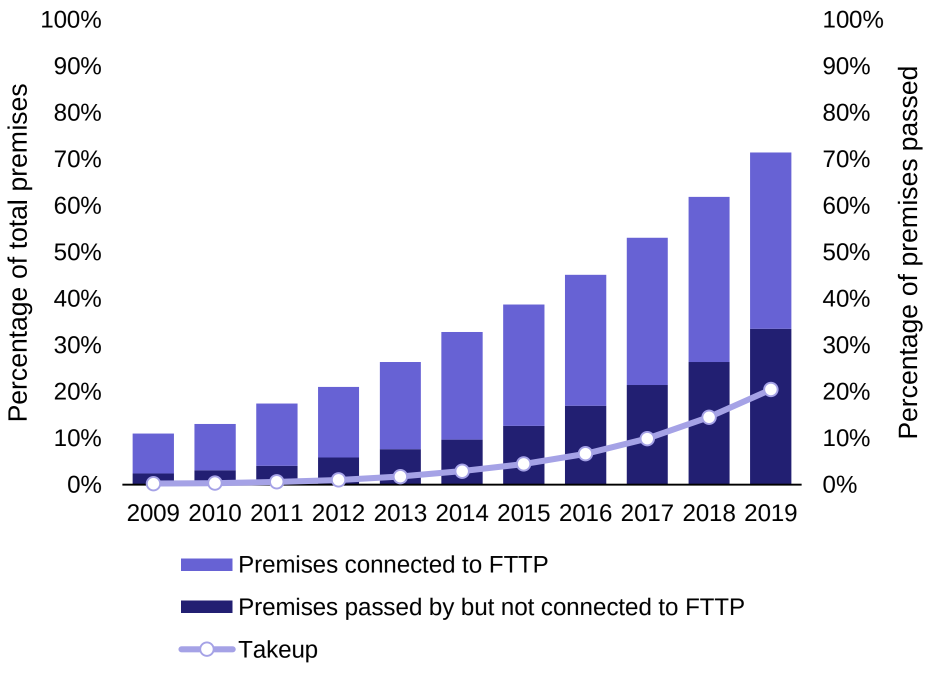
The main factor that differentiates fibre deployment in each zone is the localisation of the 'mutualisation point' ('point de mutualisation, PM). As an overall view, the ARCEP approach directly relates population density to the extent of mutualisation of fibre infrastructure. In very dense areas, infrastructure operators have to provide access to a small portion of dark fibre infrastructure on a non-discriminatory basis. In these areas, the mutualisation point is often located inside the building, which normally houses multiple dwellings. Sometimes, the mutualisation point is in street cabinets, from which a shared dark fibre network connects individual houses. Hence, in areas with high population densities, infrastructure operators only have to share the small portion of the network that goes from the mutualisation point to the individual premises. Operators are responsible for deploying the infrastructure needed to connect to the mutualisation point.

In low-density areas, mutualisation points are located inside street cabinets that normally host 1000 lines. Furthermore, the portion of shared network is publicly owned.

FTTP roll-out in France has gained momentum since 2017. As of September 2019, ARCEP reported that 36% of all fixed subscribers took speeds of over 30Mbit/s.[54] Overall, the pace of deployment of fibre infrastructure has been increasing throughout 2019. At the end of 3Q 2019, 16.7 million premises had access to FTTP, a 34% increase from 3Q 2018.

54 https://en.arcep.fr/news/press-releases/p/n/broadband-and-superfast-broadband-market-4.html

Figure 7.9: Percentage of premises passed and subscriber penetration of premises, France, 2009-2019 [Source: Analysys Mason, 2020]



Nevertheless, most of the growth comes from projects in the AMII zones, where 700 000 additional premises were connected to an FTTP network in 3Q 2019. By comparison, half as many premises in the RIP zones, approximately 350 000, became eligible to subscribe to FTTP access in the same quarter.

In order to facilitate the expansion of fibre in the RIP zones, ARCEP introduced in 2018 new rules requiring Orange to give access to its civic infrastructure.[55] Moreover, Orange is required to give operators the possibility of autonomously carrying out renovation works where needed, while retaining ownership of the infrastructure. Local operators would act as subcontractors, and hence would be refunded by Orange for their work. These provisions are meant to close the gap between rural and urban fibre development, and to progressively achieve the goals set by the THD plan.

The following three case studies are of countries where roll-out of full-fibre networks has been less intensive than in the three above, and where, for quite different reasons, a positive outcome is less certain.

7.4 Case study: Italy. Current uncertainties over future ownership

Until 2015, Italy had very little diversity of fixed broadband infrastructure. The country has never had a cable-TV network, and other than limited FTTP roll-out in four cities (Fastweb and the wholesale-only Metroweb), the sole national fixed access infrastructure was that of the historical incumbent Telecom Italia.

The issue of state ownership of one the two main players, and the issue of state broadband infrastructure policy and aid are intertwined. In December 2015, state-owned electric utility Enel established a subsidiary, Enel OpEn Fiber, which started roll-out of an entirely new, wholesale-only, FTTP network. The network uses Enel's existing overhead and underground physical infrastructure. Open Fiber estimates that use of this infrastructure has reduced its capex by about 25%. In December 2016, Enel OpEn Fiber and existing Metroweb Italia merged,

55 https://www.arcep.fr/collectivites/les-reseaux-dinitiative-publique-rip.html

resulting in Enel OpEn Fiber (since rebranded Open Fiber) being 50% owned by Enel and 50% owned by state investment vehicle Cassa Depositi e Prestiti (CDP). Thus Italy is in the unusual situation of having a privately-owned incumbent competing against a state-owned insurgent.

Open Fiber aims to pass 15.6 million households (60% coverage) by the end of 2023 (of which 14.5 million with FTTP and 1.1 million with fixed wireless). Open Fiber's wholesale model offers access at Layers 1 and 2, but the largest contracts signed with existing operators have been at Layer 1.

Italy's national ultra-broadband plan, Strategia Nazionale per la Banda Ultra-Larga or SNBUL, was approved in March 2015. The aim was to develop an NGA network capable of providing speeds of at least 100Mbit/s to at least 85% of households, with a preference for FTTP in urban areas. Italy adopted a state-aid scheme, and three tenders have been assigned, all to Open Fiber, through Infratel, the vehicle for implementing the state's broadband plans. Collectively these were worth about EUR4 billion.

Open Fiber's broadband roll-out has created major structural changes in the Italian broadband market

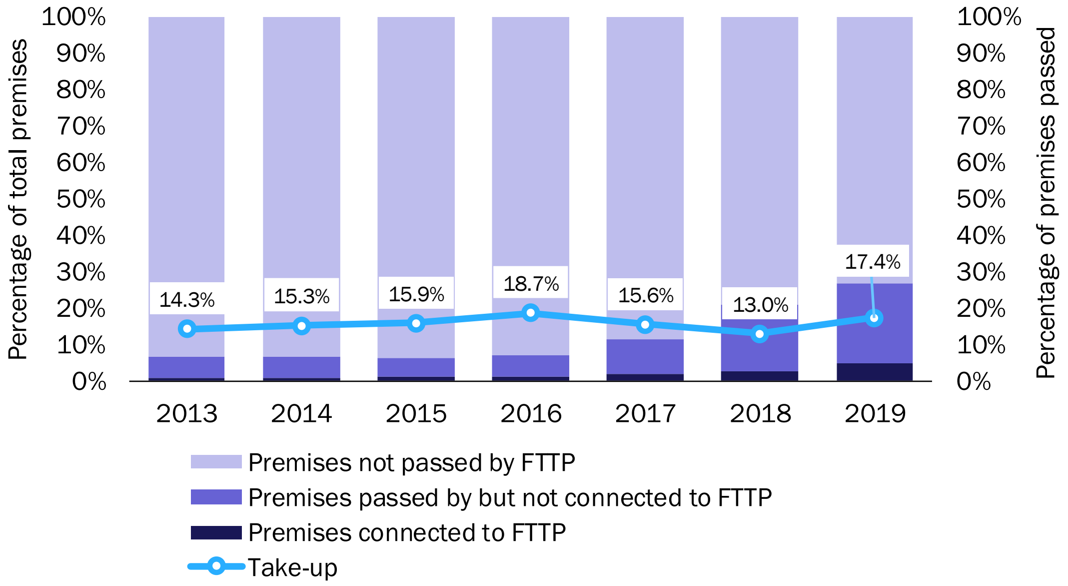
- Telecom Italia has been forced to start overbuilding its existing FTTC networks with FTTP. Previously, Telecom Italia offered retail and bitstream FTTC, and also leased out sub-loops to unbundlers that installed their own street cabinets. It created Flash Fiber, a joint venture with Fastweb, to share their existing FTTP networks and build out to 5 million premises in total. These networks overbuild Open Fiber.

- Retail prices fell very rapidly, and price differentiation on speed eroded, as the impact of Layer 1 unbundling took hold. Telecom Italia's wholesale tariffs also fell, and it introduced some Layer 1 products.

- Telecom Italia has come under sustained pressure from activist shareholders to create a separate infrastructure unit and to ultimately to merge it with Open Fiber, thus pushing Italy back effectively to a single NetCo. This is highly politicised but the move appeared to have the approval of the main party in the coalition government, the 5SM. Telecom Italia entered formal talks with Open Fiber in July 2019.

By the end of 2019, FTTP coverage had reached 27%, but take-up remained modest at 17%.

