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Foreword

This report on "Broadband Policy and Technology Developments" was prepared by the Working Party on Communication Infrastructure and Services Policy (WPCISP) and informed the review of the 2004 *Recommendation of the Council on Broadband Development.* It examines developments in the broadband market and broadband technologies. It also gives an overview of policy considerations with respect to broadband development.

After the adoption by Council of the *OECD Recommendation on Broadband Connectivity* in February 2021 [OECD/LEGAL/0322], this report was approved and declassified under the written procedure by the Committee on Digital Economy Policy (CDEP) on 31 August 2021 and was prepared for publication by the OECD Secretariat.

This report was drafted by the independent consultant J. Scott Marcus, and Lorrayne Porciuncula, Maximilian Reisch, and Verena Weber from the OECD Secretariat. The report also benefited from contributions by Frédéric Bourassa and Alexia González Fanfalone from the OECD Secretariat. It was prepared under the supervision of Verena Weber. This publication is a contribution to IOR 1.3.1.2. "Strengthening the foundations for digital transformation" of the 2019-2020 Programme of Work of the CDEP.

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Executive Summary

The promotion of widespread, affordable, and high-quality broadband is a prerequisite for the digital transformation of economies and societies. Foreseeing the role of broadband as an accelerator of economic, social and cultural development, the OECD Council in 2004 adopted the *Recommendation of the Council on Broadband Development* (hereafter "the Recommendation").

Since 2004, important developments have taken place in broadband technologies and markets. There has been a substantial evolution in both the fixed and wireless technologies that have been used, or are likely to be used in the future, to provide access to the Internet (i.e. xDSL, fibre-to-the-premises (FTTP)/fibre-to-the-home (FTTH), cable [DOCSIS standards], mobile broadband, fixed wireless access [FWA], satellite and more). Moreover, these developments have been accompanied by changes in expectations around coverage, effective adoption (and barriers to adoption), degree of usage (e.g. measured by data usage), quality of service and affordability of broadband.

As part of the review of the Recommendation, undertaken in 2018-20 and resulting in the adoption of a revised 2021 *OECD Council Recommendation on Broadband Connectivity*, this report takes stock of the changes since 2004 and identifies five large groups of policy principles and objectives that have gained in importance across the OECD:

- Relying on market mechanisms for broadband deployment to the extent possible, but going beyond them where necessary. Technological developments and policy instruments that rely primarily on market mechanisms for broadband deployment have ushered in distinct forms of innovation in market, ownership and management models, as well as varying manners of implementing the technology neutrality principle. Where market mechanisms are not sufficient to address coverage gaps or quality of service (QoS) deficits, policy makers have recognised the need to explore additional approaches to close these gaps, including public funding or subsidies, public ownership, and cost reduction mechanisms.
- Developing mobile broadband networks. The emergence of mobile broadband services has brought a myriad of possibilities and added a new dimension to broadband policymaking. Specific aspects to consider in promoting mobile broadband include fixed-mobile substitution/complementarity, coverage requirements in spectrum auctions, and the deployment of 5G networks.
- Promoting policies for the inclusive access to broadband. Policy makers have been seeking to balance multiple public policy goals related to affordable and high-speed broadband deployment, such as by using policy and regulatory measures to expand broadband, public funding, universal service provisions and ensuring QoS standards.
- Encouraging the use of broadband-based services and applications. While broadband policy arguably tends to place much focus on the supply side, policymakers have increasingly recognised the importance of demand-side policies, such as aggregating and stimulating demand, enhancing digital skills, ensuring trust (e.g. digital security, privacy and data and consumer protection), and addressing content-related issues.

- Establishing a policy and institutional framework for broadband. For effective broadband policy implementation, the institutional framework plays a key role. Issues such as the independence of national regulators, statistics and monitoring of broadband markets, and sharing of good practices, are crucial for promoting broadband development, and hence, the digital transformation.

The report finds the principles identified in the 2004 Broadband Recommendation continue to be relevant but that re-visiting the Recommendation is prudent considering that the broadband landscape has changed considerably over the last 15 years. A broad array of policy measures has emerged to promote the deployment of broadband, to foster use, and to protect consumers. Market mechanisms are still seen as the preferred approach overall; however, there has been increasing recognition that public policy interventions may be needed to complement private sector investment to ensure full and timely broadband coverage, and to avoid exclusion of disadvantaged groups. Sound policies are essential in order to deliver the benefits to consumers and society as a whole, and to preserve the virtuous cycle that ultimately drives more deployment, adoption and greater use of broadband-based services and applications.

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Introduction

Rationale for promoting broadband deployment, adoption and usage

Broadband access is of vital importance to OECD countries because it serves as a requirement to nothing less than the digital transformation of the economy and society. The role of communication networks as an accelerator of development has been recognised globally, and due to its critical importance for development and social inclusion, the task of making access to the Internet universal and affordable was approved by the United Nations as a target (Target 9.c) of the Sustainable Development Goals (SDGs) (United Nations General Assembly, 2015[1]).

Accordingly, the OECD Going Digital Integrated Policy Framework includes the objective of enhancing access to connectivity as one of the fundamental policy dimensions for a coherent and cohesive whole-of-government approach to foster the digital transformation (OECD, 2019[2]). This transformation would be unthinkable without efficient, widespread and reliable broadband connectivity.

The promotion of widespread, high-quality broadband contributes to a more prosperous and more equitable society through several main channels. These channels are synergistic in the ways in which they generate economic gains and broader societal benefits.

- *Network effects:* having more Internet users tends to increase the value of Internet services for all users.
- *Accessibility and universal service:* An Internet available to all, and at an affordable price, avoids excluding portions of the population from online services that are increasingly essential to everyday life. It thus mitigates the risk of increasing the *digital divide*.
- *Innovation:* Widespread, high-speed Internet connectivity enables the creation and use of a wide range of Internet-based services. This lifts the overall economy and boosts competitiveness.

Some services are worth more as a function of the number of individuals who are able to use them. The value of the telephone service has increased as the number of individuals reachable by telephone increased. In like manner, e-mail over the Internet has value because nearly everyone is reachable, and social media platforms have value because so many people are present on them. In each of these cases, each user who joins the system increases the value for all users. These *network effect* gains go beyond those that can be explained solely by economies of scale (Rohlfs, 2003[3]). In fact, it has been claimed that these gains are roughly proportionate to the square of the number of users (*Metcalfe's Law*). Network effects would suggest that, at least in theory, ensuring for as many users as possible to the Internet is to the benefit of all users, and of society as a whole.

Additional societal benefits flow from ensuring that Internet access is available to all, not just to those who are sufficiently well off to be able to afford it. This is essential in order to preserve "fair equality of opportunity" to all (Rawls, 1985[4]). This need has been often covered in the discussion of universal access in order to avoid increasing inequality and a class of Internet "have nots" (i.e. mitigating the risk of the emergence of a digital divide). As services accessed over the Internet become increasingly central to more and more human activities, this aspect takes on increasing importance.

The Internet serves as an enabler to many different forms of innovation. Economic gains tend to flow both from production of Information and Communications Technology (ICT) services and from their use (Jorgenson, Ho and Samuels, 2014[5]). Internet access is fundamental to nearly all ICT services today. Ensuring high quality Internet connectivity can thus be expected to contribute to the productivity of society as a whole.

The economic and societal welfare benefits that flow from widespread availability of broadband are well substantiated in the literature. In a concise literature survey, Cambini (2018[6]) identifies numerous results, such as:

- An increase of 10% in the broadband penetration rate has been estimated to lead on average to an increase of 2.8% of GDP growth (21 OECD countries) (Röller and Waverman, 2001[7]).
- The average impact of broadband infrastructure on GDP was estimated to be 0.63% (for 15 countries in the European Union, in the period 2002–2007) (Koutroumpis, 2009[8]).
- A 10% increase in the broadband penetration rate has been estimated to result in a 1-1.5% increase in annual GDP per-capita. In other words, more widespread adoption of broadband implies higher GDP growth (Czernich et al., 2011[9]).

There are challenges that accompany these gains. These include risks to security, privacy, exposure of minors to inappropriate content, and more. Nevertheless, the vast majority of research concludes that Internet adoption generates, on balance, positive net benefits for society.

Structure of the document

Once the rationale for promoting broadband has been introduced, issues around investment in broadband deployment, with a particular focus on the challenges of balancing public policy objectives with market-driven developments, are discussed. The section on policy considerations reviews a wide range of policy approaches that have been implemented or attempted in order to achieve the deployment and adoption of high-speed broadband in OECD member countries. Annex A summarises the technological evolution of broadband since the Recommendation was adopted in 2004, and Annex B summarises the evolution of broadband in terms of coverage, adoption and usage.

Investment in broadband deployment

Policymakers in OECD countries typically seek to use market mechanisms where feasible in order to achieve economic and societal goals such as broadband deployment and adoption. This view is reflected in the Broadband Recommendation, which calls on OECD member countries to implement "[e]ffective competition and continued liberalisation in infrastructure, network services and applications".

The cost of deploying ubiquitous high-speed fixed broadband can sometimes be greater than the price that consumers are willing or able to pay for it. The cost of deploying broadband in rural areas (where access lines to the home tend to be long) can be far greater than the cost of deployment in denser urban areas (see Section on Challenges in achieving full fixed broadband coverage).

As a result, placing sole reliance on commercial network operators may tend to leave coverage gaps in some OECD member countries. It might result either in rural areas that are unserved or underserved by broadband, or in deployment of broadband that does not fully provide the QoS that policymakers consider to be appropriate, or both. This implies that some OECD countries will want to consider whether there might be a role for public policy to play in promoting broadband deployment.

The achievement of full broadband coverage together with the adoption by all or nearly all of the population benefits a country as a whole. In many OECD countries, private incentives are sufficient to ensure coverage of much but not all of the national territory, and adoption by much but not all of the population.

To the extent that private incentives might not suffice, the achievement of full broadband coverage and adoption can be viewed as a particular form of a *public good.* However, it is not a *pure public good*, which would be characterised by being "non-rivalry of benefits and non-exclusion of nonpayers". Non-rivalry implies that the consumption by an economic agent (e.g. an individual, a nation) of a certain good does not detract, in the least, the consumption opportunities by other agents from the same unit of the good (Arce M, 2002[10]). Therefore, this *pure public good* characterisation would be not accurate for broadband. The achievement of full broadband coverage and adoption can be viewed instead as a *club good* that is "partially rival for its members, but excludable to non-members" (Arce M, 2002[10]). Communication networks are often viewed as *club goods*.

Thinking of the achievement of full broadband coverage and adoption as a form of *public good* may help clarify the need for a balanced approach to public policy intervention. Full achievement of a *public good* often requires public policy intervention. This is clearly the case for broadband deployment and adoption – full coverage of broadband with sufficient speed and quality may require intervention on the part of public authorities. When it comes to broadband deployment and adoption, however, the need for intervention can be limited to filling the gaps (if any) that would be left by placing sole reliance on commercial incentives.[1] Indeed, it is good practice to avoid overly broad policy interventions that risk crowding out private market-based investment that otherwise would have taken place.

This section addresses some of the challenges in realising investment to promote ubiquitous high-speed fixed and mobile broadband while also deploying next-generation networks.

Challenges in achieving full fixed broadband coverage

While there is broad consensus that a ubiquitous, high-quality broadband infrastructure is essential to the digital transformation, the question of how to foster large-scale deployment in OECD countries remains critical, particularly concerning potential investment challenges associated with deploying next-generation networks, both fixed and mobile.

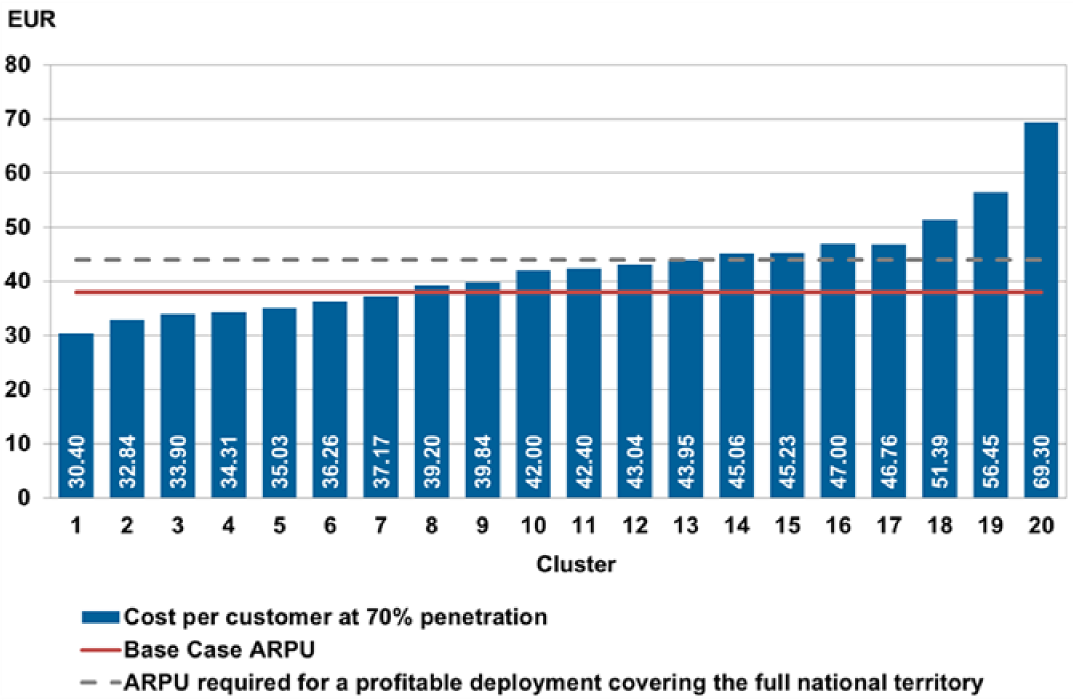
Numerous studies have explored the cost of providing adequate broadband service to areas that are unserved or underserved today. These studies identify the investment gap that can serve as a rationale for government intervention.

The 2010 National Broadband Plan (NBP) in the United States, for example, began by identifying households that lacked access to broadband with a minimum of 4 Mbps downstream and 1 Mbps upstream (FCC, 2010[11]). These tended to be in remote rural areas, often in areas with challenging terrain. Areas with more favourable population density and terrain had already been built out.

The Federal Communications Commission (FCC) in the United States then proceeded to calculate the investment gap (in terms of *net present value* (*NPV*), distinguishing between capital expenditure (*CAPEX*) and operating expenditure (*OPEX*)), required to supply all inhabitants with basic broadband with at least 4 Mbps downstream and 1 Mbps upstream. They found that about half of that investment gap was tied to just 0.2% of households (FCC, 2010[11]).

Costs tend to be higher in low-density rural areas, and lower in high-density urban areas, because the average length of each access line is less when the density of customers is high. A 2011 study by WIK-Consult for the German Federal Ministry of Economy serves to illustrate the point (WIK, 2011[12]). The study found that by breaking Germany up into 20 *geotypes* representing areas of roughly equal population but declining population density, the average cost to serve each customer with Fibre to the Home (FTTH) broadband access ranged from USD 42.30 (EUR 30.40) to USD 96.40 (EUR 69.30).[2] The authors estimated the average consumer willingness to pay for the service to be constant across Germany, and in the range of USD 52.90 (EUR 38) per month (the red line in Figure 1).

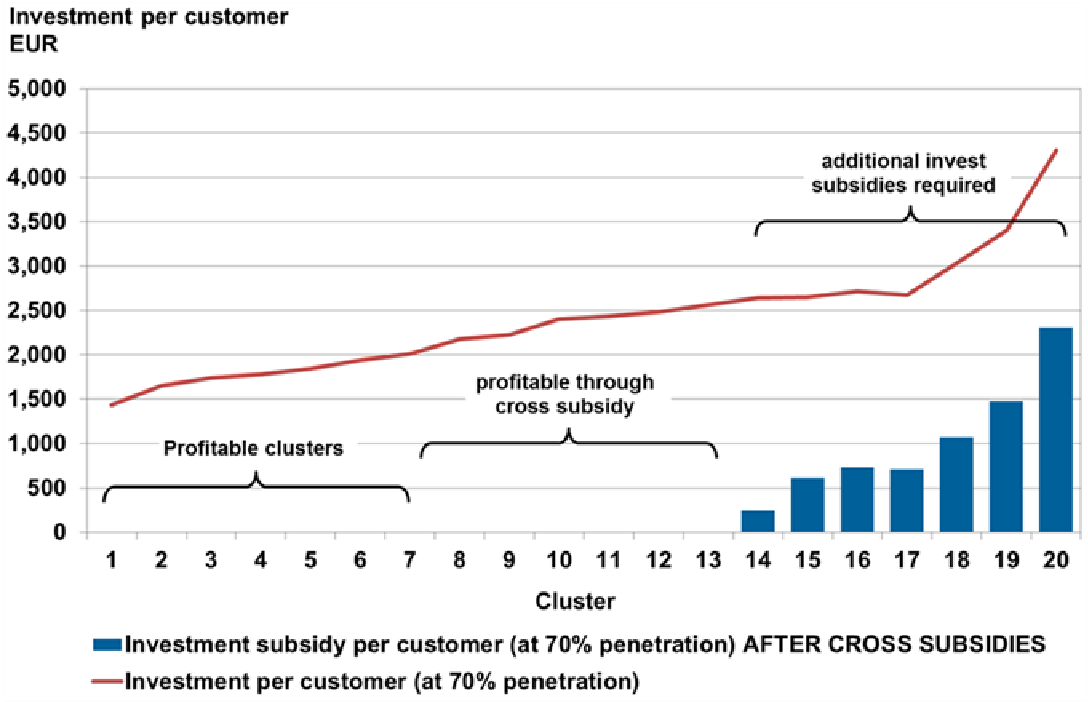
Figure 1. Cost and average revenue per user (ARPU) per customer per month for FTTH Point to Point (P2P) Ethernet at 70% penetration, Germany (2011)



Source: WIK (2011[12]), "Implications of a nationwide fibre roll-out and its need for subsidies", https://www.wik.org/uploads/media/WIK_Diskussionsbeitrag_Nr_359.pdf

According to the study, the challenge for a network operator is that in the lowest density geotypes, the amortised cost of providing the service can be considerably higher than what consumers are willing to pay (e.g. USD 96.40 of cost versus USD 52.90 of revenue per month). The same study concluded on this basis that a profit-seeking network operator would choose to deploy in only seven of the 20 equi-populous geotypes (those that appear on the left in Figure 1). In another seven geotype areas (the least populous, which appear on the right), the investment could never be profitable without public intervention (e.g. subsidy). Interestingly, the authors also found that, if the network operator were willing to subsidise unprofitable geotypes from profitable, six more geotypes (those in the middle of the figure) could be built out without running an overall loss. A profit-oriented network operator could choose not to do this, but a government or community/municipality-run network operator might (Figure 2). The detailed results would be different today, and would have been different with different modelling assumptions at the time, but the general form of the trade-offs that are shown are broadly applicable (WIK, 2011[12]).

Figure 2. Investment subsidy per customer required for FTTH P2P Ethernet, Germany (2011)



Source: WIK (2011[12]), "Implications of a nationwide fibre roll-out and its need for subsidies", https://www.wik.org/uploads/media/WIK_Diskussionsbeitrag_Nr_359.pdf

This does not necessarily imply that public policy intervention is always called for, nor does it imply that a subsidy is invariably necessary. If a country has favourable characteristics in terms of population density and dispersion, willingness to pay on the part of consumers, and/or unit costs for the technology selected, the geotypes in the rightmost group in Figure 1 might be the null set (i.e. empty). Taking this logic further, in the event that this is not already the case, public policy interventions that increase the willingness to pay (e.g. through education in digital skills) or that decrease costs (e.g. by providing cost-effective access to ducts and electric poles) might move the boundary to the right, again leading to a result where no geotype requires public subsidy.

Achieving high-coverage for mobile networks

The challenges relevant to mobile networks are somewhat different. Achieving last mile connectivity with mobile networks tends to be less problematic, since civil works (e.g. digging trenches) are not required to reach each individual house or each individual user (i.e. the access part of the network also known as "last-mile"). It is for this reason that mobile coverage is much more extensive than fixed worldwide. For mobile, the economic challenges often relate instead to ensuring sufficiently capable backhaul capabilities to the mobile cell sites.

The transition to 5G mobile services is expected to compound this problem. In areas where high capacity is needed, 5G will achieve higher data transmission capacity than 4G by using a much larger number of cells, typically operating at higher spectrum frequencies. For dense metropolitan areas, this is likely to require new backhaul facilities to be deployed, in most cases by running fibre to the base station. Key regulatory issues related to 5G will likely include: streamlining rights of way (to deploy massive numbers of small cells and backhaul connecting the cells), efficient spectrum management, deployment and access to backhaul and backbone facilities, and new forms of infrastructure sharing (OECD, 2019[13]).

In countries and regions that have extensive fixed broadband coverage, the backhaul is sometimes provided by the same fixed networks that serve consumers, for instance over spare dark fibre strands that are available as a by-product of a residential FTTH or hybrid fibre-coaxial (HFC) deployment. A satisfactory deployment of fixed broadband can thus contribute to adequate mobile broadband coverage.

Box 1 summarises comprehensive assessments of the funding required to achieve full, high quality fixed and mobile coverage of the European Union (as of 2019) and the United States (as of 2010).

Box 1. The combined fixed and mobile funding gap in the European Union and the United States

European Union

The European Union can serve as an example to provide a perspective on the magnitude of the broadband investment challenge. The European Investment Bank has estimated the magnitude of the funding gap to achieve the European Union's fixed and mobile broadband objectives, as expressed in the Digital Agenda for Europe (DAE) (European Commission, 2010[14])together with the European Gigabit Strategy (EGS) (European Commission, 2016[15]). The DAE requires full coverage of the European Union with basic broadband (already achieved), and seeks to further ensure that "by 2020, (i) everyone in the European Union has access to much higher internet speeds of above 30 Mbps and (ii) 50% or more of households in the European Union subscribe to internet connections above 100 Mbps."

The EGS goes much further, establishing strategic objectives by 2020 of (i) achieving availability of 5G connectivity as a fully-fledged commercial service in at least one major city in each Member State; and by 2025 of achieving (ii) "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;" (iii) uninterrupted 5G coverage for all urban areas and all major terrestrial transport paths; and (iv) providing access to Internet connectivity offering a downlink of at least 100 Mbps, upgradable to Gigabit speed, to all households in the European Union, rural or urban.

The European Investment Bank (EIB) found that a total investment of USD 453 billion (EUR 384 billion) would be required by 2025 under the most likely assumptions. Of this, USD 149 billion (EUR 126), i.e. 33%, would be required to complete achievement of the 2010 DAE; USD 77 billion (EUR 65 billion), i.e. 17%, would be needed to meet the 5G connectivity goals; USD 111 billion (EUR 94 billion), i.e. 24%, would be required for rural connectivity, and USD 116 billion (EUR 98 billion), i.e. 26%, would be required for gigabit connectivity to companies and institutions ("socio-economic drivers").

Under more ambitious goals and assumptions, the total investment to 2025 would be USD 505 billion (EUR 428 billion) instead of the USD 453 billion (EUR 384 billion) associated with the most likely scenario. Conversely, under more modest goals and assumptions, with greater reliance on wireless for rural coverage and a much smaller number of companies and institutions to be provided with gigabit connectivity, the total investment to 2025 would be just USD 227 billion (EUR 192 billion), or roughly half of the cost of the most likely scenario.

The EIB further estimated that USD 153 billion (EUR 130 billion, i.e. 33% of that funding, could be expected to come from private investments, and that the remaining USD 300 billion (EUR 254 billion) represented an investment gap that would somehow have to be addressed by some combination of public policy interventions (European Investment Bank, 2018[16]).

United States

In the United States, the amount of public subsidy required was studied in depth as part of the National Broadband Plan (NBP) (FCC, 2010[11]). The NBP and its companion work, "The Broadband Availability

Gap" (FCC, 2010[17])[3] took a comprehensive approach to the analysis of costs, beginning with (1) an assessment of the degree of existing coverage, (2) a review of plans of all network operators, (3) an estimate of costs to cover the gap with each of the available fixed and mobile technologies, and finally (4) a geographically granular assessment of the combined cost of covering the full national territory with broadband meeting defined targets of speed (4 Mbps downstream and 1 Mbps upstream) and quality.

They identified seven million housing units in the United States without access to terrestrial broadband infrastructure capable of meeting the target of 4 Mbps download and 1 Mbps upload. In estimating the funding gap, they took into account not only technology and population density, but also average length of roads to reach the household, and possible presence of hills or otherwise challenging terrain. Taking into account a wide range of factors, they identified a coverage funding gap of USD 23.5 billion 2010 dollars, assuming coverage of 100% of households and only one subsidised network in each unserved area. The most expensive 0.2% (250K) of unserved households represented about half of the gap (see Section Challenges in achieving full fixed broadband coverage).

They proposed the use of federal funding to close the investment gap. The universal service fund was to be updated and re-targeted (see Section Promoting policies for inclusive access to broadband). These changes have since been put in place.

The FCC took a broad view of the problem, considering not only the supply side but also possible demand side measures to promote adoption and usage. They also assessed a wide range of national purposes, including health care, education, emergency services, energy and environment, and more (FCC, 2010[11]; FCC, 2010[17]). For a recent assessment of the current state of play in the United States, see the report "Broadband Internet Access and the Digital Divide" (Congressional Research Service (CRS), 2019[18]).

Policy considerations

This section provides an overview of broadband policies organised into five main groups: (1) fostering market mechanisms for broadband deployment, but going beyond them where necessary; (2) developing mobile broadband networks; (3) promoting policies for inclusive access to broadband; (4) encouraging use of broadband-based services and applications; and (5) establishing a policy and institutional framework for broadband.

Where a subsection corresponds to elements from the Recommendation, a citation of the Recommendation is included. However, some discussions bear little relationship to any of the specific points that appear in the Recommendation and many of the measures taken reflect approaches that had not been visible in 2004. In a few instances, a citation relates to more than one thematic area and consequently appears in more than one section, while in other sections no citation is included since they correspond to a thematic area on which the 2004 Recommendation is silent.

While a number of OECD member countries have benefitted from the Recommendation in implementing their own broadband policies (see the report on "Implementation and Usage of the 2004 Broadband Recommendation"), it is also clear that different specific policy approaches have been implemented within this broad framework of promoting inclusive access to high-quality broadband services. This is not surprising. Policy choices for broadband tend to be influenced not only by national preferences, but also by national circumstances and by path dependencies. Particularly noteworthy among these are:

- population density and dispersion;
- topography (i.e. highlands, forests and islands);

- the degree to which the legacy (copper) communication network had been deployed at the dawn of the broadband era;
- sub-loop length from the street cabinet to the distribution point in the home;
- presence or absence of cable;
- civil works considerations (such as availability of ducts and equivalents, and the acceptability to the public of aerial fibre).

Utilising and augmenting market mechanisms to promote broadband deployment

Excerpt of the Recommendation:

• "Effective competition and continued liberalisation in infrastructure, network services and applications in the face of convergence across different technological platforms that supply broadband services and maintain transparent, non-discriminatory market policies.

• Policies that encourage investment in new technological infrastructure, content and applications in order to ensure wide take-up."

It is widely accepted that market mechanisms generally lead (in the absence of market distortions) to improved competition, innovation, interoperability, and consumer choice (Katz and Shapiro, 1985[19]). In the context of broadband, commercial incentives for profit-motivated network operators are arguably the most effective means of ensuring that the services that consumers and other users want are in fact provided.