Figure 7.10: Percentage of premises passed by and connected to FTTP, Italy, 2009–2019



Source: Analysys Mason

7.5 Case study: UK. Commercial enthusiasm for FTTP may disguise future problems

The UK has enjoyed some policy success with earlier generations of broadband. This has delivered approximately 97% coverage of 30Mbit/s against the original EC Digital Agenda target of 100%, putting the UK near the top of European rankings in that respect. The historical SMP operator[56], Openreach (a structurally separated arm of BT) opted for FTTC/VDSL as its strategic technology for next-generation broadband. High coverage was achieved through some public funding, via a state vehicle, Broadband Delivery UK, of intervention projects in rural areas (almost all won by Openreach and hence mainly FTTC), and a 'clawback' mechanism that allowed BDUK to recover subsidy in areas where a sufficient commercial return was made. This allowed funds to be reallocated to ever more economically challenging areas.

Regulatory policy on FTTC/VDSL leant heavily on virtual unbundled local access (VULA), a Layer 2 service with a local interconnect option, intended as a successor product to ADSL unbundling because sub-loop unbundling (Layer 1 unbundling at the cabinet) was judged commercially unviable. VULA has also been the preferred approach (i.e. there appears to be no push for Layer 1 unbundling) for Openreach FTTP, which it started deploying in small volumes in 2010. However, until the last 2 years, Openreach FTTP, where it has been deployed, has been deployed **instead of** FTTC rather than on top of FTTC.

The National Infrastructure Commission published its National Infrastructure Assessment in July 2018. It placed a strong emphasis on digital infrastructure. It recommended the following:

- Ofcom should promote network competition to drive the commercial roll-out of full-fibre, by deregulating where competition is effective and guaranteeing a fair bet on risky investments before regulating any uncompetitive areas
- government should partly subsidise roll-out to rural and remote communities, beginning by 2020, starting with the hardest to reach areas

[56] An operator with Significant Market Power enjoys a position of economic strength such that it can behave to an appreciable extent independently of competitors and customers

- government and Ofcom should allow for copper switch-off by 2025
- government and Ofcom should take action to cut the cost of full-fibre deployment including:
  - government should ensure the processes for obtaining wayleaves and connecting new builds are the same for digital infrastructure as for other utilities by 2019
  - local government should designate ‘digital champions’ to improve telecoms processes such as street work permissions and access to publicly owned assets
  - Ofcom should monitor the accessibility of Openreach’s duct and pole infrastructure by levels of usage.

The subsequent Future Telecoms Infrastructure Review (FTIR), conducted by the Department for Culture Media and Sport (DCMS) and published in November 2018, expressed a view that:

- at least 40% of the UK could support three gigabit-capable broadband networks
- up to a further 50% could support two gigabit-capable broadband networks
- parts of the country (around 10% of premises), while commercially viable for at least one operator, may not benefit from investment.
- in the final approximately 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.

The FTIR proposed a target of 15 million FTTP coverage by 2025, 30 million by 2030 and full coverage (about 33 million) by 2033. To make this possible, it reiterated that it was necessary to:

- make the cost of deploying fibre networks as low as possible by addressing barriers to deployment that both increase costs and cause delays
- support 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)
- incentivise competitive network investment through stable, long-term regulation
- adopt an ‘outside in’ approach to deployment that means gigabit-capable connectivity across all areas of the UK is achieved at the same time
- implement a switchover process that stimulates demand for full-fibre services

The future prime minister, Boris Johnson, described the FTIR coverage targets as ‘laughably unambitious’, and pledged to reset the target universal full-fibre coverage target to 2025. In September 2019, the then Chancellor of the Exchequer Sajid Javid confirmed the GBP5 billion investment ‘to support the roll-out of full-fibre, 5G and other gigabit-capable networks to the hardest-to-reach 20% of the country’. This appears to shift the targets from full-fibre to ‘gigabit-capable’.

Ofcom has been leaning more heavily on mandating access at regulated prices to Openreach ducts and poles in order to stimulate local FTTP build. Openreach had previously offered a physical infrastructure access (PIA) product, but it had rather few takers. The revised product is different in the following key ways:

- substantially lower tariffs than the previous regulated product physical infrastructure access product PIA, including a price cap
- an obligation on Openreach, where required, to fund remedial works to the ducts to a maximum of about GBP100 per premises passed
- the removal of a previous prohibition on the use of ducts and poles for any other purpose than broadband (e.g. leased lines or backhaul).

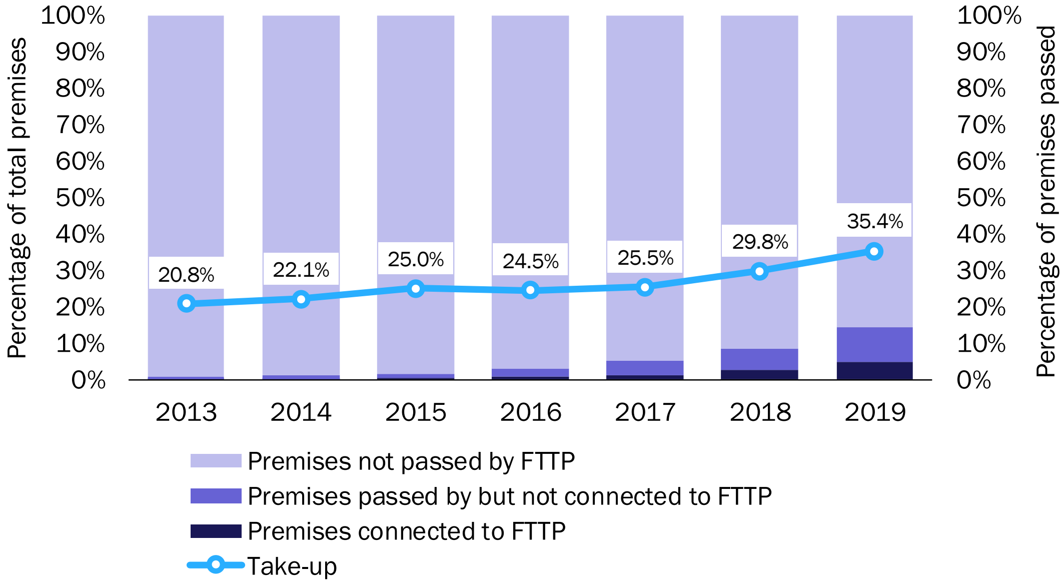
The increasing viability of PIA for alternative operators is part of the reason for the recent surge in investment plans by new, alternative FTTP players. However, there are other reasons. The FTIR recognised that "availability of capital is not the key constraint" to accelerated FTTP build.[57] Infrastructure investors (particularly pension funds and sovereign wealth funds) are looking for new areas for relatively low-risk investment. There are other reasons too: investors recognise that demand is likely to catch up with FTTP, and that dense full-fibre networks will also serve an important additional function in facilitating 5G. This surge in investment by outside players is one factor that has encouraged Openreach to accelerate its own FTTP deployment in FTTC areas (and to cut back on an interim G.fast solution that it had hitherto preferred). Its wholesale FTTP tariffs in those areas carry a premium, whereas in those areas where no FTTP was built they have similar tariffs to FTTC on speeds both types of broadband are capable of delivering.

In fact, commercial FTTP projects are proliferating in the UK. While many of these are still 'ambitions' rather than fully funded plans and therefore may not be realised, the total alternative operator coverage ambition amounts to over 20 million premises, two-thirds of the UK. Openreach has an ambition 'given the right regulatory circumstances' to reach 20 million by the mid to late 2020s.

While this investment is welcome, its fragmented nature may pose problems in the future: inefficient overbuild, significant gaps in coverage, and a legacy of different architecture and suppliers that would be difficult to consolidate if that were required. This is discussed further in Chapter 8.

At the end of 2019, FTTP networks (including those rolled out by cable operators) reached about 14% of UK premises, and take-up was beginning to pick up.

Figure 7.11: Percentage of premises passed by and connected to FTTP, UK, 2009–2019



Source: Analysys Mason

The investment boom has thrown up several distinct business models. CityFibre has a wholesale-only model, and it seeks major long-term contracts with major service providers. Its current model is to offer access at Layer 2. Various others, including many in rural or semi-rural non-cabled areas, are pushing an integrated retail-only model. Hyperoptic is also retail-only and has focused on urban multi-dwelling units: not all of its roll-out will be strictly FTTP: it may include some FTTB+LAN. Virgin Media has extended and added new cities to its network

---

57 See https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/732496/Future_Telecoms_Infrastructure_Review.pdf, p5

with a mixture of coax and FTTP. Virgin Media's owner Liberty Global got code powers for a new subsidiary 'Liberty Networks', which seeks co-investment partners for roll-out of FTTP networks in areas where it would face a low level of competition.

Initial roll-out announcements appeared to indicate some differences between the roll-out plans of Openreach and those of CityFibre, with the former focusing on the largest cities[58], and the latter focusing on second-tier cities and towns generally with a population of between 50 000 and 500 000. There appears now to be more of an overlap between the two.

The rate of roll-out achieved by Openreach (about 100 000 per month at YE 2019) has so far been significantly faster than that of its competitors: Virgin Media about 40 000 (of which about half FTTP) and CityFibre closer to 15 000. This is unsurprising given an asymmetry of human resources, but if alternative operators are to roll out to a footprint of a similar size, they will have to accelerate the rate at which they pass premises. Nevertheless, when combined, the rate is still far short of that currently seen in France, where the current run-rate for all operators is about three times this figure with comparable resources. Openreach has taken on additional staff, and has indicated that it believes it could peak at 3 million annually.

A further development in the UK is the evolving role of cable networks. Cable networks have historically been closed-access in the UK and elsewhere. For mainly regulatory reasons, wholesale access to cable broadband networks has become more common in the past 2 years. Virgin Media faces no such regulatory pressure, but it is legitimate to ask whether voluntary wholesale access would be a prudent business move by Virgin Media. In countries like Spain where there is more than one major alternative FTTP player, it is cable rather than the new entrant that appears to be performing least well in terms of churn. Wholesale access to DOCSIS 3.1 might therefore be seen as a defensive measure by creating a commercially attractive alternative to altnet FTTP, thereby simultaneously weakening the business case for altnet FTTP build and diminishing the pressure on Openreach to respond. By way of comparison, Telefónica Deutschland's access to Vodafone Deutschland's DOCSIS network, an agreement that was imposed as a remedy to Vodafone's acquisition of UnityMedia, certainly dampens the case for new alternative FTTP in Germany, as Telefónica would be among the largest potential wholesale customer of any new network.