Historically, in most OECD countries communication services were provided by a single incumbent network operator, often a government postal, telegraph, and telephone service (PTT). In the absence of effective competition, these network operators had only limited incentive to provide innovative services or attractive prices to their customers. Over the past twenty years or so, all or nearly all OECD countries have transformed their communication environments so as to enable competition for communication services (i.e. liberalisation). The liberalisation of the sector and the corresponding entry of competitive network operators have contributed greatly to the deployment of broadband. That being said, merely allowing entry into the market does not necessarily ensure that competition will emerge given the high-fixed costs that characterise the communication sector. In other words, the cost structure of communication markets (i.e. high investment needs and fixed costs with barriers to entry) is conducive to oligopoly/monopoly market structure if left unregulated. As such, a determining factor that has driven communication prices down and extended coverage of broadband networks in most OECD countries is regulation that fosters competition. In particular, for the fixed network – complementary regulatory measures are often needed (see Promoting policies for inclusive access to broadband). In line with this thinking, however, regulation should not be needlessly burdensome; otherwise, there is a risk that incentives to invest are undermined. If the government itself is a network operator or a service provider, it should be careful not to crowd out private commercially motivated network operators and service providers, and must not favour network access or services that government itself offers over those offered by commercial providers.

The Recommendation refers to encouraging investment not only in networks, but also in content and applications (see also Encouraging use of broadband-based services and applications). Communication networks are a crucial enabler for a complex ecosystem – they enable consumers to access a wide range of content, applications and services. For the system to offer value to its users, network access, content, applications and services must all be available.

Competition among broadband providers

Excerpt of the 2004 Recommendation:

• Effective competition and continued liberalisation in infrastructure, network services and applications in the face of convergence across different technological platforms that supply broadband services and maintain transparent, non-discriminatory market policies.

There are many different means of fostering competition for broadband services today, some of which had not been considered at the time of the 2004 Recommendation.

The last mile of the fixed network has a strong tendency to natural monopoly. Typically, there will be portions of the national territory where it is not economically viable for two or more undertakings to lay wires or fibre to the same house. If given free rein, this tendency to natural monopoly could under some circumstances tend to lead to competitive bottlenecks, to high prices to consumers, to a low degree of innovation and/or to limited incentives to improve broadband technology.

This concern could be less significant in countries that have more than one fixed network access to most homes. For mobile networks, it should be feasible to arrange for coverage by more than one mobile network for most of the national territory, especially when mobile network operators can rely to wholesalers to some extent such as tower companies. National regulatory authorities can use regulatory tools, such as spectrum licensing measures or merger control to ensure that enough mobile operators are active and that there is satisfactory competition in the mobile market.

Some OECD countries (especially those that are members of the European Union) seek to compensate for the limitations imposed by the tendency to natural monopoly in the fixed network by means of *wholesale remedy* obligations imposed on network operators that are found to have significant market power (SMP). Competitors can then obtain necessary wholesale inputs under regulated cost-oriented prices, terms and conditions. If wholesale remedies are effective, it is generally not necessary to apply remedies at the retail level.

Care must be taken in crafting these remedies. If the firm that possesses these bottleneck assets is permitted to favour its own retail activities (or the activities of affiliated entities) over those of competitors, it is likely to be difficult, if not impossible, for competitors at the retail level to successfully enter the market. Remedies can be applied to passive infrastructure such as ducts and poles, as well as to active infrastructure.

In France, for example, remedies have applied for many years to in-building wiring, and they apply to the first mover in a building irrespective of whether that network operator possesses SMP overall. The European Electronics Communication Code (EECC) codifies this approach (i.e. imposing access obligations on non-replicable wiring irrespective of SMP) across the European Union, subject to suitable safeguards and restrictions (European Commission, 2018[20]).[4]

Other solutions have been put in place, including government management or ownership, and/or wholesale-only networks. Others, notably in the United States, have largely phased out this wholesale remedies approach, placing primary reliance instead on market competition.

Alternative ownership or management models

A number of alternative ownership and/or management models have been attempted in recent years, some of which mainly emerged after the Recommendation was adopted. The emergence of these new models reflects technology evolution, market developments and policy or regulatory concerns. Among these models are: (1) ownership and/or operation by the government; (2) structural or functional separation of the incumbent network operator; (3) co-investment models, primarily for the fixed network; and (4) mobile network infrastructure sharing.

Opinions on their effectiveness vary, and in some cases it is too early to judge, but it seems fair to say that some appear to have been more effective than others. A recent OECD report documents new approaches to ownership models exploring how operators aim to provide connectivity and services in the future (OECD, 2019[21]).

Ownership and/or operation by the government

A number of OECD countries have chosen to address gaps in broadband coverage gaps or quality, not by subsidising private network operators (see Section Promoting policies for inclusive access to broadband), but by taking an ownership share and/or an operational role in broadband networks.

Perhaps the best known example of government ownership at the national level is the Australian *National Broadband Network* (*NBN*).[5] The network was originally envisioned to cover 93% of Australian premises with a mix of fast fixed broadband services, with the remainder served by wireless and satellite technologies.

Many fibre-based broadband networks are operated at the municipal level. In many cases, these networks offer wholesale-only services. The municipal broadband networks in Sweden are widely viewed as having been effective and successful in driving Sweden’s high fibre take-up since the liberalisation of the communication market (OECD, 2015[22]). Some have involved public private partnerships, others have been privatised following initial public ownership and some are community driven.

Mexico has launched a mobile wholesale access network in the 700 MHz frequency band, the *Red Compartida*. The network is privately operated by a consortium and the oversight of the project is undertaken by PROMTEL which is an entity within Mexico’s ICT Ministry. Deployment of the wholesale network started in 2018. Its success will depend on many factors, including the access conditions provided to mobile and virtual mobile network operators (OECD, 2017[23]).

Structural, functional separation and wholesale-only networks

A number of countries have attempted to split their main incumbent fixed network operator into (1) a wholesale entity operating the physical infrastructure, and providing network services to multiple retail service providers; and (2) a retail service provider that purchases underlying network services from the wholesale entity, and competes with other retail entities.

Compared to the wholesale remedies approach, separation can make it easier to ensure that the wholesale entity (which typically has considerable market power relative to its underlying last mile infrastructure) does not discriminate in favour of its affiliated retail operations. Ideally, it eliminates the incentive to discriminate.

In a number of countries, an effort was made to *functionally* separate the vertically integrated entity into operationally separate business entities while maintaining common ownership (i.e. functional or operational separation) in order to attempt to preserve existing economies of scale and scope. This was most notably the case in the United Kingdom and in New Zealand. In the United Kingdom case, the incumbent network operator agreed to a voluntary separation, but did so under the threat of a referral to the United Kingdom competition authority. On the other hand, full ownership separation constitutes a “structural separation”.

With functional separation, the retail entity may be subject to substantial competition, while the wholesale entity typically may be subject to only limited competition. Therefore, ensuring that the wholesale entity cannot discriminate in favour of the still-somewhat-affiliated retail entity is key.

There are many ways to implement functional separation, distinguished by the degree of decoupling achieved. The more extreme forms are closer in effect to a full structural separation (Cave, 2007[24]).

The European Union's EECC distinguishes between voluntary and mandatory functional separation[6] (European Commission, 2018[20]). In either case, some regulatory relief is possible to the extent that the separation successfully achieves non-discrimination among retail providers of broadband services.

Maintaining functional separation appears to be challenging in practice. In New Zealand, former Telecom New Zealand (TNZ) chose to switch to full structural separation, whereby the split entity does not maintain common ownership, after a few years. In the United Kingdom, a shift to full structural separation is likewise in progress. Meanwhile, the fixed incumbent in the Czech Republic voluntarily opted for a structural separation (OECD, 2019[21]).

Fixed network co-investment models

In the EECC, the European Union has offered a degree of regulatory flexibility to (fixed) network operators who agree to jointly invest in high-speed broadband network infrastructure[7] (European Commission, 2018[20]). Namely, the EECC establishes that an operator with SMP will be able to propose commitments on offers for co-investment in new networks that consist of optical fibre elements up to the end-user premises or base station. In return for these commitments, that require to fulfil a number of criteria on access for co-investors and third parties, if made binding by the national regulatory authority, the operator with SMP would be exempted from ex-ante regulation. The proposed structure is thought to be more incentive-compatible for the incumbent network operators, and thus less onerous and easier to enforce. It is too soon to say whether the new scheme will in fact be used to a significant degree, or whether it will in fact have the hoped-for effect.

Mobile network infrastructure sharing

Among mobile network operators, the sharing of network assets can provide a means of achieving economies of scale that can be viewed as providing a practical alternative to an outright merger. Mobile assets that could be shared include masts, spectrum, or even the radio access network (RAN).

Some countries achieve similar synergies in a different way. One example is the growing number of tower companies across the OECD (OECD, 2019[21]). In the United States, for example, mobile masts are often provided by independent firms who serve multiple mobile network operators.

Market players will often be in a better position than policymakers to identify opportunities to share infrastructure. There is thus good reason to prefer placing primary reliance on market mechanisms in most cases. Policymakers should be careful not to needlessly impede infrastructure sharing.

However, sharing of infrastructure may raise competitive concerns as it increases the risk that firms might effectively collude, to the detriment of competitors and/or consumers. As a practical matter, countries in the European Union have tended for this reason to be much more open to sharing of passive assets such as masts, than to the sharing of active assets such as the radio access network (Table 1).

Table 1. Infrastructure sharing obligations imposed on operators

Number of countries among European Union 28, 2007-15.

	Site sharing	Mast sharing	RAN sharing, separate spectrum	RAN sharing, joint spectrum	Core network sharing
Yes	26	26	6	2	0
No/not allowed	2	2	21	26	28

Note: The table records any infrastructure sharing obligations included as part of a requirement for an award of 700 or 800 MHz licences.
Source: Cullen International, as reported in (Marcus et al., 2017[25]).

Measures to reduce costs of network deployment

Competition is an important means of promoting broadband deployment, but it is by no means the only tool available to policymakers. In cases where commercial incentives alone do not suffice to drive the desired deployment of broadband services, there are other ways to try to close the gap, while relying primarily on market mechanisms. Measures to reduce the cost of network deployment is one of the options.

There are numerous means available to governments to seek to drive down the unit costs of network deployment. Civil works play a large role in the cost of broadband deployment, especially in the case of Fibre to the premises (FTTP)/FTTH deployments. Most of the cost reduction measures relate in one way or another to the cost of civil works.

Some countries are open to aerial deployment of broadband infrastructure, Japan being an example. Western European countries tend to have regulations against aerial deployment. Aerial deployment greatly reduces CAPEX needed for the initial deployment of high-speed broadband; however, it implies that the lines are vulnerable to any extreme weather conditions, which will tend to increase OPEX and to reduce robustness of networks.

Access to infrastructure put in place for a different purpose can likewise reduce broadband deployment costs. The United States, for instance, has long-standing rules enabling network operators to demand the right to attach telecommunication lines to utility poles at cost-based prices. French cities, such as Paris, benefit analogously from the use of sewers dating back to the days of Baron Haussmann in the Nineteenth Century.

A number of countries in the European Union, including Portugal and Poland, have long had procedures in place whereby the national regulatory authority could oblige utilities such as electricity, water or sewage to provide maps showing where they had infrastructure available that would be of potential value for broadband network deployment. Network operators can request access to these facilities.

These national rules were subsequently codified at the European Union level in the *Cost Reduction Directive* of 2014 (European Union, 2014[26]). Network operators can demand access to these facilities. The parties then agree on a price. If they cannot agree, the national regulatory authority responsible for communications arbitrates. Unfortunately, European Union Member States have taken some time to put the Directive into effect; consequently, there is very little experience on which to judge the degree to which it might have been effective (Godlovitch et al., 2018[27]). The Directive also establishes a maximum period within which municipal and national authorities must grant (or reject) permission to deploy network infrastructure, covering *all* permits (not just network authorisation).

Among mobile network operators, the sharing of network assets (i.e. masts, spectrum, or radio access network) can provide a means of reducing deployment costs (see Alternative ownership or management models).

Technological neutrality

Excerpt of the 2004 Recommendation:

- *Technologically neutral policy and regulation among competing and developing technologies to encourage interoperability, innovation and expand choice, taking into consideration that convergence of platforms and services requires the reassessment and consistency of regulatory frameworks.*

The logic of technological neutrality is clear. The choice among technological alternatives should be left, the logic goes, as much as possible to the market. Most would argue that it is not the business of government to pick technological winners and losers, and that government has not historically shown itself to be optimal at doing so.

In practice, the question that has arisen is the degree to which FTTP/FTTH solutions should be favoured by policymakers. There is widespread recognition that FTTP/FTTH is the most capable and most future-proof technology available today. Recent OECD work has also shown that the network operators which are leading in terms of speed performance use next generation access networks, i.e. FTTP or *Data over Cable Service Interface Specification* (DOCSIS) 3.1 (OECD, 2019[21]).

While practically all communication operators deploy fibre deep into their networks, there is some debate around the speed with which it is necessary or desirable to migrate to FTTP/FTTH. As noted in Annex A, fibre to the cabinet (FTTC) solutions including very high-speed rate digital subscriber line (VDSL) and G.Fast have delivered greater speeds that some would have predicted some years ago. However, the suitability of VDSL and G.Fast in a specific setting depends on the detailed characteristics of the network, since the speed achievable with these technologies significantly decreases with the distance from the cabinet (see Figure A-4). In countries with ubiquitous cable such as the United States and Canada, new cable standards, such as DOCSIS 3.1, provide a viable alternative to FTTP/FTTH. An open question, for the moment, is to which degree fixed wireless access (FWA) solutions, including wireless solutions based on 5G, will be able to provide viable alternative to FTTP/FTTH. The answer to this question will probably depend on issues such as capacity of the network, geographical area and the frequency band in use.

With respect to policies, some countries leave the choice of technology entirely to the marketplace. Others have explicitly sought to promote a preferred technology, typically FTTP/FTTH. For example in Japan and Korea, the principle of technological neutrality has been established as a good practice, but in the case of 5G and FTTH, the government has been implementing policy initiatives to promote FTTP/FTTH.

The European Union, has wrestled with this question and has largely landed on the side of technological neutrality, while making the case for future proof technologies. Recital 14 of the recently enacted European Electronic Communications Code (EECC) clarifies the European Union's position:

> *"The current response towards [increasing] demand is to bring optical fibre closer and closer to the user, and future 'very high capacity networks' require performance parameters which are equivalent to those that a network based on optical fibre elements at least up to the distribution point at the serving location can deliver. In the case of fixed-line broadband, this corresponds to network performance equivalent to that achievable by an optical fibre installation up to a multi-dwelling building, considered to be the serving location. In the case of wireless connection, this corresponds to network performance similar to that achievable based on an optical fibre installation up to the base station, considered to be the serving location. […] In accordance with the principle of technology neutrality, other technologies and transmission media should not be excluded, where they compare with that baseline scenario in terms of their capabilities."*

This definition from the EECC is easily met by FTTP/FTTH solutions, but does not exclude other technologies that are able to deliver this speed and that can meet the corresponding QoS requirements such as cable based on the DOCSIS 3.1 standard. The text of the EECC can thus be said to be technologically neutral, as long as the provided speed matches the network performance equivalent to that achievable by an optical fibre installation up to the distribution point.

Germany established the Gigabit Initiative in 2017 by the Network Alliance for a Digital Germany, an initiative of the Federal Ministry of Transport and Digital Infrastructure (BMVI), which was further updated through the 5G Strategy in July 2017 and the Gigabit targets of the 2018 Coalition Agreement. These Gigabit targets have been formulated in a technology-neutral way. This initiative was also mentioned in the Digitalisation Implementation Strategy, which has least been updated in June 2021. Measures include, inter alia, to connect new residential areas with fibre to the building (FTTB) or FTTH in accordance with the provisions of the Facilitation of the Deployment of Digital High-Speed Networks (DigiNetzG) bill, to provide poorly served business parks exclusively with fibre connections by the end of 2019. For this purpose, funding by the Federal Government's overall Gigabit funding scheme is used. New business parks will be provided with optical fibre from the start, in line with the DigiNetzG (BMVI, 2017[28]). Moreover, Germany has transposed the European Electronic Communications Code (EECC) in national law that will enter into force in mid-December 2021. The transposition created an opportunity to bring fibre and other fibre-like technologies in terms of quality and performance closer to the end user by accelerating and streamlining permit procedures, compounding detailed data on communication infrastructure – existing and to-be-built – and enhancing the use of passive infrastructure.

In Switzerland, when various companies began to invest in the construction of FTTH networks, the Swiss communication regulator (ComCom) organised several roundtables in order to promote the dialogue between stakeholders to help finding common solutions. These roundtables led to the creation of several working groups whose aim was to develop solutions for better coordination in the deployment of optical fibre networks. In this context, consensus was reached on issues such as in-building wiring, access to fibre optic networks by various operators, and legal aspects of contracts between building owners and operators. The only exception to the principle of technological neutrality in Switzerland concerns the regulation of wholesale access to the dominant operator's resources and services. The obligations to offer fully unbundled access to the local loop and high-speed access to competitors are limited to the incumbent operator's copper network. By exempting the incumbent's new generation networks from the potential unbundling obligation, this deviation from the principle of technological neutrality may have indirectly benefited investments in the deployment of optical fibre.

Technological neutrality may be relevant to phasing out old network technology. Some operators have been analysing at what point their traditional copper network should be shut down as well as how to treat 2G or 3G networks in the future. With respect to public policy, the question arises whether this decision should be left to network operators only or whether there is a role for public policy to play in making this decision. There is an argument to be made for permitting the network operators to make this judgment themselves, subject to providing suitable notice to competitor networks that rely on wholesale access to an incumbent's copper network. Some countries have, however, considered mandating a shutdown of the copper network in order to ensure a full transition to future proof technologies. This is a question that is likely to continue to be debated in the years to come.

Developing mobile broadband networks

There are many considerations that are specific to policies that aim to promote mobile broadband. Since mobile broadband was barely visible at the time that the Recommendation was adopted, the Recommendation does not include principles or policy instruments for mobile networks.

Fixed-mobile substitution/complementarity

A threshold question relates to the degree to which fixed and mobile services should be viewed as being equivalent. This seemingly simple question has a complex answer. To an economist, the natural starting point relates to substitutability versus complementarity of the services. If a consumer has a mobile broadband service, holding their income constant, does that make him or her *more likely* (complementarity) or *less likely* (substitution) to have a fixed broadband service?

The answer to this seemingly straightforward question is complex. Cross-elasticities of demand (the degree to which having one service influences demand for another related service) are crucial in answering it. On the basis of survey data from 27 countries in the European Union, Grzybowski and Verboven (2013[29]) found that "households tend to perceive mobile and fixed-line connections as substitutes. But at the same time there is substantial heterogeneity across households and regions, so that both services are often perceived as complementary."

In a way, all wireless technologies are essentially extensions of fixed networks. Wi-Fi extends the fixed network over a short range and allows nomadic usage; while cellular networks extend the fixed network over a much larger area and allows both nomadic and mobile usage. Competition between fixed and mobile does not require the two services to be perfect substitutes for all customers –

the *potential ability* to substitute a mobile service for a fixed service can also serve to promote competition. Nonetheless, while there is certainly substitution for services between mobile and fixed subscriptions, such as telephony, at present, differences in capacity constraints in terms of spectrum and backhaul have meant that they are largely viewed as complementary for Internet access by many users. Over time, this may change for some users (as seems to already be the case in Finland and Austria) if unlimited data offers become more common. In Austria, where most data-only subscriptions are unlimited and have a fixed monthly fee, about a third of total Internet data traffic is transmitted over mobile networks (Austrian Regulatory Authority for Broadcasting and Telecommunications, 2018[30]).

In low-density areas, mobile networks may be the only network available. This is the case in large parts of the world. Under these circumstances, it is clear that mobile broadband services may function as a substitute for fixed services. For most consumers, fixed and mobile services are not effective substitutes, since fixed networks do not offer mobility, and mobile broadband offers often do not match the same speeds or data allowances than fixed broadband services.

Survey data seem to indicate that people use their mobile-capable devices differently when Wi-Fi is available (typically based on fixed network capability and from home or at work) than when it is not (Marcus and Burns, 2013[31]). People were more likely to do software updates, and more likely to view long format videos online, when they had Wi-Fi connectivity. Price, stability and robustness appeared to play a role in these decisions. Nonetheless, people tend to maintain both fixed and mobile subscriptions due to their complementary nature, and the offloading of traffic benefits both cellular providers and users. That is, substitution occurs largely in a user's choice of a particular access technology at certain point in time of the day rather than between subscriptions. Whether this might change with the further deployment of 5G is an open question for now.

The key constraint on cellular networks for substituting for fixed broadband is capacity in most countries, whether defined as the amount of available spectrum or the type of backhaul technology connecting any cellular tower. However, it is possible that the increased speed and reliability of 4G and 5G mobile services is reducing this preference over time. Price presumably also plays a large role – for a consumer with a reliable service and a flat rate package permitting a large volume of GB/month, there is perhaps less reason to prefer Wi-Fi over the mobile network.

In the United States, for example, the FCC does not consider fixed and mobile broadband to be full substitutes for one another. Both fixed and mobile services can enable access to information, entertainment, and employment options; however, the FCC argues that there are salient differences between the two. Beyond the most obvious distinction that mobile services allow for broadband access while on the move, there are variations in consumer preferences and demands for fixed and mobile services. Each are important services that provide different functionalities, tailored to serve different consumer needs. In the 2019 Broadband Deployment Report, the FCC concluded that it was not necessary to specify, among a wide range of use cases, the circumstances in which fixed and mobile broadband are or are not close substitutes (FCC, 2019[32]).

The Latvian national regulatory authority, the Public Utilities Commission (SPRK), concluded, after a detailed assessment, that mobile broadband cannot yet be regarded as a full substitute to fixed broadband in Latvia, even though fixed operators face competitive pressure from mobile operators. They concluded that mobile broadband access should be viewed as being complementary to fixed broadband when provided by mobile plans that do not provide unlimited data volumes.

Coverage requirements in spectrum auctions

One means of ensuring rural broadband coverage, assuming that mobile coverage is deemed to be sufficient, is by placing coverage obligations at the time the spectrum licences suitable for mobile services are auctioned off. The bidder is obliged to commit to cover some portion of the national territory or the national population. Coverage obligations in auctions have proven an effective tool used in OECD countries to extend mobile broadband coverage in rural and remote areas. However, the extent of coverage obligations should not impede certain actors from bidding in the auction (OECD, 2019[33]).

Coverage obligations tend to be viewed by bidders as a cost, who will therefore internalise this cost in the amount that they are willing to bid. As such, it may lead to lower revenues raised in the auction However, a reduction in auction revenue should not necessarily be viewed as a defect,[8] as policy makers pursue several public objectives when an auction is held. Namely, an auction is held to ensure allocative efficiency, as it is an efficient means of ensuring that spectrum is assigned to the party that values it most, which will tend to be the network operator that will use it best.

In addition, other objectives pursued in auctions include enhancing competition in the market and providing incentives to expand coverage of mobile networks. To embody these objectives, policy makers take into account the different elements of the auction design (e.g. reserve prices, spectrum caps, coverage obligations).

In some cases, it might be possible to reduce the cost of coverage obligations by permitting the successful bidders to agree to meet the coverage obligations jointly, rather than individually with overlapping coverage, provided that sufficient competition among MNOs can be maintained.

5G and the need for large numbers of small cells

As noted in Achieving high-coverage for mobile networks and in recent OECD work, the migration to 5G mobile networks is expected to lead over time to network *densification*, with large numbers of small cells in dense metropolitan areas likely in the medium-term (although macro cells will continue to be used extensively, and will be the primary means of coverage in low density areas). This has important implications for the deployment of high-speed mobile broadband.

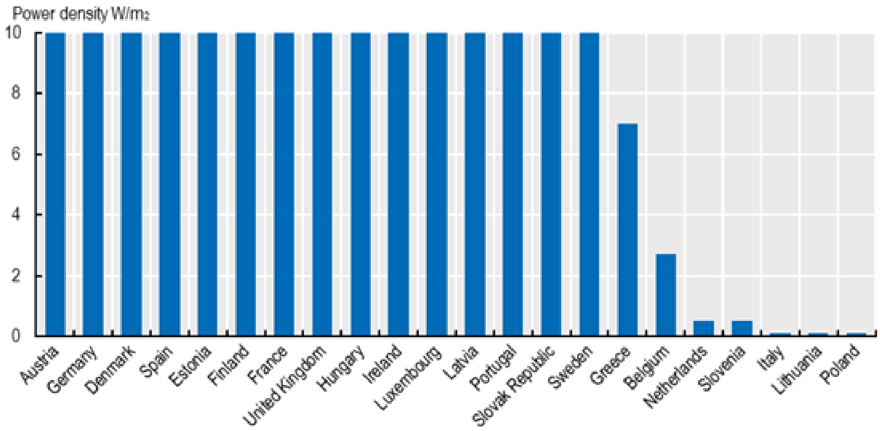
Firstly, the cells, even though small, will in most cases need fibre-based backhaul. This implies that mobile deployment in metropolitan areas is likely to be synergistic with the deeper deployment of fibre in the fixed network. Serious challenges might be expected in obtaining necessary permits from municipalities to deploy a potentially large number of new cells (Pujol et al., 2019[34]) A recent OECD report provides a detailed discussion on 5G considerations (OECD, 2019[13]).

Health effects of Electromagnetic Fields (EMF)

The challenges in expanding the number of mobile base stations could potentially be compounded by restrictive standards on emitted power. Most countries follow the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines; however, some countries (and cities) enforce far more restrictive standards, as is evident by the assessment undertaken by Poland (Figure 3). Restrictive EMF limits have been set in a number of Eastern European countries for historical reasons, and also in countries such as Italy and in municipalities such as Brussels.

At the same time, this is a complex and sensitive issue. Although no negative health effects have been conclusively demonstrated for mobile equipment used at power levels allowed by the ICNIRP standards, research continues.[9]

Figure 3. Permissible EMF levels, selected OECD countries



Note: Acceptable levels of electromagnetic fields on the example of frequencies greater than 2 GHz.
Source: Adapted from (Sołtysik, 2017[35]), based on (European Commission, 2008[36]).

Promoting policies for inclusive access to broadband

Multiple interrelated public policy goals

Excerpt of the 2004 Recommendation:

• Recognition of the primary role of the private sector in the expansion of coverage and the use of broadband, with complementary government initiatives that take care not to distort the market.

• Assessment of the market-driven availability and diffusion of broadband services in order to determine whether government initiatives are appropriate and how they should be structured.

• Policies that promote access on fair terms and at competitive prices to all communities, irrespective of location, in order to realise the full benefits of broadband services.

• Encouragement of research and development in the field of ICT for the development of broadband and enhancement of its economic, social and cultural effectiveness.

Achieving inclusive broadband deployment is not a single objective; rather, there are multiple objectives that must somehow be balanced and achieved together.

Due to differing national contexts, some countries may place substantial weight on policy interventions in order to achieve broadband deployment, adoption, and usage, while others may rely primarily on market mechanisms supported by only very limited public policy interventions. In either case, a clear focus on policy goals is definitely needed.

In addition to population, topography and existing infrastructure, broadband policymaking depends on the consideration of a range of interrelated goals. In many OECD countries, these goals are explicitly recognised in NBPs. Among the most important are:

- promotion of the best-quality and most cost-effective broadband technology;
- coverage that is as ubiquitous as possible, and available to all who want it; and
- affordability of broadband to all.

These goals are interlinked, but they have somewhat different implications for policies, for the institution responsible for implementation, and for accountability.

It is useful to distinguish at the outset between regulatory measures and broader policy measures. Broad policy measures are established through the political process, which in OECD countries is ultimately accountable to the electorate. Regulatory measures, by contrast, are implemented by regulatory authorities who are intended to be impartial and independent, as much as possible, from the political process. Regulation is possible once the political process has established objective rules for the regulatory authority to follow.

With respect to promotion of the best and most cost-effective broadband technology, most OECD countries currently take a technology-neutral stance (see also Technological neutrality). Many technology alternatives are available. The choice among alternative broadband technologies is left to the market in these countries.

In some countries, the choice among broadband technologies may instead be treated as a matter of policy, and thus influenced or driven by policymakers (or in some cases by regulators). Where policymakers promote a particular set of broadband technologies, the QoS sought is typically the best possible at reasonable cost for those who are willing and able to pay for it.