7.6 Case study: Germany. Lofty ambitions but slow progress

In January 2016, the German federal government passed the DigiNetz law that was intended to clear obstacles to an expansion of fibre networks, in order to preserve Germany's leading role in mobility and science, as well as in research, innovation and industry.[59] The set of measures included:

- an obligation to lay fibres on traffic construction sites
- an obligation to make new building developments fibre-ready
- support for underserved areas.

[58] Openreach intends that in those exchange areas where it rolls out FTTP it covers all premises.

[59] https://www.bmvi.de/SharedDocs/DE/Artikel/DG/diginetz-gesetz.html

The law also underlined the EU Broadband Cost Reduction Directive of 2014 by creating the conditions for exploiting synergies with other utility and transport infrastructures. The law established an infrastructure database and an organ for conflict resolution.

In March 2018, the federal government identified nationwide expansion of gigabit networks by 2025 as a priority goal.[60] Among the aims of the policy developed are the expansion of fibre infrastructure to each community, with a preference for FTTP. Schools, industrial parks, public-sector institutions and hospitals are to be connected directly to fibre-optic networks by 2022. It identified a public financing requirement of between EUR10 billion and EUR12 billion, part of which would be raised by spectrum auctions. This funding is not exclusively for FTTP: it includes other fixed technologies and mobile.

Vodafone’s cable network is by far the most expansive gigabit-capable network in Germany. It covers 24 million households (nearly 60% of Germany) and has mostly been upgraded to DOCSIS 3.1. It has expanded its network with some FTTP, but this has been to reach mainly business areas. Other smaller cable operators take cable coverage in Germany to over 30 million premises, or nearly three quarters of all premises in Germany.

Deutsche Telekom, the historical incumbent, has pursued an FTTC strategy and it remains the largest network in terms of end users. It has upgraded about 60% of its lines to 35b supervectoring, enabling downlink speeds of up to 250Mbit/s. Its technology choice is guided by two key factors: the topology of the flexibility points in the existing copper network, and the absence of ducts on the distribution side between the street cabinet and the end user.

The historical copper network has a lower ratio of lines to cabinets than is usual in a fixed telephone network: Deutsche Telekom has about 300 000 cabinets in a country with a population of 82 million , compared with BT’s 85 000 in a country with a population of 68 million. Therefore, the mean distribution loop length is shorter in Germany (around 250–300m) compared with about 500m mean length in the UK and 700m on the Orange copper network in France. This short sub-loop length makes copper acceleration technologies more effective. However, it also means that in an FTTC network fibre comes closer to end users than in most other copper networks, which should, all other things being equal, reduce the upgrade costs of the distribution side from FTTC to FTTP.

However, all other things are not equal, and Telekom faces a particular challenge on the distribution side of the cabinet. Most of the Telekom network has directly buried copper cables between street cabinets and end users so FTTP build requires more civil engineering than in other countries, inevitably driving up costs.

Deutsche Telekom has been generally very cautious about FTTP, and its CEOs have over the years warned of the high costs and/or the impossibility of full FTTP coverage. It has indicated that it believes the cost of full coverage would be between EUR60 billion and EUR80 billion (between EUR1400 and EUR1900 per premises very much at the high end of the scale by European standards). Over the last 10 years, it has rolled out FTTP in some pilot towns on a small scale, and more recently developed a number of somewhat larger-scale co-investments.

Of particular note is the trend towards co-investment models. Telekom has a 50:50 co-investment with utility EWE to serve 1.5 million premises, and an asymmetric co-investment with Stuttgart municipality to serve a slightly smaller number of premises. The German regulator BNetzA indicated in August 2018 that a 50:50 co-investment would not be subject to the same regulation as Telekom itself as the joint venture could not be

[60] https://www.bundesregierung.de/breg-de/themen/digital-made-in-de/infrastruktur-und-ausstattung-1543992

understood as the legal successor to Telekom. The EWE JV (Glasfaser NordWest) was approved by the German competition authorities (Bundeskartellamt) in December 2019, subject to the following conditions.

- That Telekom and EWE refrain from specific strategic defence measures in relation to telecoms companies that are also intending to expand fibre-optic networks, and from solely focusing on urban areas that already have cable networks.
- That third parties will also be granted non-discriminatory access to the new network and that within a specific period (unstated) a particular share (unstated) of the connections will be handed over to competing telecoms companies that can then market them to the end users.

Telekom has indicated that it will ramp up deployment to 2 million premises passed annually from 2021: at that rate, full coverage would not be achieved until 2040.

Until recently, altnet FTTP activity was on a smaller scale than in the UK. Much of the alternative investment focused on areas off the cable network infrastructure, and often underserved by Telekom. Inexio, a rural-focused altnet acquired by infrastructure fund EQT said it aimed to roll out to 2 million premises by 2030. In February 2020, the altnet Deutsche Glasfaser was acquired by funds EQT and OMERS for an estimated EUR2.5 billion, and announced a huge EUR7 billion FTTP investment plan, which it said would focus on serving mainly rural areas.

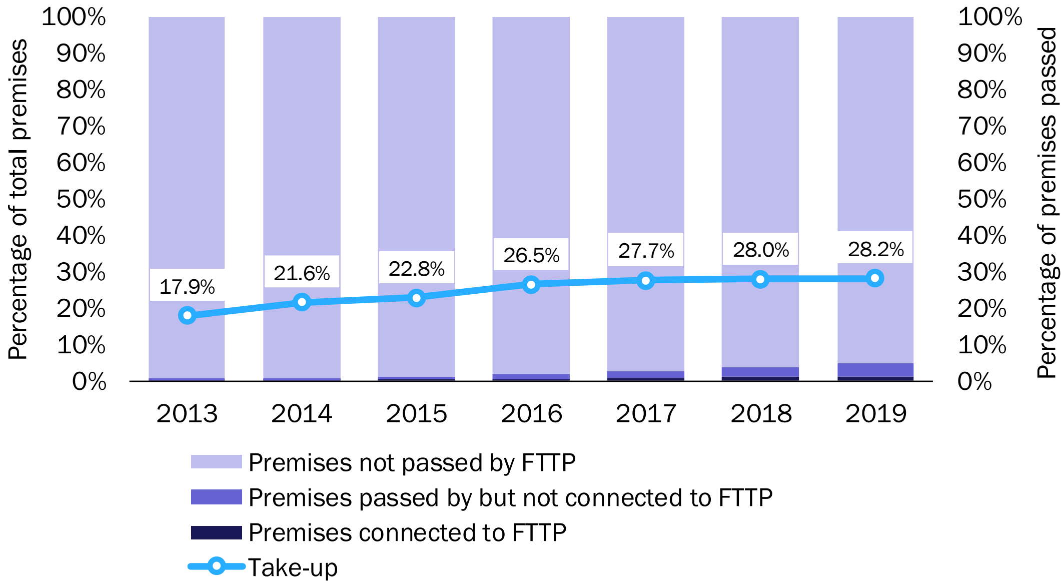
No alternative FTTP operator is at the time of writing posing a major challenge to Vodafone and Telekom in urban and suburban areas. This stands in contrast to the situation in the UK. A further factor limiting competition is the result of one of the commitments offered by Vodafone to the EC to secure its acquisition of the cable operator UnityMedia, namely the opening of its DOCSIS network to a third party, Telefónica Deutschland. This may have the effect of stimulating Telekom to build FTTP, but may also dampen investment from third parties in areas that already have cable networks.

Some regional or city alternative operators have rolled out small amounts, and have supplemented this with some FTTB/VDSL. Telekom has focused some of its FTTP roll-out in areas where FTTB/VDSL has gained some traction. FTTB/VDSL by alternative operators poses problems because the frequency ranges that are desirable for an FTTB/VDSL deployment are broader than for FTTC/VDSL and can interfere with the frequency ranges on the FTTC/VDSL vectoring system that Telekom already has in place at the street cabinet. In theory, Telekom, as ultimate owner of the copper network, could shut these players down. What this shows is that it is extremely technically – not to mention legally – challenging for a passive copper network to support two different OpCos with different target markets and strategic aims. This is the opposite of what is the case on fibre.

A noteworthy development in January 2020 was Telekom's agreement to use Deutsche Glasfaser's network. While this is a pilot scheme for Telekom, and limited to one small town, it is an indication of the loosening of the relationship between network owners and operating companies that has been seen in other countries where deployment is more advanced.

At the end of 2019, coverage of FTTP was under 5% in Germany, and the higher cost of roll-out would appear to indicate that coverage will not increase as fast as in the UK in the coming years.

Figure 7.12: Percentage of premises passed by and connected to FTTP, Germany, 2009–2019



Source: Analysys Mason

8. Strategies for encouraging full-fibre broadband networks

Any government policy to promote full-fibre networks will contain specific practical measures to lower or remove barriers to commercial deployment, and it will provide loan funding or subsidies where necessary. This chapter will consider these measures. There is also a bigger picture than removing barriers and subsidy: how best to use policy and regulation to encourage proactive infrastructure-first models, and how to connect this with other political and social priorities. These will be discussed in the final Conclusions and Recommendations chapter of this report.

8.1 Specific measures to lower or remove barriers to deployment

Effective wayleave law is an important means of facilitating FTTP deployments

Disputes over the rights of operators to deploy their network infrastructure on privately held property, and over the rents paid to landlords, can be a significant obstacle to rapid FTTP deployments. It is therefore important that governments introduce or update legislation regarding these rights, or wayleaves, which facilitates network roll-outs.

In New Zealand, the government has reformed its right-of-way legislation to make it easier to connect homes in multi-dwelling units to the FTTP network. The legislation extends the rights of operators to install fibre in the absence of consent from landlords and neighbours sharing the building or complex, for low-disruption installations. The UK government is planning to introduce similar legislation to streamline the consent procedure in granting wayleaves in multi-dwelling units. Additionally, it plans to establish a "right to entry" alongside that of other utilities, giving operators the right to obtain a warrant to install broadband connectivity.

Where possible, fibre-optic cables should be laid beneath roads and other public spaces. This is less disruptive to property owners and tenants and removes the potentially time-consuming requirement for the acquisition of wayleaves on privately-held property. In many countries, including Denmark, Finland and Japan, right-of-way in public spaces is granted at the municipal level. This is often (as in the case of Finland) granted along with the use of ducts installed by the municipality or by other utilities. In a number of countries, access to pre-existing ducts has greatly facilitated the roll-out of the FTTP network, reducing the time and cost otherwise required by road digs. This is the case in Spain and Portugal, and it is a major factor behind its rapid deployment of FTTP and its relatively low public spend per household passed.

"Dig once" policies, which provide pre-existing passive infrastructure for later use in network deployments, significantly reduce roll-out costs for operators and minimise disruption for landlords, tenants and the general public.

Infrastructure sharing reduces costs and improves speed of deployment

Infrastructure sharing is an important way in which the cost and duration of FTTP roll-outs can be significantly reduced. According to the EC, infrastructure sharing can allow savings in network deployments of up to 60%.[61] By sharing ducts and poles, and by renting or co-investing in the passive fibre network, operators can avoid costly and unnecessary over-build, improving the efficiency of the deployment and increasing the rate at which coverage is expanded. This is a particularly important strategy in areas of low population density, in which the business case for overlapping networks would be questionable. Urban Iceland already had full coverage by two FTTP players on totally separate infrastructures, but rural areas presented huge cost challenges. The Icelandic

[61] https://ec.europa.eu/digital-single-market/en/access-passive-infrastructure

regulator PFS insisted that the two main network FTTP network builders should in any new build areas create a duct infrastructure that the other would be allowed to use.[62]

Furthermore, cross-industry infrastructure sharing and collaboration with other civil works projects can improve the efficiency of deployments, especially in cases in which public investment is involved. This also reduces the disruption and environmental damage caused by the deployment. A European directive announced in 2018 requires operators to give access to their physical infrastructure (ducts, poles etc.) to operators intending to roll out VHCNs under “fair and reasonable” terms.[63]

The Portuguese government was one of the first to recognise the importance of infrastructure sharing. In January 2009, it signed an agreement with four fixed network operators based on co-operatively sharing ducts and infrastructure information. As an incentive to co-operate, it opened a EUR800 million line of credit for FTTP roll-out, this at a time of deep economic crisis. The immediate result was a phase of rapid, low-cost roll-out, and the longer-term benefit the highest level of FTTP coverage in Europe, fast approaching the 100% coverage target that the government had set in 2009.

A similar policy regime assists fibre deployment in Spain, where widespread access to pre-existing ducts significantly reduces the costs of FTTP roll-outs. The first operator to a building is required to share vertical infrastructure, and Telefónica (as the incumbent) offers regulated duct access. These policies have been essential to the success of the FTTP deployments that have taken place in Spain, where capex per urban premises passed is around EUR150–300.

Infrastructure sharing is also an important part of the FTTP deployment policy in France. In dense areas (17% of the country), the first operator to reach a building is required to share vertical and horizontal infrastructure, although operators are permitted to build overlapping networks. In other areas, operators agree to build a single last-mile network, and the operator that builds the network is required to offer wholesale services, either through co-investment (ab initio or ex post) or rental access to the passive infrastructure (with bitstream also an option).

In China, deployments of the backbone, aggregation and access layers of the network have frequently been carried out in collaboration with other civil infrastructure projects. Collaboration has occurred on varying scales, including with construction of electrical power lines, oil pipelines, highways and railways, gas and water pipes, municipal construction, and the installation of utilities into existing buildings. This has resulted in a reduction in civil work costs of fibre deployments of 30%. Such a strategy may also be employed as part of “dig once” policies, laying empty ducts concurrently with other public works for later use in network deployments.

In Ireland, the FTTP wholesaler SIRO, launched in 2015 as a joint venture between Vodafone and state-owned electricity company ESB, uses ESB’s pole infrastructure in Cork and smaller regional towns. In several European countries, utility companies have deployed their own FTTP networks. This trend is most pronounced in some of the Nordic countries (Denmark, Norway and Iceland), Switzerland, and more recently, and on a much grander scale, Italy, where state-owned energy company Enel is rolling out a national FTTP network. In Icelandic, Swiss and Italian utility networks, the business model is wholesale-only, and in Switzerland and Italy, the dominant type of wholesale is Layer 1 unbundling.

[62] Though not a member of the EU, Iceland has made a commitment to adopt all of the Directives of the EU in the fields of electronic communications

[63] https://ec.europa.eu/digital-single-market/en/access-passive-infrastructure

Pre-installing fibre-optic cables in new real estate developments assists the roll-out of the last mile

Installation of passive fibre-optic cables (dark fibre) in new real estate developments, undertaken by the property developer, is an effective way of relieving some of the burden of last-mile deployments from operators. In a similar manner to collaborations with civil infrastructure projects, pre-installation reduces the cost required and disruption caused by fibre deployment. It can also increase the value of new-build properties.

A pre-installation policy was enacted early on in France, where the 2008 Law for the Modernisation of the Economy (LME) requires fibre to be installed in newly built residential developments. Additionally, the operator that carries out the installation and management of the fibre lines on behalf of the property developer is required to provide non-discriminatory wholesale access to the infrastructure deployed in the building.[64] This policy promotes faster take-up of FTTP and stimulates competition at the retail level.

In China, real estate developers are required by local authorities to lay passive fibre-optic cables in newly built residential developments, leading into each residential unit. Fibre installation can also be undertaken in existing premises in collaboration with other utility works including gas and electricity maintenance. The UK government is proposing legislation to mandate the installation of infrastructure to support gigabit-capable connections in new builds, with joint obligation on developers and operators and choice at the retail level for customers.[65]

The UK Digital Minister announced in March 2020 that the government would, parliamentary time permitting, amend building regulations to guarantee that all new homes have the right infrastructure to support gigabit broadband. Housing developers would have to work with operators to install connections of at least 1Gbit/s in new-build homes, up to a cost cap of GBP2000 per dwelling.[66]

Other countries provide the option for pre-installation in new developments, rather than mandating it. This is the case in New Zealand, where property developers can opt for their developments to be connected to the nationwide FTTP network. In Singapore, existing commercial properties can choose to have fibre installed, even if they or their tenants do not plan to take up FTTP immediately. This reduces the time required to deliver fibre broadband services by up to two thirds.[67]

Nonetheless, the rate of new building in European countries is slow, and while these measures are useful and could even create local 'halo' effects, their impact in transforming networks to full-fibre will be rather limited.

Optimising the workforce in a construction capacity-constrained environment

A network roll-out is impossible without a workforce to execute it, and the speed, cost and efficiency of a deployment will depend heavily on the size and competence of the human resources carrying it out or the efficacy of the tools they use to simplify the processes involved. It also critically depends on how quickly an existing copper-based operator can shift human resources from maintaining the copper networks to building and maintaining an FTTP network.

The cost of constructing the passive ODN in Europe is typically about or over 80% of the total capex, and most of that 80% goes in capitalised labour costs. Several of the key European markets where there is a low level of FTTP infrastructure currently have high levels of employment and/or skills shortages in relevant areas. This

[64] https://archives.arcep.fr/fileadmin/reprise/dossiers/fibre/2009-1106-arcep-optical-fibre-decision-en.pdf p. 6

[65] https://researchbriefings.files.parliament.uk/documents/CBP-8392/CBP-8392.pdf p. 21

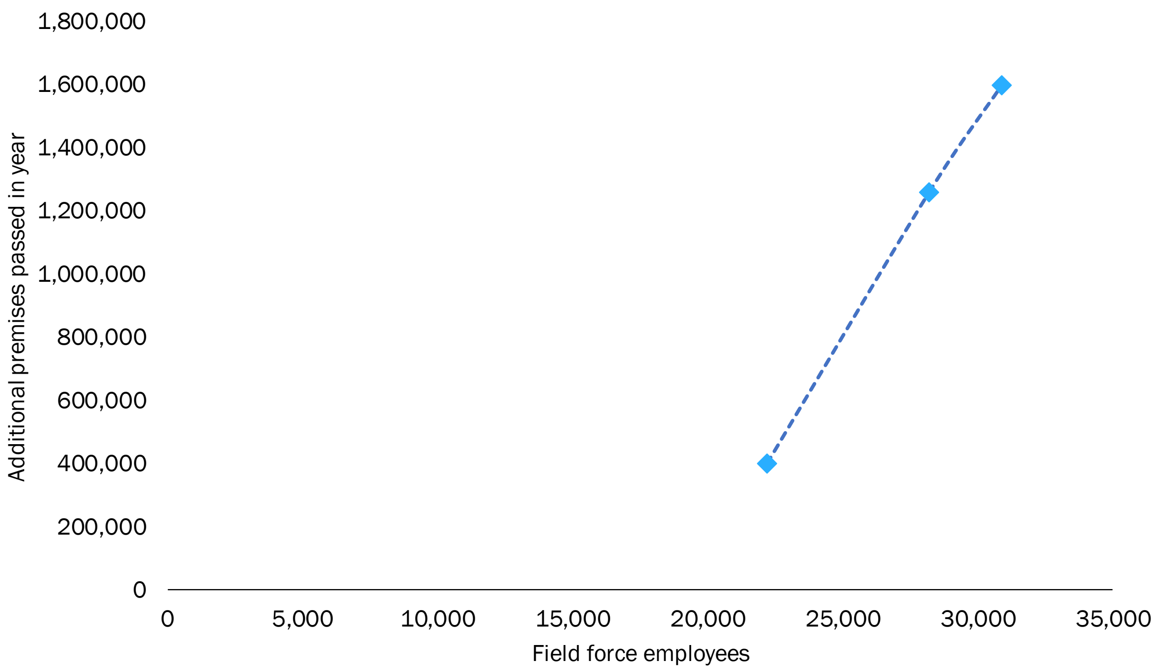
[66] https://www.gov.uk/government/news/new-build-homes-to-come-gigabit-speed-ready

[67] https://www.straitstimes.com/tech/more-buildings-opt-to-have-fibre-optic-cables-pre-installed

creates inflationary pressure on wages and a slowdown in the capacity to deploy. For example, in the UK, telecoms engineering has been identified as an area subject to a skills shortage.[68] This stands in contrast to the situation in the late 2000s and early 2010s in Spain and Portugal, where the major operators initiated FTTP deployment at the bottom of an economic cycle, and where there was therefore a pool of suitable employees and contracting businesses.