Ensuring ubiquitous coverage of the national territory with high-quality broadband is typically treated as a matter of policy, rather than regulation. The implementation of overall broadband promotion policy is typically the responsibility of one or more Ministries.

Ensuring universal service of broadband consists of making affordable broadband of decent speeds available to the whole population. Universal service is one of several mechanisms that can be used to mitigate or avoid the emergence of a digital divide. A digital divide exists either where individuals (e.g. due to their income, level of skills, gender, age or location) or where businesses (e.g. due to their size) have poor access to broadband, or where it is not available at a price that they can reasonably afford. Universal service has often (but not always) been treated as a regulatory matter. As such, a national regulatory authority might be responsible for implementation, ideally with authority clearly delegated by the political process and with accountability to the courts.

To the extent that both overall broadband promotion policies and universal service policies seek to ensure coverage, there could sometimes be duplication of efforts. In Europe, a 2013 study for the European Parliament suggested "a possible phase-out of Universal Service in favour of alternative regimes such as state aid and direct support for end-users" (Marcus et al., 2013[37]). This suggestion was taken up in the EECC (European Commission, 2018[20]).[10]

Public funding to achieve coverage

As noted previously, there are many countries where commercial network operators would tend not to be motivated to supply broadband access at suitable levels of quality to 100% of the national territory. In order to ensure broadband coverage at suitable QoS in areas where commercial incentives do not suffice to ensure that commercial providers to provide the service, many countries (not all) may offer some level of public funding or "state aid".

A range of safeguards typically apply. Public funding has the potential to distort competition. If public funding were provided to public or private network operators indiscriminately, it would carry the risk of crowding out private investment that otherwise would have occurred, and/or of providing the subsidised entity with unfair advantages in competing with non-subsidised entities. Since public funding for low-density areas usually implies monopoly provision, controls are needed to prevent anticompetitive practices that might impact the firms that provide services to end users based on the subsidised infrastructure.

Public funding is subject to State Aid rules in the European Union. The European Commission has published guidelines as to how State Aid rules should be applied to broadband services (European Commission, 2013[38]). The new revisions to the regulatory framework are designed to comply with these State Aid rules (European Commission, 2018[20]). The key European Union State Aid rules are summarised here because they address the relevant issues in ways that are potentially useful for other countries to understand (Box 2).[11]

Box 2. State Aid rules in the European Union

Under European Union State Aid, public funding can be appropriate in 'white areas' where "there is no broadband infrastructure and it is unlikely to be developed in the near future [typically considered to be the next three years]. … [By contrast, when] in a given geographical zone there are or there will be in the near future at least two basic broadband networks of different operators and broadband services are provided under competitive conditions (infrastructure-based competition), it can be assumed that there is no market failure. Accordingly, there is very little scope for State intervention to bring further benefits." In areas where prospects are intermediate between these two extremes ("grey areas"), a more detailed assessment is called for.

Public funding could be used to encourage a new competitor to enter the market. This is logical, but caution is in order. The new firm must have the technical, managerial and financial resources to successfully deploy the needed infrastructure.

In the European Union, where public funding for broadband is permissible in principle, the following principles must be adhered to (European Commission, 2013[38]):

- Detailed *mapping and analysis* of the coverage to be provided;
- Public consultation;
- A *competitive selection* process in keeping with European Union public procurement rules, and ensuring objective evaluation criteria and equal and non-discriminatory treatment of all bidders;
- Selection of the economically most advantageous offer;
- *Technological neutrality* so as not to not favour or exclude any particular technology or network platform;
- Re-use of existing infrastructure were available;
- *Wholesale access*: Third parties' effective wholesale access to the subsidised broadband infrastructure in order to enable third-party operators to compete with the subsidised entity (if the subsidised entity is also present at the retail level), thereby strengthening choice and competition in the areas concerned by the measure while at the same time avoiding the creation of regional service monopolies at retail level;
- Compliance of *wholesale access pricing* with benchmark levels established by the national regulatory authority;
- *Monitoring, transparency and reporting mechanisms*, together with possible mechanisms to deal with gains that might be substantially larger than anticipated.

In the United States, the amount of public funding required was studied in depth as part of the NBP (FCC, 2010[11]).[12] Achieving full coverage is particularly challenging in the United States because there are many areas with low population density and challenging terrain (see Challenges in achieving full fixed broadband coverage). In related work, the FCC identified a coverage funding gap of USD 23.5 billion, assuming only one subsidised network in each unserved area (FCC, 2010[17]). In order to close the funding gap in the United States, the NBP advocated a reform of universal service mechanisms so as to support deployment of broadband and voice in high-cost areas, and to ensure that low-income Americans could afford broadband. This has been implemented in four sub-programmes, all implemented as part of an overall universal programme overseen by the FCC and operationally run by the Universal Service Administrative Company, or USAC: (1) the Connect America Fund (CAF) for rural areas; (2) a sub-programme to support low-income consumers; (3) a sub-programme to support schools and libraries (E-rate); and (4) a sub-programme to support rural health care. Larger network operators that accept funds under CAF Phase II, the current incarnation of the CAF, are obliged to offer broadband services at speeds of at least 10 Mbps downstream and 1 Mbps upstream, with a round trip latency of not more than 100 milliseconds round trip, and consumer prices must be reasonably comparable to those in urban areas.

Quality of Service (QoS) standards

In discussing public policy intervention to achieve broadband penetration, and especially in speaking of the use of public funding, it is necessary to consider not only the geographical coverage that is to be sought, but also the QoS that is desired. Broadband speed is clearly a key QoS consideration, but by no means the only one. It is necessary as well to consider the latency, jitter, and frequency of dropped packets that must be achieved, as well the reliability and robustness that is desired (OECD, 2019[21]).[13] The QoS desired will tend to have substantial implications for any public policy intervention undertaken to foster coverage.

Assuring good QoS is clearly an aspect of protecting consumers, but countries differ in the degree to which they choose to intervene, and in the form that any intervention takes. Among the options available to a country are the following: (1) to leave QoS purely to market forces; (2) to provide reliable measures of QoS delivered so as to enable consumers to make informed choices, but otherwise to leave matters to market forces; (3) to require network operators to make disclosures to consumers as regards QoS, but make no attempt to enforce commitments made by the network operators; (4) to require network operators to make disclosures to consumers as regards QoS, and to enforce the commitments made (for instance as a matter of truth in advertising); or (5) to mandate minimum QoS standards in one or more dimensions.

For example, the communication regulator in France, *Autorité de régulation des communications électroniques* (Arcep), is finding ways to provide users with precise and personalised information, whether it comes from the users themselves (crowdsourcing) or collected by the regulator from operators. Arcep's priority is to make data on coverage and quality of communication networks available to users, so that competition is not limited to prices but also enhances network investment. Given that the "crowd-sourced" quality measures of broadband depend on factors related to the user environment, Arcep adopted in October 2019 a decision that aimed at implementing in operators' set-top boxes an Application Programming Interface (API) characterising the user environment.

In a similar fashion, the Korean government, through the National Information Society Agency (NIA), monitors the quality of mobile and fixed broadband providers and renders the results publicly available. The NIA has gone to great lengths to measure the quality of both fixed and wireless broadband in order to contrast the advertised speeds with actual speeds experienced by users. The first communication service quality evaluations by the NIA started in 1999 for wired telephones, 2G, and fixed broadband. It now encompasses various services including LTE services and Gigabit wired Internet, and 5G. Network quality measurement is rather a complex endeavour in Korea, as it involves "in the field" measurement of quality with a vehicle, and requires a precise sampling technique across the country. According to the NIA, the communication service quality evaluation has significantly contributed to broadband development by inducing the quality improvement of communication service providers. Furthermore, it has helped increase competition by providing users with objective quality information on communications services, so that they can choose providers accordingly (NIA, 2017[39]).

With its Telecoms Single Market (TSM) Regulation of 2015, the European Union put in place a regime where network operators are obliged to inform consumers of the broadband speed that they commit to deliver, and also of any traffic management practices that they employ (i.e. third and fourth of the five categories above). A network operator can be sanctioned, if it systematically or wilfully fails to adhere to its commitments. In addition, some practices that deviate from the goals of network neutrality are explicitly prohibited. Many EU countries have put in place measurement programmes to determine whether network operators might be systematically falling short on their commitments (James Allen, 2017[40]).

The United States FCC has had a voluntary QoS measurement programme in place since 2011. The FCC works in collaboration with *SamKnows*, an international statistics and analytics firm. Consumer volunteers are sent test devices that measure various broadband performance metrics including download speed, upload speed, and latency. The FCC then prepares an annual report based on these statistics. In parallel with this voluntary activity, the FCC requires (typically rural) network operators who receive "high-cost support" to test their broadband networks for compliance with the appropriate speed and latency metrics (FCC, 2019[41]).

Encouraging use of broadband-based services and applications

The services and applications that broadband enables are distinct from the broadband infrastructure itself; however, it is useful to reflect on them as well. First, these applications represent the true value delivered to businesses and consumers –broadband infrastructure is merely the means by which they are delivered. Second, they are crucial in the virtuous cycle of broadband. Applications and services provide the demand for broadband access, without which there would be no deployment.

With that in mind, the focus in this section is on the implications of broadband-based services and applications for the underlying broadband infrastructure. Mitigating impediments to the usage of broadband-based applications and services is vital. Many aspects of the applications and services, including security, privacy, consumer protection and more, are dealt with at length in other OECD work streams and need only limited and targeted coverage in this report.

Driving demand

Excerpt of the 2004 Recommendation:

• Both supply-based approaches to encourage infrastructure, content, and service provision and demand-based approaches, such as demand aggregation in sparsely populated areas, as a virtuous cycle to promote take-up and effective use of broadband services.

Broadband policy arguably tends to place much focus on the supply side, and little on the demand side. The demand side is equally important, and may in fact be more amenable and more responsive to public policy initiatives.

Korea, for instance, is widely viewed as a success story for broadband deployment and adoption. It is widely assumed, apparently incorrectly, that last mile facilities were subsidised by the Korean government. It appears, however, that broadband deployment instead greatly benefitted from Korean government initiatives to make high quality personal computers available to all Koreans at a modest price. Broadband adoption was 'pulled' by consumer demand rather than being 'pushed' by supply (Marcus et al., 2013[42]).

A few years back, two econometric panel regression studies by mostly the same groups of authors assessed the relative effectiveness of supply side versus demand side measures (Belloc, Nicita and Rossi, 2011[43]; Parcu, 2011[44]). The demand side measures considered in Parcu (2011[44]) were:

- Demand aggregation policies coordinate consumer demand in order to achieve economies of scale so as to increase the profitability of the network roll-out.
- Direct demand subsidies can be provided in the form of discounts on the purchase of equipment or broadband services, direct subsidies, or tax breaks.

- Coordinating government demand positions governments as 'lead users' of broadband technologies, and can provide enhanced digital government applications.
- Incentives to private demand target relatively weak segments of potential demand including persons mainly in charge with domestic work in their own household, schoolchildren and the elderly.
- Incentives to business demand seek to increase business awareness of the benefits of broadband access.

In line with "coordinating government demand", policymakers may have the opportunity to use the public procurement process to promote broadband take-up by consumers. By offering high value digital government services that can best be accessed over the Internet, for instance, policymakers can make broadband access more attractive. This directly addresses the problem of lack of interest on the part of the consumer, which in the case of the European Union is the biggest single reason why consumers do not choose to adopt broadband access at home (see Annex B). Given that a significant fraction of GDP is spent by means of public procurement in most countries, this is a potentially powerful policy lever. It is unlikely, however, to drive a demand to migrate to *high-speed* broadband, since most digital government applications require only modest bandwidth.

All of these forms of demand stimulation had statistically significant positive effects once deployment was sufficiently advanced. By contrast, many supply side measures had no statistically significant effect (the exceptions being the use of Public Private Partnerships (PPPs) and the availability of long-term loans); even among those that did, none had as strong an effect as demand aggregation or direct demand subsidies (Marcus et al., 2013[42]; Parcu, 2011[44]).

Skills development

The power and potential of broadband and the technologies broadband enables for individuals, governments and firms depend on their effective usage. As previously noted (see Annex B), the most significant reasons for people in the European Union not having Internet access at home are either that the content is perceived as being not useful or not interesting, or due to lack of skills. These correspond to 46% and 43%, respectively, of respondents from European Union (EU 28) households with at least one member aged 16 to 74, and with no Internet access at home as of April 2017. Among OECD member countries, simple Internet use among individuals is widespread; however, less than 80% of individuals are daily Internet users so far. More sophisticated online activities are less common in most OECD countries, but on the rise. Typically, usage rates decline with the degree of sophistication of an online activity. For example, in the OECD, 74% of individuals use the Internet for email, but only 9% take online courses (OECD, 2019[2]).

These challenges presumably cannot be solved solely by means of supply-side measures. Educational attainment and skills are key factors affecting individuals' usage. For example, the usage gap between high and low-educated individuals aged between 16 and 74 is over 40% for some activities, such as Internet banking. Other important factors (that might be related to education levels) influencing usage include age, employment status, income, gender, and (non-)acceptance of using digital technologies (OECD, 2019[2]).

The lack of skills could potentially be addressed by means of training. The perceived lack of interesting content is a multi-dimensional problem, but it is likely that improved user education in digital skills needs to be part of any solution. In the context of e-commerce, OECD work provides a potentially useful perspective on the promotion of education, awareness and digital competence (OECD, 2016[45]).

Enabling everyone to participate in a digital society also depends on ensuring that everyone has key foundational skills (e.g. literacy, numeracy). Promotion of the acquisition of these skills might entail easing access and offering incentives for adult learning, and improving the recognition of skills acquired after initial education. Social policies that support mobility and redistribution can also help to reduce digital divides (OECD, 2019[2]).

Trust

Excerpt of the 2004 Recommendation:

• A culture of security to enhance trust in the use of ICT by business and consumers, effective enforcement of privacy and consumer protection, and more generally, strengthened cross-border co-operation between all stakeholders to reach these goals.