In 2018, UK wholesale operator Openreach employed 22 200 field engineers[69], and by the end of 2019 has recruited a further 6000, mostly applied to the FTTP roll-out. Additionally, it had opened 10 fibre installation training facilities[70] in order to improve the productivity of its workforce. This coincided with an acceleration of the expansion of FTTP coverage by Openreach. Figure 8.1 shows the actual and projected additional coverage plotted against the number of field engineers at Openreach.

Figure 8.1: Openreach field force and additional premises passed, 2018–2020 [Source: Analysys Mason, 2020]



From this, we would assume that about 18 000 employees are still committed to maintaining the copper network. Orange France has a roughly similar number of employees and a roughly similar field force to that of BT Group in the UK. Orange France passed 2.6 million additional premises in 2019.

Figure 8.2 compares Openreach's performance with that of other operators.

[68] https://www.engineeringuk.com/news-media/engineers-remain-on-uk-skills-shortage-list/

[69] https://www.theregister.co.uk/2018/03/15/openreach_to_hire_3500_more_engineers/

[70] https://www.computerweekly.com/news/252465350/Telcos-hail-progress-improvements-in-meeting-UK-full-fibre-broadband-deployment-targets

Figure 8.2: Field workforce sizes and FTTP deployments carried out by various operators [Source: Analysys Mason, 2020]

Operator (country)	Year	Field-force	Additional premises passed	*Estimated premises passed per field force engineer / (FTTP engineer)*
Openreach (UK)	2018	22 200	400 000	18 / *(95)*
	2019	28 200	1 263 000	45 / *(124)*
	2020	30 900	1 600 000	52 / *(124)*
Telia (Sweden)	2018	c. 2000	200 000	c. 100
Orange (France)	2018	c. 23 000	2 600 000	c. 113
Chorus (NZ)	2015	c. 800	142 000	c. 178

Evidently, the ratios above depend on the proportion of the field-force allocated to FTTP. In the cases of Chorus and Orange, we would assume a higher proportion allocated to fibre. Therefore, the speed at which regulation allows for the decommissioning of copper networks will make a great difference to a network builder's ability to reallocate existing workforce in labour-constrained markets.

The ratio is strongly correlated with the size and level of expertise of the workforce and how well industrialised the processes of network build actually are. Other factors can hinder widespread and efficient roll-outs, including poor infrastructure sharing, wayleave and state-aid policy. As discussed above, it is necessary to tackle all of these areas in order to produce positive results in full-fibre deployments.

Many operators are likely to use contracted engineers who would not be reported in their employment figures, and whose presence distorts these ratios. Openreach has accelerated hiring and training of in-house engineers, and has indicated publicly that it has concerns over the supply chain for labour because of the UK's departure from the EU. At the very least, a country outside the EU single market and facing a skills shortage should prioritise suitably skilled would-be migrants.

New technologies can improve the efficiency of ODN deployment

However, roll-out need not lean so heavily on technician-level staffing, and the workforce productivity of network deployment and of connecting individual customers can be transformed by digital tools to accelerate change. These are choices that network operators need to make themselves. However, decision makers in publicly-funded network deployments should be aware that these three factors can make a big difference to the speed and cost of roll-out, and could swing the argument in favour of intervention in marginal regions.

Network builders can industrialise their processes in the following ways.

- Digital design tools to improve output of network design engineers. Automated tools can establish the optimal coverage area, the best route for a customer connection and efficiently integrate deployment to help achieve business goals. These tools can massively increase (up to 10 times) the output in terms of premises passed for a skilled network design engineer.

- Digitalisation of inventory and workflow management to improve management efficiency by replacing manual, often paper-based, processes. This can greatly reduce time, for example, in service provisioning for customers ordering a new connection at the same time as service. One issue that many FTTP players have faced is that new connections often require more than one engineer visit, and that getting it right first time has not always been possible, and in some instances 'right first time' has been as low as 55%. Digital tools can bring this figure close to 100%, simultaneously reducing costs and improving customer satisfaction, and the same tools can be used to improve the accuracy and efficiency of trouble-shooting any faults in the ODN.

- Pre-connectorisation of fibre helps to de-skill and therefore accelerate ODN deployment by eliminating the in situ task of splicing fibre, which requires greater skills and which is more labour-intensive. This has been shown in some Latin American FTTP roll-outs to reduce TCO by 25% and time to market by 30%.[71]

Accelerating the rate at which copper and coax can be released

Copper decommissioning enables significant release of property, and ultimately of scrap copper. Telefónica Spain reckons that 65% of exchange property will become redundant. KCOM (a local incumbent in the UK) reckons that the value of scrap copper is between 5% and 10% of the total capex of FTTP. Being allowed to liquidise these assets swiftly could save on opex and could also offset a significant proportion of the cost of FTTP roll-out.

Many European incumbent telcos have signalled their intention to decommission copper (for example, Telenor and Telefónica Spain), but the timescales are very drawn out and reactive rather than proactive, and the recovery of copper is not always part of the plan. A few small jurisdictions in Europe have already done so. Jersey Telecom (JT) has a full-fibre network with 100% island coverage and decommissioned all copper in late 2019. This made Jersey one of the few places in the world to have gone entirely copper-free.

Coax decommissioning is further off. At the time of writing, we believe that Singapore is the only country where all coax networks have been decommissioned. However, there are signs elsewhere that it is on operators' radars.

- Altice USA has started to replace coax with full-fibre GPON and NG-PON2.
- Optus in Australia appears set to decommission its coax network.

Many cablecos (for example Virgin Media UK) have for many years built FTTP as opposed to coax in greenfield builds. Cablecos have the interim option of running their existing RF video and DOCSIS systems on full-fibre networks, although it should be noted that the ITU PON standards have separate downstream wavelengths for linear TV.

Outside the EU, the process of copper decommissioning tends to be simpler and quicker, although there is no more likelihood that copper will actually be recovered. Singapore has had no functioning copper network for over a year. Inside the EU, the process tends to get bogged down in the detail of pro-competition regulation. Telefónica describes the process of shuttering a local exchange as taking up to 6 years. This is because in Europe copper-based operators have obligations both to retail customers and to wholesale customers, which may be co-located in the exchange and utilising copper or FTTC/VDSL loops. The notification period for closure of a retail-only exchange is 1 year in Spain, but technically a wholesale customer could stay on copper in the exchange for up to 5 years. By way of contrast, for Verizon, which has few wholesale obligations, the notification period for retail customers has been reduced by the FCC from 180 to just 90 days.

[71] See https://www.huawei.com/en/about-huawei/publications/communicate/88/latin-american-operators-accelerate-full-fibre-deployment

The European timelines seem excessive, but there are further measures that an operator with a copper network could proactively take to expedite the process, and there are measures that policy-makers could adopt to help it along. VAT exemption on customer connections is one such approach. Another policy that could accelerate the process, and one that has been tried and tested in other verticals, is scrappage schemes. For end users, such a scheme would provide some financial incentive to migrate to full-fibre fibre. An example of this sort of approach from a different vertical is Travel for London's scrappage scheme, which provides trade-in grants for suitable vans and private vehicles belonging to low-income households that are used in London's ultra-low emission zone.

End-user incentives for copper-to-fibre migration could potentially work the same way. Schemes of this kind inevitably distort competition to some extent, and can require a lenient interpretation of state-aid rules. There are *de minimis* exemptions (i.e. the subsidy is small and direct to end-users) that can be considered an acceptable trade-off.

For operators, a scrappage scheme offering a guaranteed price for copper would be another approach. Spot prices for scrap copper are volatile, but when high represent a meaningful figure well above what the actual cost of recovery is. The environmental benefits in each end-user case may not be huge, and now is not a particularly useful time for economic stimulus, but together an approach that favoured more rapid migration would be an example of joined-up thinking.

8.2 Public investment

Public subsidy of the capital cost of deployment in non-commercial areas is well established, but the levels vary enormously, and they need to be seen in the context of other public economic infrastructure expenditure. Furthermore, other mechanisms can be used, such as tax-breaks and opex subsidy. The need for subsidy can often get overstated and politicised, and the creation of heavily-regulated part-publicly-funded entities can in fact stimulate private investment.

Capex loan and subsidy

Figure 8.3 shows announced historical and planned public investments in VHCN roll-outs in a selection of countries. The amount of investment required per premises passed in each country depends on a number of factors, including the level of economic development, the population density and remoteness of end-user premises, and the availability of existing network infrastructure. Additionally, public funding in a number of national strategies is prioritised or reserved for funding deployment in remote locations, where commercially funded rollouts would not be viable or would require subsidies. For example, the planned policies in France and the UK explicitly state the proportion of premises that are considered remote and for which funding is allocated. In other countries (such as Sweden and New Zealand), the policies do not mention the proportion of premises for which funding is allocated; because most of the public funds will probably go towards covering remote areas, the actual public spend per premises passed is likely to be greater than that listed in Figure 8.3.

Figure 8.3: Public investment in VHCN roll-outs in selected countries [Source: various]

Country	Public FTTP spend (EUR million)[72]	Time period	Spend per additional premises passed in time period (EUR)
Sweden	685[73]	2007–2020	1154
Singapore	374[74]	2009–2014	225
Australia	30 090[75]	2009–2020	2500
New Zealand	1050[76]	2011–2022	555[77]
Germany	4000[78]	2012–2019	1818
UK (BDUK schemes)	2040	2013–2020	370
France	3300[79]	2013–2022	216[80]
Poland	1000[81]	2014–2020	146
Italy	5000[82]	2015–2020	663
Spain	525[83]	2018–2021	102
Ireland	2100[84]	2020–2026	3890
UK (gigabit)	5640[85]	2020–2025	880[86]

The higher figures here will be offset by clawback mechanisms (where excess profits or deployment underspend are recouped), and further by possible sale of the state entity at some future time.

These figures vary greatly in the scale and scope. It is instructive, however, to compare the much higher proportionate state investment in other types of infrastructure. The Irish National Broadband Plan above has, on the face of it, the highest capex per premises passed. Figure 8.4 compares public spend per capita on broadband in Ireland with public spend on roads, rail, water and power distribution in Ireland, and with public spend on transport and broadband in the UK. In each case the spend has been normalised for the duration of the plans.

[72] Forex at time of publication of source if no conversion from local currency given in the source.

[73] https://www.oecd-ilibrary.org/docserver/9789264302259-4-en.pdf?expires=1579878500&id=id&accname=guest&checksum=15B79F616D631D4035A42D76E32F945E p. 66

[74] https://www.networkworld.com/article/2257284/singapore-embarks-on-fibre-optic-cable-installation.html

[75] https://www.abc.net.au/news/2018-08-31/nbn-cost-revised-up-to-51-billion-dollars/10187108. Note this is total cost: NBN is state-owned

[76] https://www.mbie.govt.nz/science-and-technology/it-communications-and-broadband/fast-broadband/broadband-and-mobile-programmes/

[77] The policy aims to cover 87% of the population by 2022.

[78] https://ec.europa.eu/digital-single-market/en/country-information-germany

[79] https://www.amenagement-numerique.gouv.fr%2Ffr%2Fgarantir-du-tres-haut-debit-tous-2022

[80] The policy subsidises rollout to the most remote 45% of premises.

[81] https://ec.europa.eu/digital-single-market/en/country-information-poland

[82] https://ec.europa.eu/digital-single-market/en/country-information-italy

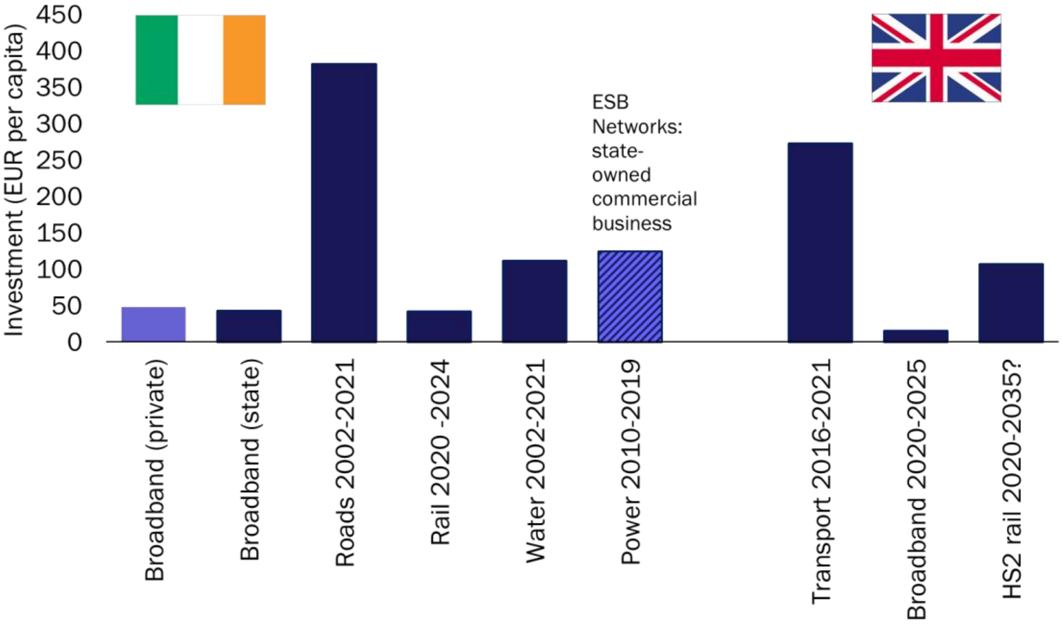
[83] https://opticalconnectionsnews.com/2018/03/spain-green-lights-e525-million-fibre-expansion/

[84] https://www.gov.ie/en/press-release/e15062-high-speed-broadband-for-11m-people-in-homes-schools-businesses-acro/

[85] https://www.gov.uk/guidance/building-digital-uk

[86] The policy aims to cover the most remote 20% of premises by 2025.

Figure 8.4: Normalised public spend per capita on selected economic infrastructure, Ireland and UK [Source: Analysys Mason, 2020]



Perverse consequences of creating regulated subsidised rural networks

Public subsidy can stimulate the very thing that it posits as impossible: commercial roll-out. One effect of establishing delineated areas that require subsidy, and of creating a heavily regulated entity to builds and operate it, is that commercial operators often find ways of funding coverage of parts of those areas on a purely commercial basis. Examples of this are as follows.

- The AMEL zones in France, where operators found ways to deliver unsubsidised FTTP in RIP areas.
- eir's encroachment into 300 000 premises in the originally designated NBP area (34% of the original total).
- In January 2020, BT CEO Philip Jansen suggested that operators might commercially collaborate (no overbuild in return for mutual access) on a single FTTP network in the final 20–30% of premises in the UK, in effect without any interference from government.

Strict regulation and high wholesale tariffs etc tend to serve as a means to establish exactly where publicly funded remedies are genuinely needed. Indeed, the extent of the need for public funds to subsidise non-commercial areas has always been a matter of highly politicised debate. BDUK, the UK government vehicle that allocated gap funding for FTTC roll-out in the first half of the 2010s, recognised this by creating a clawback mechanism to gap funding. This required subsidy to be paid back when and where it turned out that FTTC was commercially profitable without funding. This clawback was then allocated to ever more commercially difficult areas.

There are two main reasons why this tends to happen.

- Uncertainty over demand leading to over-conservative estimates, especially in rural areas with few if any viable alternatives.
- Uncertainty over capital costs leading to inflated estimates. This has been exacerbated by established operators, where they face little motivation to roll out (i.e. no competition).

If wholesale rates for a subsidised project are averaged over a whole area, it is possible in principle to conjecture that the less difficult parts of that area could be built and self-supplied at a lower cost.

9. Conclusions and recommendations

In this final chapter, we pull together the key conclusions of previous chapters and make specific recommendations for policy makers in government and regulatory authorities.

The latest European coverage targets for FTTP (strictly speaking VHCN) for 2025 are unlikely to be met given expectations based on current operator plans. Although some countries have deployed FTTP rapidly, most are likely to miss EC FTTP coverage targets and lag behind benchmark peers – although European operators and governments have more ambition than those in the USA. The regulatory environment in Europe (EECC 2018) is shifting a little in favour of investment in network infrastructure notably EECC 2018, although results will only show through its specific implementation in individual countries. It is possible that the UK could push a more pro-investment line after it leaves the EU, but that will not happen immediately.

Demand is strong and does not need to be defined solely in terms of bandwidth

Broadband is essentially a utility. Consumers and businesses demand reliable, ubiquitous high-performance bandwidth at an affordable price. Reliable high speed reduces broadband users' intention to churn more than anything else. Ubiquity means more than bandwidth to the door: it should rightly mean anywhere in the 'great indoors' where over 95% of data is consumed. Policy should not focus overly on current high-bandwidth use cases. These may tell us something about the direction of travel for applications, but if we are to understand full-fibre as infrastructure to serve for decades they may not be entirely convincing on their own.

These demands are best met by full-fibre access networks. There are few caveats with full-fibre networks. No other fixed or wireless networking technologies come even close to matching the performance, reliability and predictability of the technologies that use fibre. Copper technologies will barely reach 1Gbit/s in any practical way, DOCSIS 4.0 has to be the end of the runway for cable, and mmWave 5G FWA has shortcomings.

In fact, in regions and countries where full-fibre FTTP networks have been available the longest, FTTP is clearly the preferred consumer and business choice and take-up is very high. In other areas where it has been available for less time, FTTP take-up is picking up swiftly.

Demand is one side of the equation. It is equally vital to recognise the long-term (many decades) advantages in terms of operating efficiency, service possibilities and environmental protection. A converged network architecture of fibre optics, Wi-Fi and 5G represents the highest performance, most efficient and greenest technology combination.

A more dirigiste approach is required

There is a significant one-off cost to achieving all of this. Over and above what operators have committed to do so far, the cost of reaching 99% of premises in Europe from today's infrastructure coverage would be somewhere between EUR80 billion and EUR120 billion (this figure does not include any additional cost to provide 5G coverage). This does not mean that additional money cannot or will not be raised privately, but it does indicate that additional policy measures to encourage further investment, and additional public funding, will be required to accelerate its deployment.