As noted throughout, societal benefits from broadband depend on actual use, not just on deployment. If consumers are to use Internet services accessed by means of broadband, they must have confidence in the following: (1) in the security of networks and services, (2) that the services that they use properly secure their sensitive private data, and (3) that any online purchases enjoy appropriate levels of consumer protection.

Security and privacy are of vital importance. They have been long-standing OECD concerns, as evidenced by numerous Recommendations and reports. Noteworthy contributions in recent year include a Recommendation on digital security risk management for economic and social prosperity, a Recommendation on privacy and cross-border flows of personal data, and a Recommendation on critical information infrastructures (OECD, 2008[46]).[14]

The present report does not discuss these themes further here because they are already addressed by separate streams of OECD activities. Consumer protection is also covered by a separate stream of work, but it warrants attention here because some aspects of network and online consumer protection are implemented by the same agencies that implement regulation of electronic communications.

The 2004 Broadband Recommendation does not clearly cover sector-specific consumer challenges and empowerment policies, even though they have been active sector-specific policy areas for OECD member countries for many years. There are a wide range of potential concerns, including information asymmetries between network operators and consumers, providing assurance that the services delivered are in conformance with the commitments of the network operators (see also In the United States, the amount of public funding required was studied in depth as part of the NBP . Achieving full coverage is particularly challenging in the United States because there are many areas with low population density and challenging terrain (see Challenges in achieving full fixed broadband coverage). In related work, the FCC identified a coverage funding gap of USD 23.5 billion, assuming only one subsidised network in each unserved area . In order to close the funding gap in the United States, the NBP advocated a reform of universal service mechanisms so as to support deployment of broadband and voice in high-cost areas, and to ensure that low-income Americans could afford broadband. This has been implemented in four sub-programmes, all implemented as part of an overall universal programme overseen by the FCC and operationally run by the Universal Service Administrative Company, or USAC: (1) the Connect America Fund (CAF) for rural areas; (2) a sub-programme to support low-income consumers; (3) a sub-programme to support schools and libraries (E-rate); and (4) a sub-programme to support rural health care. Larger network operators that accept funds under CAF Phase II, the current incarnation of the CAF, are obliged to offer broadband services at speeds of at least 10 Mbps downstream and 1 Mbps upstream, with a round trip latency of not more than 100 milliseconds round trip, and consumer prices must be reasonably comparable to those in urban areas.

Quality of Service (QoS) standards), consumer privacy, and more.

Among OECD contributions in this space, particularly noteworthy is a 2016 Recommendation addressing consumer protection in e-commerce (OECD, 2016[45]). This work outlined the many benefits that e-commerce had brought over a decade to consumers, including wider choice at competitive prices; however, it also pointed to the greater complexity of the evolving online environment and the related risks for consumers.

The Recommendation on Consumer Protection in E-commerce takes a multi-pronged approach to ensuring protection in the online environment at least as good as that in the offline world, based on ensuring: (1) transparent and effective protection; (2) fair business, advertising and marketing practices; (3) appropriate online disclosures; (4) an appropriate order confirmation process; (5) easy-to-use, robust payment arrangements; (6) fair, easy-to-use, transparent and effective means of dispute resolution and redress; (7) suitable privacy and security safeguards; and (8) adequate public education, awareness and digital competence (OECD, 2016[45]). Given that network access is often ordered over the network, and maintained over the network once the subscription is in place, these same principles of consumer protection in e-commerce are, for the most part, also applicable to the relationship between the consumer of broadband services and the network operator; at the same time, many aspects of consumer protection in the context of broadband services are outside the scope of the Recommendation on Consumer Protection in E-Commerce (OECD, 2016[45]). Given the highly technical nature of broadband service, and the tendency toward information asymmetries between network operators and consumers, there is a clear need to ensure comprehensive consumer protection for users of broadband services.

Content-related issues

Excerpt of the 2004 Recommendation:

- *Regulatory frameworks that balance the interests of suppliers and users, in areas such as the protection of intellectual property rights, and digital rights management without disadvantaging innovative e-business models.*

Content-related issues are a broad class of policy-making which encompasses, among others, intellectual property, media pluralism, freedom of expression, inappropriate content, and fake news. In most OECD countries, these issues are dealt with by means of legal instruments that are entirely distinct from those that govern the regulation of communication networks.

The emphasis that the 2004 Recommendation placed on intellectual property rights management is logical to the extent that content, and especially audio-visual content, is a key driver for broadband usage and thus a principal component of the demand for broadband (Marcus et al., 2013[42]). This is immediately visible in estimates of current and near future Internet usage provided in the Cisco VNI. Video traffic is expected to increase from 75% of all consumer plus business Internet traffic in 2017 to 82% in 2022 (Cisco, 2019[47]). However, issues around intellectual property rights and digital rights management, while relevant, represent only one aspect of a broad class of content-related issues.

Many aspects of content policy, while important in their own merit, are often independent of broadband deployment. Consequently, these aspects are not discussed further in this report. That being said, content has an effect on adoption and use, and access to content and its distribution, in turn, has an effect on communication market competition due to convergence. One content policy related topic that is clearly relevant to broadband is the network neutrality issue. This issue is not explored here, however, it is addressed in a recent OECD report, “The Effects of Zero Rating” (OECD, 2019[48]).

Establishing a policy and institutional framework for broadband

The focus of this section is on the *process* whereby policy relevant to broadband is formulated, rather than on the *substance* of the policies that are implemented.

The 2004 Recommendation does not contain any points that explicitly speak to the process by means of which broadband policy should be formulated in OECD and other countries; however, the theme is clearly relevant, and it is taken up explicitly in Chapter 4 of the 2008 review of the 2004 Recommendation (OECD, 2008[49]).

The OECD has also issued a "Recommendation of the OECD Council on Principles for Internet Policy Making" (OECD, 2011[50]). A number of the specific principles that this Recommendation encourages OECD countries to take account of are relevant here, including:

- encouraging multi-stakeholder co-operation in policy development processes;
- developing capacities to bring publicly available, reliable data into the policy development process;
- ensuring transparency, fair process, and accountability; and
- giving appropriate priority to enforcement efforts.

This section takes up four distinct elements of the policy formulation process for broadband Internet access:

- the policy formulation process;
- the need for a regulatory authority that is independent from political pressure;
- the elaboration of clear and consistent statistics on broadband coverage, adoption and use, together with relevant social and economic impacts; and
- the benefits of sharing good broadband practice with other countries.

Policy formulation

The previous review of the Broadband Recommendation observed that as of 2008, "… only a few countries have specific broadband policy assessment and evaluation activities which mean that broadband plans can be implemented in a more effective and accountable manner. Plans rarely include mechanisms to review the performance of government initiatives" (OECD, 2008[49]).

Today, this has changed. Most countries have published NBPs (Table 2). While almost all OECD countries have NBPs, some OECD countries have already reached such a high penetration of high-speed connectivity that their NBPs have become a component in broader and more ambitious digital agendas to provide even faster broadband to all, irrespective of location (e.g. Sweden), or to deploy new generations of mobile networks (e.g. Japan). Israel, on the other hand, due to its dimensions and the relatively high density of even its peripheral areas, does not have a NBP as such, choosing instead to reach policy objectives through market-based actions of Israel's broadband operators (OECD, 2018[51]).

Table 2. OECD National Broadband Plans

Including Digital Strategies or National Development Plans with connectivity components

Country	National Broadband Plan/ Digital Strategy
Australia	National Broadband Network (2009-2020)
Austria	Broadband Strategy 2020 (2014-2020)
Belgium	Digital Belgium – Plan for Ultrafast Internet in Belgium (2015-2020)
Canada	High-speed Access for All: Canada's Connectivity Strategy
Chile	Agenda Digital Chile (2016-2020)
Colombia[15]	National Development Plan 2018-2022
Czech Republic	National Plan for the Development of NGN (2016-2020)

Denmark	Better broadband and mobile coverage in Denmark (2013-2020)
Estonia	EstWin project
Finland	Broadband Implementation Plan (2016-2019)
France	France Très Haut Débit (2013-2022)
Germany	Digitale Agenda (2014-2017) Implementation Strategy of the Federal Government for Shaping Digital Change
Greece	National Broadband Plan Next Generation (2014-2020)
Hungary	National Infocommunication Strategy (2014-2020)
Ireland	National Broadband Strategy (2012-2020)
Israel	A public consultation is ongoing
Italy	Strategy for Next Generation Access Network (2015-2020)
Japan	Declaration of the Creation of the Most Advanced IT Nation in the World (2013-2021)
Latvia	Development of Next Generation Electronic Communications Networks in Rural Areas (2013-2020)
Mexico	México Conectado Programme (2015-2019)
Netherlands	Digital Agenda for the Netherlands (2016-2021)
New Zealand	Ultra-Fast Broadband (UFB) programme, the Rural Broadband Initiative (RBI) and the Mobile Black Spot Fund (MBSF)
Norway	Digital Agenda for Norway (2016-2020)
Poland	National Broadband Plan (2014-2020)
Portugal	Agenda Digital Portugal (2015-2020)
Slovakia	Strategic Document for Digital Growth and Next Generation Access Infrastructure (2014-2020)
Slovenia	Development of Next-Generation Broadband Networks (2015-2020)
Spain	Digital Agenda for Spain (2013-2020)
Sweden	A Completely Connected Sweden by 2025 - a Broadband Strategy (2016-2025)
Switzerland	Digital Strategy Switzerland (2016-2020)
Turkey	National Broadband Strategy and Action Plan (2017-2020)
United Kingdom	UK Next Generation Network Infrastructure Deployment Plan (2015)
United States	Connecting America: The National Broadband Plan (2010-2020)

Note: (*) New strategy/plan being prepared,
Source: OECD (2018[51]), "Bridging the rural digital divide", https://dx.doi.org/10.1787/852bd3b9-en

It stands to reason that broadband planning should contribute to positive outcomes; however, the degree to which countries actually adhere to their published plans is uncertain, and the degree to which benefits flow from the plans is likewise unclear.

The OECD has been promoting objective, transparent, fact-based policymaking for many years, and these same principles are relevant to broadband. The specific principles called out in the "Recommendation of the OECD Council on Principles for Internet Policy Making" reflect good practice and are surely relevant here (OECD, 2011[50]):

- encouraging multi-stakeholder co-operation in policy development processes;
- ensuring transparency, fair process, and accountability; and
- giving appropriate priority to enforcement efforts.

Independence of the national regulatory authority

As noted in Section Promoting policies for inclusive access to broadband, distinct policy threads are visible for broadband: a *policy* thread, for which accountability is political, and to the electorate; and a *regulatory* thread that operates under authority delegated from the political level. The regulatory thread is administrative, typically with accountability to the courts.

Good governance requires assigning the right functions to appropriate and capable institutions. There is value in separating some regulatory functions in public bodies, especially those related to administering or implementing regulation, from the policy-setting and fiscal policy functions that are exercised by the government. It is important to distinguish between proper influence in accordance with national constitutional law (by means for instance of public consultations, which are essential for transparency and for the formulation of sound policy) and undue influence by the government or by the regulated industry (OECD, 2016[52]).

Statistics on broadband

The 2008 Review of the Recommendation had already identified the importance of "appropriate and internationally comparable broadband metrics. Policy makers need a wider range of quality indicators to see where their own policies are succeeding and where adjustments may be necessary. Without them, it is difficult for policy makers to judge the level of development in their own domestic markets and to observe trends emerging globally" (OECD, 2008[49]).

There are many different kinds of statistical analysis, imposing distinct functional requirements on the statistics collected. For some analyses, simple descriptive statistics within a single country suffice. For benchmarking and for international comparisons, cross-comparability of statistics is crucial. For longitudinal studies (e.g. of a single country over a period of many years), it is important that the definitions of the statistics remain stable. For panel data regressions, it is generally crucial both that the data are cross-comparable across countries and that categories remain stable over time.

The OECD has played a major role in ameliorating gaps in availability and cross-comparability of statistics. In this regard, the statistics on fixed and mobile broadband adoption per 100 inhabitants are particularly noteworthy (see Annex B). OECD price basket data has also played a useful role (see Annex B). OECD adoption and price data are widely used in econometric analyses that would be practically unthinkable in their absence.

The challenge in defining broadband in order to measure adoption (and other characteristics) is that the definition has generally been made in terms of advertised speed, and that the common perception of what constitutes an "acceptable" basic service, or a high-speed service, changes over time as the price/performance of the technology changes. Allowing speed boundaries to float freely might, however, jeopardise the ability to conduct longitudinal analyses or panel data regression analysis. Even as things stand, these boundaries are not fully uniform among OECD member countries, but at least they are close.

The current broadband baseline speed definition of the OECD is 256 Kbps. In 2012, one reason why there was no consensus among OECD countries to raise the threshold speed was that some countries had already incorporated descriptions of broadband speeds into legal instruments. A change in the definition of broadband could have had implications for the universal service frameworks in those countries.

In 2019, however, there is a widening gap between national broadband targets and the minimum speeds embedded in some universal service legal instruments. In addition, policy instruments may sometimes not refer to different broadband services in terms of speeds or technology, but more generally as "fast broadband", "high-speed broadband", "very-high speed broadband", "ultra-high-speed broadband", without necessarily defining the terms. This makes such terms less comparable across countries (OECD, 2018[51]).

While speed tiers ensure that harmonised comparisons can be made across countries, these speed tiers may not always reflect the reality in leading countries where higher speeds can be observed. An increased threshold speed for reporting broadband data could be considered by OECD countries. Moreover, given the evolving consumer and business demands and commercial offers, a regular adaptation of the baseline speed along with speed tiers could be examined (e.g. while 10 Gbps offers are still outliers, they were not available at all for consumers in 2012).

Measurement of coverage poses greater challenges. The European Union does a comprehensive annual survey, and is obliging the European Union member states under the EECC (European Commission, 2018[20]) to assess not only current coverage but also the expected coverage in the next three years. A number of countries have done one-time analyses as part of their broadband planning process (see for instance the United States (FCC, 2010[11]) and others, such as Canada, incorporate some coverage statistics within their annual or biannual regulatory reports (CRTC, 2017[53]).