Governments have to be more dirigiste. Historically, western governments have played a significant and often ignored role in many technologies, especially at an early stage, and this role has helped to create new markets that otherwise would not exist (for example, ride-hailing services such as Uber would not be possible without government-funded GPS). The Chinese government has played an instrumental role in supporting the development of technology and new markets for IoT, and hence the IoT units of Chinese operators are thriving. Americans seem to be ‘unlearning’ the positive role of the state, and European governments should avoid this trap.

Enabling the conditions for flourishing competition-driven innovation and service improvement is where public money is best spent, and it is to this end that policy should be directed.

Policy recommendations

In general, policy should treat fibre as infrastructure and should encourage a diversity of vendors, a diversity of operating companies and diversity of services that use it. It should encourage options for access at as low a layer as is feasible: this means a preference for physical infrastructure access or dark fibre access. Public money, where required, should preferably be spent enabling low layer access.

In countries, or in regions of countries, with little relevant physical infrastructure, public money may be better spent creating ducts for competing fibre infrastructures. In other words, public money should be invested in enabling the kind of model that has already delivered results in France, Spain and Portugal. Absence of duct access now looks like the largest single obstacle to FTTP roll-out in the most ‘difficult’ European countries. Access to ducts would be strictly regulated, but would ideally not become itself a highly transactional or hyper-commercialised business.

As an alternative to duct build, policy should encourage or mandate the building of networks with end-to-end multi-fibre. This should be built into the design of the physical ODN. This is a critical feature of the successful network in Singapore and of the new Open Fiber network in Italy. Layer 1 unbundling worked on copper networks to the benefit of end users (lower prices, less of the artificial price differentiation based on speed typical of Layer 2 bitstream), and there is every reason to believe it also will on FTTP.

Unbundling of PTP FTTP is technically straight-forward and most operators that have built this type of FTTP already offer fibre unbundling. Unbundling existing PONs is not impossible, but is made harder if the introduction is an afterthought to the roll-out. One possible alternative is wavelength unbundling, but this relies on active equipment that is still too expensive for the mass market. Copper unbundling, and its successors, while providing great benefits to end-users, had the negative consequence of discouraging real autonomous network build (essentially alternative operator FTTP). FTTP unbundling likewise will not encourage autonomous competing fibre network build in the way that duct access does. Arguably, however, that no longer matters as much: there is no obvious successor medium to fibre. Moreover, what unbundling can do, and bitstream cannot, is to encourage a greater diversity of technologies (GPON, XGS-PON, 10G-EPONs, NG-PON2, future 25G-, 50G- and 100G PONs, PTP) to sit on the fibre network, and thereby to increase the possible use cases that utilise the infrastructure.

Where private investment is flourishing, governments should avoid crowding out private investment. However, a completely *laissez-faire* approach is unlikely to prove optimal in the long run, and risks a re-run of the market failures of CATV roll-out at the end of the last century. In some markets, retro-fitting a more managed approach to fibre, along the lines of the French model with its regional franchises and its de-risking balance of obligations and rewards, may avert inefficient investment and patchy or disappointing outcomes for end users and failures for investors. Oversight of already commercially negotiated shared networks or mutualised access in non-urban areas could be part of this approach, if this ultimately allows public money to be focused on the most economically challenging areas to be covered.

Inevitably there will be regions and geographies that need help, although the extent of this requirement may have been overstated. Whatever the true extent, the level of public investment either as aid or as loans needs always to be seen in the context of other infrastructure projects. FTTP is the ideal technical solution, but there will always be competition between government departments for budget. Providing high-cost per premises passed FTTP for the final 10% (or less) will always be a tough call, and voices that advocate cheaper and less efficient options, or more wireless alternatives, will get heard. Hence it is important to compare the opportunity costs and relative costs of other major state-funded infrastructure projects such as high-speed rail and nation-building highways.

Practical enablement

Where this has not already been done, governments should impose stricter and more forward-looking building regulation. FTTP-readiness even before the ODN is built is an obvious place to start. It would be even more future-looking to impose or encourage the installation of mini-OLTs/passive optical LANs across rooms in new buildings, which would be relatively low cost in the context of total construction costs. The involvement of ETSI and other organisations at a regional level would be helpful, for example with respect to the development of national regulations for new buildings.

Governments should take measures to combat the shortage in skilled workforce required for the mass deployment of fibre. Some operators insist that capacity shortages (which includes machinery as well as labour) are driving them to short-term work-arounds. Since roll-out has been uneven in Europe, there will be some pools of skilled labour from countries where most of the roll-out has been done. However, the other logical response to construction capacity shortfall is to encourage as far as possible any means that industrialises the process of roll-out, thereby simultaneously digitalising desk-based planning and file-based paperwork, and deskilling and accelerating the rate of roll-out.

Governments should consider tax incentives on fibre network build and on fibre customer connections. A copper scrappage scheme with a guaranteed price for scrap should also be considered.

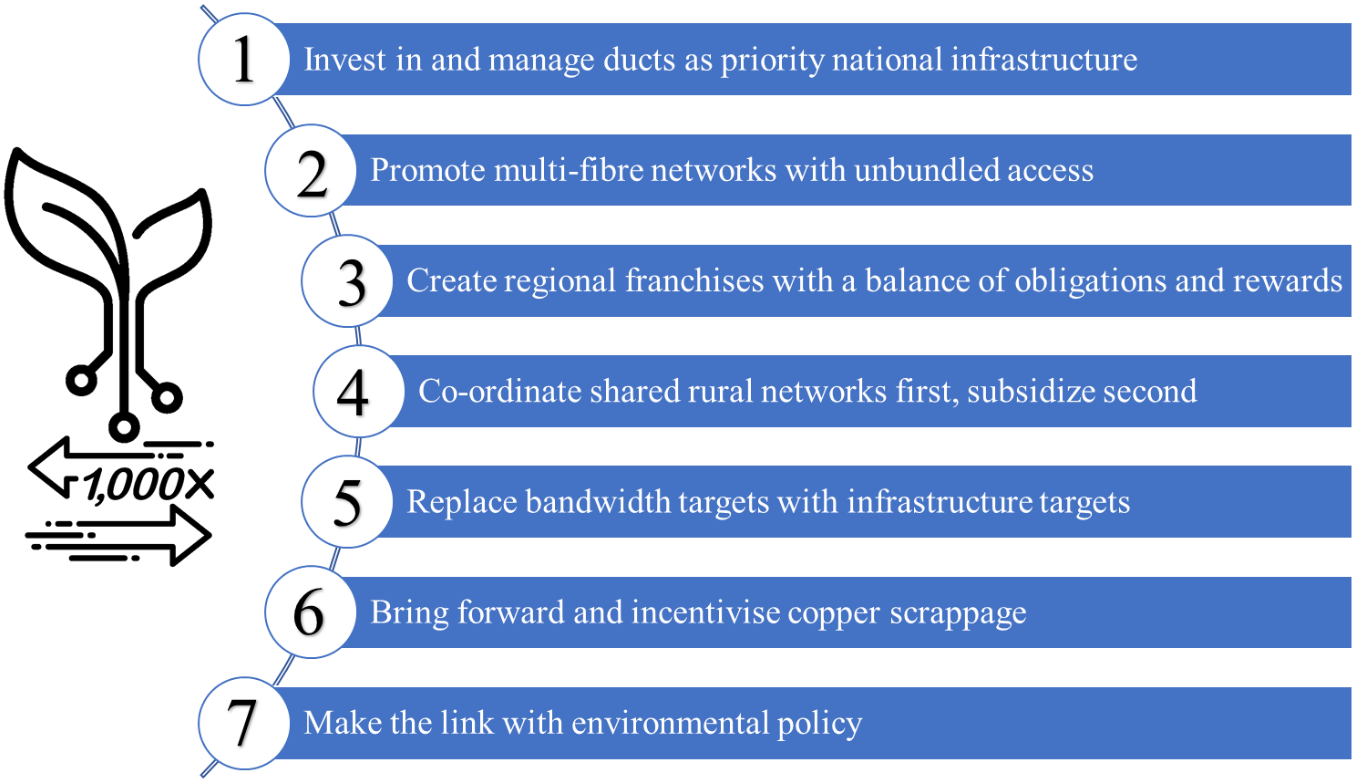
The bigger picture: European digital aspirations and environmental considerations

The case for full-fibre networks requires long-term and broader thinking in order to achieve a vision of a simple, open and level playing field for diversity and innovation. If Europe truly aspires to be a digital player, as opposed to simply being a digital consumer, then digital infrastructure policy needs to set its sights far further out than 2025 targets for coverage at 1Gbit/s.

One simple change would be to have no more endlessly changing bandwidth targets. Bandwidth demand will move on over time, but fibre itself is a one-off. Bandwidth targets have the perverse effect of encouraging vendors and operators to deliver short-term solutions that will become increasingly unsustainable. In fact, policy has tended towards what is erroneously called ‘technology agnosticism’ but is in fact little more than infrastructure agnosticism. This is often driven by short-term cost considerations and by the vested interests of players wishing to squeeze more out of legacy or suboptimal infrastructure. True technology agnosticism should encourage as far as possible the full panoply of future-looking technologies (NG-PONs, 5G/6G, Wi-Fi 6/7 and their successors), and of course of services in the digital ecosystem. This is likely to be better achieved by ***less*** agnosticism about the type of infrastructure deployed. A relentless focus on getting the right kind of infrastructure deployed rather than on bandwidth targets is the right approach.

There should be joined-up thinking between telecoms/ICT and environmental policy. The EU’s new Green Deal sets, by global standards, ambitious carbon-neutrality goals. During 2019, telecoms operators in Europe gave clear signals that telecoms operators in Europe are getting more serious about greenhouse gas targets and the circular economy. There are few examples of green clauses in telecoms policy and planning, or in national broadband plans. Creating and managing duct infrastructure could remove barriers to the deployment of other environment-friendly non-ICT infrastructure in the future. Pro-competition policy should not short-sightedly delay the decommissioning of older and inefficient telecoms networks. FTTP networks can make a major contribution to operator efficiency, and a combination of obligations and rewards for those that deploy FTTP should be countenanced. Tax incentives (or the removal of disincentives) could encourage the right kind of network build.