For many OECD countries, however, data on coverage tend to be unavailable or inconsistent. Even within the European Union, where statistics on coverage are more established, wherever more than one network technology is available, there tend to be huge challenges in assessing the degree to which coverage overlaps. Similarly, comparability of network coverage of key road and railway infrastructure is just currently being developed within the European Union context (European Commission, 2018[54]). OECD countries should consider whether they would like to analyse coverage more closely.

Survey data are extremely important for assessing reasons why inhabitants do not have a communication service (see Annex B). They also can serve as an important cross-check on adoption data – for example, for mobile adoption, many countries have more than 100 active SIMs per 100 inhabitants. It can be useful to know how many individuals per 100 inhabitants *do not* have access to a mobile phone, which is typically ascertainable only by means of surveys. Once again, Eurostat data tends to be available for those OECD member countries that are also European Union countries, but surveys along these lines are only available every other year for other OECD countries.

Sharing of good practices

The 2008 Review (OECD, 2008[49]) observed: “Improved policy co-ordination among various agencies, ministries and the private sector will be essential. It is also important that policy makers also look beyond their national borders to find best practices in other member countries.” This continues to be the case.

OECD continues to be a prime channel for the sharing of good practice, not only for its members, but for other countries as well. In addition to the thematic reports, since the *Recommendation* was adopted, the OECD has produced a number of country and regional reviews, building on the body of good practices and methodology developed by the OECD over the years. The telecommunication (and in some cases, also broadcasting) country reviews, such as the ones on Mexico (2012 and 2017) and Colombia (2014), strive to provide recommendations to help countries foster a sound telecommunication sector as a basis for a flourishing digital transformation (Box 3).

Box 3. OECD Telecommunication Country Reviews

Mexico

The *OECD Review of Telecommunication Policy and Regulation in Mexico* (OECD, 2012[55]), released in 2012, provided a comprehensive examination of the sector at the time, highlighting potential areas for regulatory and policy reform. Since then, the Mexican telecommunication sector has experienced substantial progress both from a legal and regulatory perspective, but also with respect to current market dynamics. The changes derive, to an important extent, from the Constitutional reform that has taken place in Mexico since 2013, which closely reflect the 2012 OECD recommendations.

The *OECD Telecommunication and Broadcasting Review of Mexico 2017* (OECD, 2017[23]) assessed subsequent market developments in the telecommunication and broadcasting sectors in Mexico, evaluated the implementation of the 2012 OECD recommendations, and put forward a number of recommendations for the future. It recorded the remarkable progress made in implementing policy and regulatory changes and identified areas where more could be done to continue the momentum that had brought tangible benefits to the people of Mexico.

Colombia

The *OECD Review of Telecommunication Policy and Regulation in Colombia* (OECD, 2014[56]) was released in 2014. It put forward recommendations aimed at furthering regulatory reform and stimulating market competition and investment in the telecommunication sector as a building block for the future development of the Colombian economy. It aimed to help achieve one of the government's goals, which was to develop a knowledge-intensive society.

More recently, the OECD has started producing OECD Reviews of Digital Transformation: Going Digital, as a whole-of-government examination of the opportunities and challenges raised by digitalisation. The first of these reviews was undertaken for Sweden (2018), which included one chapter on "enabling access", that is, an analysis of the state of connectivity and telecommunication markets in the country. Similarly, regional studies such as the *Broadband Policies for Latin America and the Caribbean: A Digital Economy Toolkit* (OECD/IDB, 2016[57]) offer a broader analysis of regions and enable benchmarking against roughly comparable countries.

In addition to the channels available through the OECD Committees and Working Parties, there are many additional channels for the exchange of good industrial and regulatory policy practice, including:

- the International Telecommunications Union (ITU);
- the United Nations, for instance through the Internet Governance Forum;
- the Internet Society;
- international trade associations;
- various regional associations, including the Body of European Regulators for Electronic Communications (BEREC), Telecomunicaciones de América Latina (ASIET), the Communication Regulator of Southern Africa (CRASA), and more.

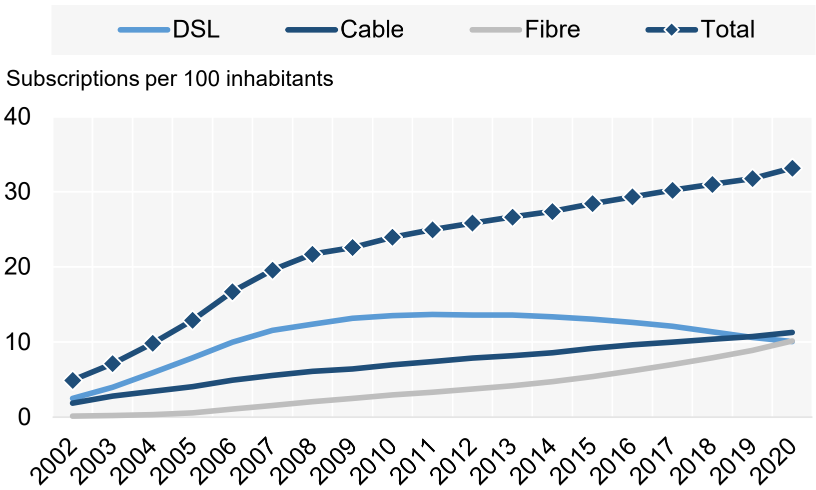
Annex A. The evolution of broadband technology

This annex reviews the various fixed and wireless technologies that have been used, or are likely to be used in the future, to provide broadband access to the Internet.

Fixed broadband technology over time

When examining the deployment of fixed broadband by technology in OECD countries at an aggregated level, there has been an overall trend away from DSL to cable and fibre (Figure A.4). The level of DSL deployment reached its peak and remained roughly constant from 2010 through 2013, but has declined since.

Figure A.4. Fixed broadband technology developments, OECD (2002-20)



Source: OECD Broadband statistics, http://www.oecd.org/sti/broadband/broadband-statistics/

However, when examining these technology developments in selected OECD countries, a varied pattern emerges (Figure A.2). Total fixed broadband has steadily grown in all OECD countries, but the inflection point for DSL came earlier in some countries than in others. In some OECD countries, the growth has been primarily in terms of fibre, while in others, the growth was largely taken up by cable. High cable growth countries, for example in the United States, Canada, the Netherlands and Germany, were already characterised by substantial cable deployment before the beginning of the broadband era.

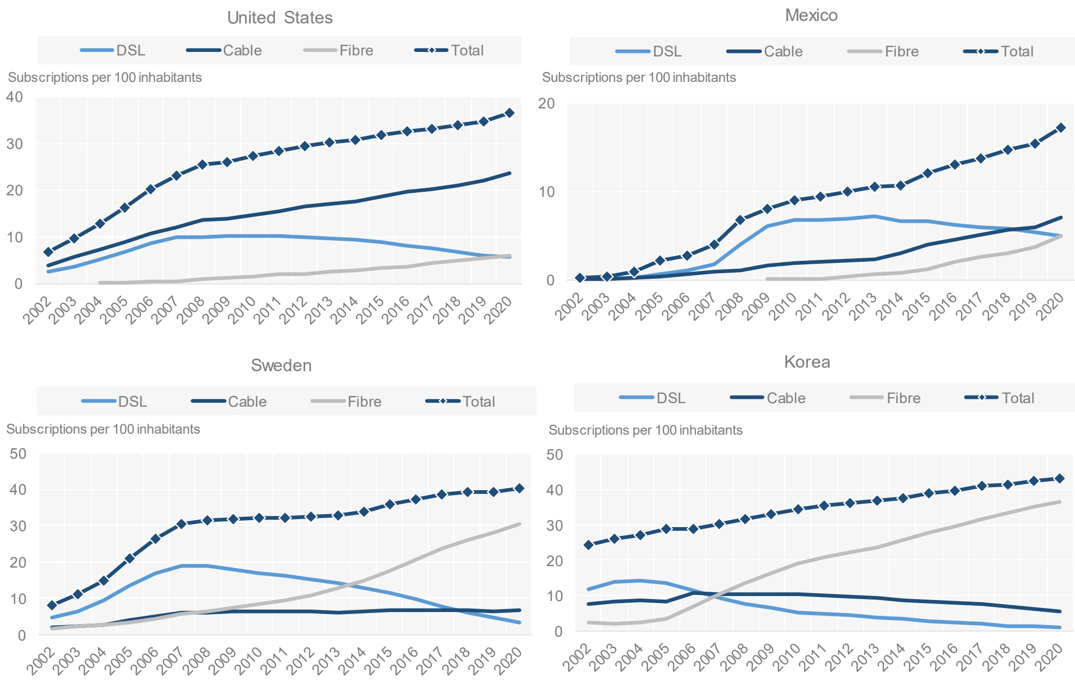
In the United States, DSL peaked in 2009–10 period. Cable provided 24 subscriptions per 100 inhabitants, representing 65% of all fixed broadband in December 2020. Fibre has shown steady growth in this country, but as of December 2020, it represented only 6 subscriptions per 100 inhabitants, or 16.4% of fixed broadband connections. As of December 2020, there were four times as many cable broadband subscriptions as fibre broadband subscriptions in the United States. Indeed, there was a modest tendency for cable to gain at the expense of the combined total of DSL and fibre subscriptions. Cable grew from 2015 to 2020 at a constant annual growth rate (CAGR) of 5.4%, while DSL declined by 8% annually over the same period.

In Sweden, DSL had already begun to decline in 2009. Cable showed only modest and inconsistent growth from that point onwards, with subscriptions ranging from one year to the next around 6 to 6.8 per 100 inhabitants, and most recently with 6.5 subscriptions per 100 inhabitants in December 2020. Fibre, by contrast, has shown dramatic growth, likely boosted by Sweden's successful approach to municipal fibre networks. Fibre represented three quarters of Sweden's fixed broadband in December 2020, or 30 subscriptions per 100 inhabitants.

Mexico is in a different position than many of the other OECD countries. It had 17 fixed broadband subscriptions per 100 inhabitants in December 2020, which is less than half the fixed broadband take-up of Sweden or the United States. The number of DSL subscriptions did not begin to decline until 2014. As of December 2020, cable subscriptions per 100 inhabitants were slightly higher than DSL subscriptions at 7 versus 4.9, respectively, while fibre subscriptions at 5 per 100 inhabitants were growing relatively fast and have surpassed DSL subscriptions.

Korea's performance in terms of broadband is widely viewed as being exceptional. Korea already had a fixed broadband penetration of 24.3 per 100 inhabitants in 2002, reaching a penetration of 43 per 100 inhabitants in December 2020, where 85% of fixed broadband subscriptions were fibre. DSL was already beginning its decline in 2005, while cable began a gradual decline starting in 2007. Cable subscriptions were three times as plentiful as fibre in 2002, and were already significant at 7.5 per 100 inhabitants. The ratio has reversed today – fibre subscriptions were more than six times as plentiful as cable as of December 2020.

Figure A.5. Broadband technology developments, selected OECD countries



Source: OECD Broadband statistics, http://www.oecd.org/sti/broadband/broadband-statistics/

xDSL

Asymmetric Digital Subscriber Line (ADSL) is a technology that was initially developed to provide a more efficient means of using existing copper telephone lines to the home. It takes advantage of frequencies that are higher than those used for traditional voice services on the copper line. Development began in the late nineties. It is asymmetric in that it provides more bandwidth downstream toward the home than it provides upstream toward the network.

Over the past years, an increase in the speed achievable through DSL and related technologies, partially based on the use of copper lines, was enabled through improvements in technology, together with a progressive deepening of fibre within communication networks. This evolution has enabled communication networks to provide greater speed to the end user, and has been referred to by the Austrian national regulatory authority as the "second life of copper".

This evolution is noticeable with very-high-bit-rate digital subscriber line (VDSL) and with very-high-bit-rate digital subscriber line 2 (VDSL2) and beyond (Caio, Marcus and Pogorel, 2014[58]). With all of these technologies, the longer the length of the copper loop (from central office to the home) or sub-loop (from the street cabinet to the home), the lower the bandwidth that can be provided due to signal attenuation, which continues to be one of the main challenges of this technology.

The assumption for VDSL and VDSL2 was that these broadband access technologies would operate over copper, not from the central office as with ADSL, but rather from the street cabinet. The street cabinets would be connected to the central office by means of fibre. However, in practice, many actual implementations have been based on the use of copper from the central office – as long as the length of the copper is short enough, it does not matter where it is running from.

VDSL2 Vectoring achieves further speed improvements by applying noise cancellation techniques. Once again, the relationship between the length of the copper sub-loop and the speed achievable plays a decisive role (Alcatel-Lucent, 2012[59]). A noteworthy regulatory challenge with vectoring is that it is impractical at present for multiple vectored VDSL lines in the same copper bundle to be driven by different network operators, as the noise cancellation has to be done on an integrated basis.

More recently, a further development has been that of G.Fast, with the prospect of further evolution. G.Fast is a fibre to the distribution point (FTTdp) technology, which means that the nominal assumption is that copper is present only from the distribution point for a building (often in the basement) to a device in the consumer's living quarters. The G.Fast technology aims at achieving very high speeds over very short distances. According to Mariotte and Van der Putten (2017[60]), aggregate download speeds service rate targets over 0.5mm copper are in the range of:

- 900 Mbps at 100m
- 600 Mbps at 200m
- 300 Mbps at 300m

In countries where the length of the existing copper sub-loop is sufficiently short, deployments based on VDSL can require less CAPEX than high-end FTTP/FTTH deployments. A 2014 study by WIK estimated (under suitable assumptions and at costs that were current at the time) that VDSL would cost only a fifth as much as FTTP/FTTH in Germany in all geotypes (i.e. areas of progressively lower population density) (Table A.3).This, however, is in part due to the specific topology of the network in a country with many street cabinets and short sub-loops. Whether FTTC/VDSL solutions are suitable for a given city, region or country can be heavily dependent on details of how the copper network was historically deployed.