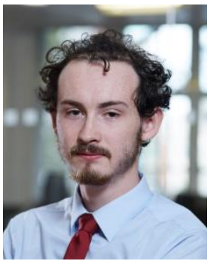
Figure 9.1: Seven key recommendations for policy [Source: Analysys Mason, 2020]



10. About the authors

Dr Rupert Wood (Research Director) Rupert is the lead analyst for our ***Operator Investment Strategies***, ***Network Traffic*** and ***Spectrum*** research programmes. His research covers the following areas: the evolution of operators' investment priorities; operator business structures; business models for FTTx and convergence; fixed broadband technology; the economic impact of digital transformation; capex forecasting; and network traffic forecasting. He has extensive experience of advising senior management on strategic issues. Rupert has a PhD from the University of Cambridge, where he was a Lecturer before joining Analysys Mason

Stephen Wilson (Principal Analyst) Stephen is the lead analyst for Analysys Mason's ***Fixed Broadband Services*** and ***Asia–Pacific*** research programmes. He leads Analysys Mason's annual FTTx coverage, capex and conversion forecasts, and other recent areas of focus include copper decommissioning and multi-gigabit speeds. Stephen has more than 10 years of experience in the telecoms sector and is a graduate in Philosophy, Politics and Economics from St Catherine's College, Oxford University



Casey Cragg (Research Analyst) is a member of the ***Regional Markets*** research team in London, contributing primarily to the ***Telecoms Market Matrix*** and ***European Country Reports*** programmes. Casey holds an MSci in Astrophysics from University College London. His dissertation was an investigation of the evolution of the statistical distribution of galaxies in the universe

Francesco Paolo Bellomo (Research Analyst) is a member of the Data Team in London, contributing primarily to the ***Telecoms Market Matrix*** and ***European Country Reports*** programmes. Francesco holds a BSc in Economics and Finance from Queen Mary, University of London, and a MSc in Finance from Warwick Business School.

Ian Watt (Manager) is a member of the Custom Research team in London. He has extensive experience in analysing broadband access markets and has worked in this area with a wide range of investors, incumbents, new entrants, regulators and government departments. Ian holds a BSc in Economics from The London School of Economics and an MBA from INSEAD.

11. Analysys Mason's consulting and research are uniquely positioned

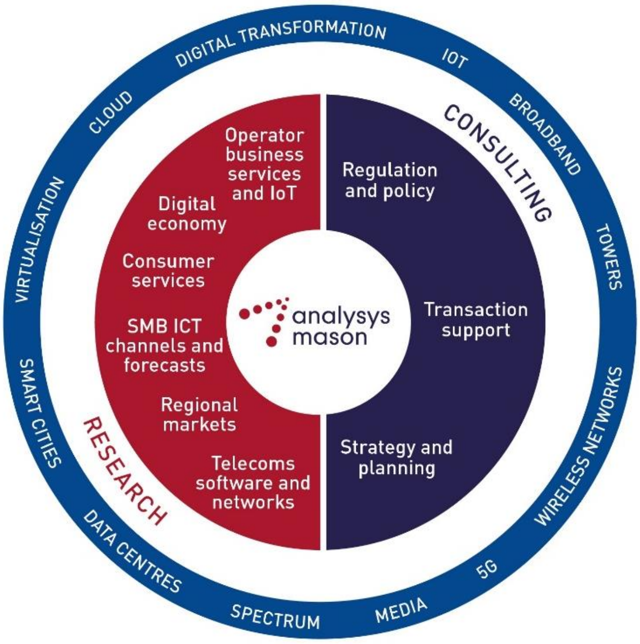
Analysys Mason is a trusted adviser on telecoms, technology and media. We work with our clients, including communications service providers (CSPs), regulators and end users to:

- design winning strategies that deliver measurable results
- make informed decisions based on market intelligence and analytical rigour
- develop innovative propositions to gain competitive advantage.

We have over 260 staff in 17 offices and are respected worldwide for the exceptional quality of our work, as well as our independence and flexibility in responding to client needs. For over 30 years, we have been helping clients in more than 110 countries to maximise their opportunities.

Consulting

- We deliver tangible benefits to clients across the telecoms industry:
  - communications and digital service providers, vendors, financial and strategic investors, private equity and infrastructure funds, governments, regulators, broadcasters, and service and content providers.
- Our sector specialists understand the distinct local challenges facing clients, in addition to the wider effects of global forces.
- We are future-focused and help clients understand the challenges and opportunities that new technology brings.



Research

Our dedicated team of analysts track and forecast the different services accessed by consumers and enterprises.

We offer detailed insight into the software, infrastructure and technology delivering those services.

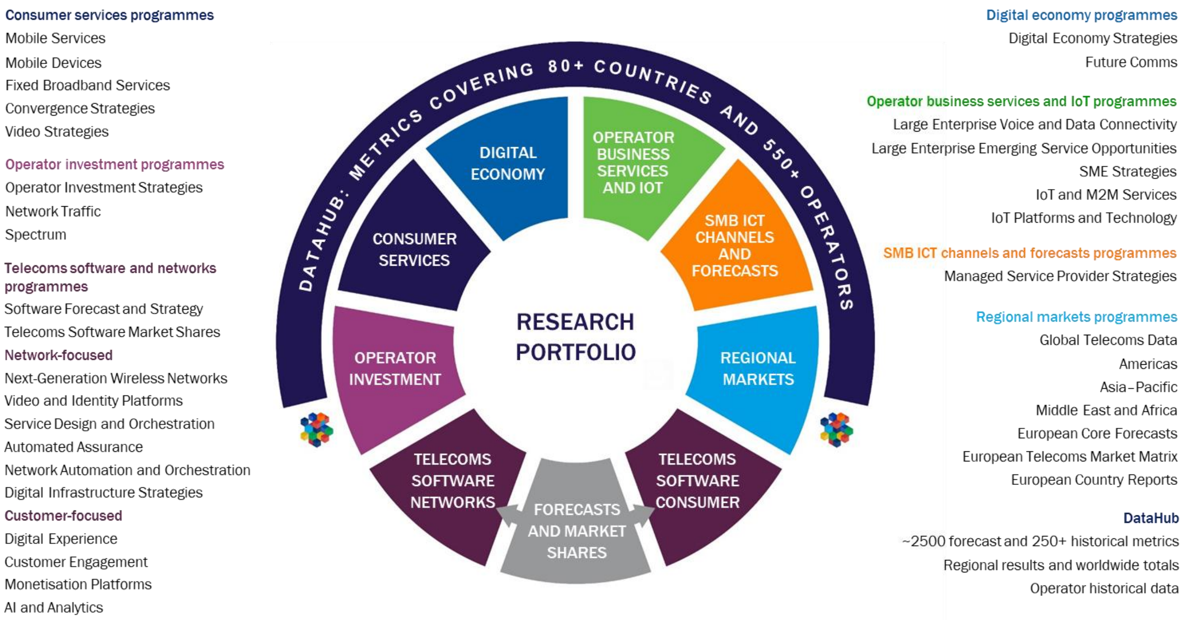
Clients benefit from regular and timely intelligence, and direct access to analysts.

12. Research from Analysys Mason

We provide dedicated coverage of developments in the telecoms, media and technology (TMT) sectors, through a range of research programmes that focus on different services and regions of the world.

The division consists of a specialised team of analysts, who provide dedicated coverage of TMT issues and trends. Our experts understand not only the complexities of the TMT sectors, but the unique challenges of companies, regulators and other stakeholders operating in such a dynamic industry.

Our subscription research programmes cover the following key areas.



Each subscription programme provides a combination of quantitative deliverables, including access to more than 3 million consumer and industry data points, as well as research articles and reports on emerging trends drawn from our library of research and consulting work.

Our custom research service offers in-depth, tailored analysis that addresses specific issues to meet your exact requirements.

Alongside our standardised suite of research programmes, Analysys Mason's Custom Research team undertakes specialised, bespoke research projects for clients. The dedicated team offers tailored investigations and answers complex questions on markets, competitors and services with customised industry intelligence and insights.

For more information about our research services, please visit www.analysysmason.com/research.

13. Consulting from Analysys Mason

For more than 30 years, our consultants have been bringing the benefits of applied intelligence to enable clients around the world to make the most of their opportunities.

Our clients in the telecoms, media and technology (TMT) sectors operate in dynamic markets where change is constant. We help shape their understanding of the future so they can thrive in these demanding conditions. To do that, we have developed rigorous methodologies that deliver real results for clients around the world.

Our focus is exclusively on TMT. We advise clients on regulatory matters, help shape spectrum policy and develop spectrum strategy, support multi-billion dollar investments, advise on operational performance and develop new business strategies. Such projects result in a depth of knowledge and a range of expertise that sets us apart.

REGULATION AND POLICY

- Policy development and response
- Ex-ante market reviews, remedies, costing …
- Universal Service Obligation (USO)
- Scarce resources: radio spectrum management, auction support, numbering …
- Ex-post/abuse of dominance
- Postal sector

analysysmason.com/consulting

TRANSACTION SUPPORT

- Commercial due diligence
- Technical due diligence
- Mergers and acquisitions (M&As)
- Debt and initial public offerings (IPOs)
- Joint-venture structuring
- Mid-market financial sponsors

STRATEGY AND PLANNING

- Commercial expertise
- Technology optimisation
- New digital frontiers

We look beyond the obvious to understand a situation from a client's perspective. Most importantly, we never forget that the point of consultancy is to provide appropriate and practical solutions. We help clients solve their most pressing problems, enabling them to go farther, faster and achieve their commercial objectives.

For more information about our consulting services, please visit www.analysysmason.com/consulting.