Table A.3. Costs per home connected of FTTC/VDSL with vectoring at 70% penetration, Germany (2014)

Cluster	FTTH/P2P	FTTCab Vectoring	Delta
1	USD 1 910 (EUR 1 440)	USD 424 (EUR 320)	78%
2	USD 2 188 (EUR 1 650)	USD 464 (EUR 350)	79%
3	USD 2 308 (EUR 1 740)	USD 491 (EUR 370)	79%
4	USD 2 360 (EUR 1 780)	USD 491 (EUR 370)	79%
5	USD 2 440 (EUR 1 840)	USD 491 (EUR 370)	80%
6	USD 2 573 (EUR 1 940)	USD 504 (EUR 380)	80%
7	USD 2 665 (EUR 2 010)	USD 544 (EUR 410)	80%
8	USD 2 891 (EUR 2 180)	USD 557 (EUR 420)	81%
9	USD 2 958 (EUR 2 230)	USD 584 (EUR 440)	80%
10	USD 3 196 (EUR 2410)	USD 637 (EUR 480)	80%
11	USD 3 236 (EUR 2 440)	USD 663 (EUR 500)	80%
12	USD 3 289 (EUR 2 480)	USD 690 (EUR 520)	79%
13	USD 3 395 (EUR 2 560)	USD 743 (EUR 560)	78%
14	USD 3 501 (EUR 2 640)	USD 796 (EUR 600)	77%
15	USD 3 515 (EUR 2 650)	USD 782 (EUR 590)	78%
16	USD 3 594 (EUR 2 710)	USD 849 (EUR 640)	76%
17	USD 3 541 (EUR 2 670)	USD 902 (EUR 680)	75%
18	USD 4 018 (EUR 3 030)	USD 1 101 (EUR 830)	73%
19	USD 4 522 (EUR 3 410)	USD 1 353 (EUR 1 020)	70%
20	USD 5 716 (EUR 4 310)	USD 1 844 (EUR 1 390)	68%
Total	**USD 3 196 (EUR 2 410)**	**USD 663 (EUR 500)**	**77%**

Notes: EUR converted to USD according to OECD conversion rates.
Source: (Neumann, Plückebaum and Jay, 2014[61])

Fibre to the premises (FTTP) / Fibre to the Home (FTTH)

Fibre to the premises (FTTP) is a phrase that can be used to refer to networks that are either fibre to the building (FTTB) or fibre to the home (FTTH). With FTTP/FTTH solutions, copper is completely phased out of the transmission path for the communication network to the consumer's living quarters, but it also tends to imply significant "civil works" deployment cost because it is usually necessary to physically deploy new fibre, often by digging (see Section Challenges in achieving full fixed broadband coverage). In settings where civil works costs are particularly low, FTTP/FTTH will often be the preferred technology today. For new "greenfield" fixed network deployments (i.e. network deployment where none existed before), it is generally necessary to incur substantial civil works costs irrespective of the technology chosen; consequently, FTTP/FTTH is typically preferred for greenfield deployments.

FTTP/FTTH broadband networks are the most advanced and future-proof fixed broadband solutions available today. Distance from the central office matters very little in an FTTP/FTTH network (except that the signal cannot propagate faster than the speed of light – this is typically a consideration only over very long circuits).

The simplest form of FTTP/FTTH system employs one or more dedicated fibres for each consumer residence, called point-to-point (PTP) fibre architecture. This is a high performance solution given its scalability, and can offer advantages in terms of promoting competition, since it is straightforward to parcel out different fibres to different network operators. Wholesale-only network operators often choose it for that reason.

A passive optical network (PON) fibre solution uses one fibre for many consumer residences, and at some point close to the home uses passive optical splitters to send the downstream signal to up to multiple consumer residences. Encryption is used to ensure that one consumer cannot usefully eavesdrop on another's communications. For upstream communications, multiple access communication protocols typically provide multiplexing to allow the fibre to be shared.

An active optical network (AON) is functionally similar to a PON, except that the fanning out of the signal to multiple consumer residences is done using bridging or routing technology (i.e. active network components) rather than being implemented with passive components that typically require no power.

Cable television and DOCSIS

Cable television networks represent an alternative vehicle to the telecommunication network for carrying fixed broadband to the home. Advanced cable broadband systems are perhaps not as future-proof as FTTP/FTTH networks, but in all other respects, they represent a worthy competitor to FTTP/FTTH.

Cable broadband technology is based on Data over Cable Service Interface Specification (DOCSIS) standards. These are industry standards produced and maintained by Cable Labs for the industry, but they have been submitted and accepted by the International Telecommunications Union (ITU-T). The current version of the DOCSIS standard is version 3.1. In the European Union, EuroDOCSIS standards are used to deal with various standards differences, notably including the difference in the width of channels (6 MHz in the United States versus 8 MHz in the European Union).

Existing DOCSIS 3.1 standards are already suitable for speeds up to 10 Gbps downstream and 1 Gbps upstream. Ongoing standardisation of DOCSIS 4.0 promises by means of full duplex use of spectrum on the cable to enable fully symmetric 10 Gbps services in both the upstream and the downstream directions, together with low latency.

Cable broadband systems, as deployed, can easily provide 100 or 200 Mbps to subscribers, and many deployments offer much higher speeds. In the United States, industry has claimed to make 1 Gbps available to 80% of homes.

The key restriction for cable broadband is that the footprint is limited in many countries, and very little new cable is being built. The cable that is present worldwide was in almost all cases built to carry video. Once the Internet began to take off, cable network operators came to the realisation that they could upgrade their cable networks at relatively little cost so as to carry broadband Internet in parallel with the traditional audio-visual content.

Cable reaches a majority of homes in the United States and Canada, and provides the majority of high-speed fixed broadband. Fibre-based broadband to the home plays a correspondingly small role in both countries. Indeed, fibre-based broadband (including FTTH, FTTP and FTTB, but not FTTC) represented only 16.4% of all fixed broadband subscriptions in the United States in December 2020, and 22% of subscriptions in Canada, compared to an OECD average of 30.6%.

Cable passes only some 45.5% of homes in the European Union. Despite the lack of full coverage, it plays a significant role in a number of countries in Europe. Cable coverage is nearly complete in the Netherlands, Belgium, and Malta, and very significant in Portugal and Spain, but nearly completely absent in Italy and Greece (IHS Markit and Point Topic, 2020[62]). Cable has performed well in countries such as Poland and Hungary, where copper telecommunication networks were not as pervasive prior to the fall of the Soviet Union.

Cable likely plays an additional role. As a broadband technology delivered over a second wire to the home, it represents the most significant competitor to fibre-based broadband solutions offered by communication network operators. As a result, it likely provides a competitive spur to network operators who otherwise would be under very little pressure to offer improved broadband speeds and services to their customers.

Mobile broadband

Mobile broadband services were barely visible when the Broadband Recommendation was adopted in 2004, but today mobile broadband services are widely used. Indeed, the popular smart phones would scarcely be conceivable in the absence of mobile broadband. A significant number of tablets are sold with Wi-Fi only, but for smartphones, the mobile network interface is necessary.

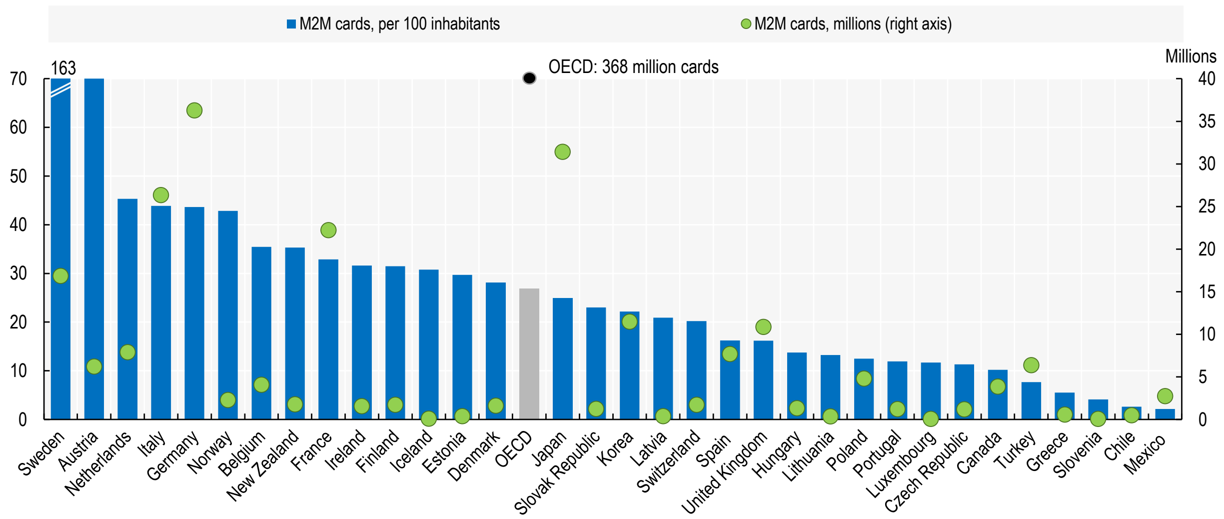
As noted in the Section Developing mobile broadband networks, there is room to debate whether fixed and mobile services substitute for one another, versus being complementary.

The adoption data in this Annex makes clear that mobile broadband is now widespread in OECD countries. In many countries, the number of mobile subscriptions is actually greater than the number of inhabitants, which necessarily means that many inhabitants maintain more than one subscription each.

Although in many OECD countries fixed networks are more pervasive, in several parts of the world, in particular in emerging economies, fixed networks have only limited penetration, and unlikely to reach the full population any time soon. In these countries, mobile networks are the prevalent access technology connecting people.

Increasingly, the users of mobile broadband networks will be machines, not people. In OECD countries, the number of subscriptions for machine-to-machine (M2M) communications is not yet as great as the number of inhabitants, but the gap is closing day by day. The traffic per connected device tends to be low today; however the number of connected devices is large and growing very rapidly (Figure A.6).

Figure A.6. M2M/embedded mobile cellular subscriptions, OECD (December 2020)



Note: OECD: Average and sum of the available data
Switzerland: Data are preliminary
Source: OECD, Broadband Portal, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

Current wireless networks are mostly fourth generation (i.e. 4G or LTE); however, a new fifth generation (5G) has already begun to deploy under 3GPP Release 15 standards. Compared to previous mobile generations, 5G networks are expected to offer not only higher speeds, lower latency rates, and greater efficiency, but have also the potential to offer customised “slices” of the network to respond to the QoS requirements of specialised applications or use cases. This fifth generation of broadband wireless networks may represent a paradigm shift, as it is the first standard conceived taking into account IoT, where many billions of IoT devices are expected to be connected, and where different IoT applications have different capacity requirements (OECD, 2019[13]). When needed, it is expected that customised slices can also provide support needed for use cases that require low power and/or very low end-to-end latency, as is likely to be the case for certain M2M use cases (OECD, 2018[63]).

Fixed wireless access

There are two main configurations for using wireless technologies to provide terrestrial broadband access. One is a fixed wireless access (FWA) broadband approach and the other is mobile (cellular) services, discussed in the previous section. Mobile and fixed wireless access have typically used different spectrum frequencies (e.g. paired vs. unpaired) and technologies. However, these distinctions are blurring as deployment via unpaired spectrum used for fixed access to homes in rural areas increases and as capacity for mobile services in urban areas expands where most fixed access is via wireline technologies. At the same time, there is potential for deployments with combined licenced/unlicensed spectrum (OECD, 2018[51]).

In France, as in other countries, mobile operators have been replacing copper line connections serving as backhaul connectivity to mobile cellular towers with fibre optic ones, and leveraging their fixed network infrastructure to the greatest extent possible to provide backhaul (Arcep, 2015[64]).

In the future, wireless technologies may also develop in ways that provide more options for backhaul (e.g. mesh wireless networks, point-to-point microwave). For 4G deployment in some rural towns in the United Kingdom, mesh networks have been trialled.

In the United States, mobile operators have historically played an important role in serving rural areas, and some of the current interest in 5G in the United States and other countries is the ability to use 5G to provide FWA services. Canada, due to its low population density, also relies heavily on fixed wireless access broadband connections compared to other OECD countries.

In Australia, the National Broadband Network (NBN) strategy as originally conceived called for providing fixed-line access to around 93% of the Australian population, fixed wireless access to 4%, and satellite to 3% of the population. A technical demonstration of fixed wireless access on the NBN achieved speeds of 1 Gbps, a theoretical maximum for the network; however, actual performance with multiple users sharing spectrum could be expected to be much less. Moreover, while these speeds are impressive, the range of FWA is still limited to 14 km from a tower (OECD, 2018[51]).

Satellite

Satellites may serve as an option to deliver broadband services to residences and businesses in rural and remote regions throughout the world, such as mountainous areas, islands or forests. Nevertheless, this access technology is not used as much in OECD countries, where the majority of people live in urban areas or in locations that are close enough to use other broadband access technologies on a more cost effective basis. As of December 2020, the share of satellite broadband over total fixed broadband subscriptions was merely 0.5% in OECD countries (OECD, 2021[65]).

The vast majority of communication satellites at present providing broadband services are *geosynchronous*, which is to say that their orbital period is aligned with the earth's rotation such that they appear to remain stationary above a single point on the equator. These satellites are located in what is known as geostationary earth orbit (GEO). GEO satellites are typically large, expensive to build and launch, and have a large coverage area. Such satellites have the ability to provide service to large contiguous areas; an individual GEO satellite may provide service in a number of different countries at any given time, which can create significant scale effects (OECD, 2017[66]). On the other hand, the orbital mechanics are such that these satellites must maintain an elevation of some 22 000 miles above the earth. At this distance, the round trip delay (i.e. latency) of data transmitted through such a satellite is some 270 milliseconds (i.e. about a quarter of a second) (Marcus, 1999[67]).

In recent years, non-geosynchronous broadband proposals have become more common with the emergence of Low-Earth Orbit (LEO) and Medium-Earth Orbit (MEO) constellations that orbit closer to the earth. LEO and MEO satellite systems offer much better network latency. Their lower altitude require more satellites than geosynchronous systems to cover a large area given. LEO systems have historically struggled to find a profitable business model; however, new technology may ameliorate this problem. New technologies, such as reusable launch vehicles and electric propulsion systems, are being developed to reduce costs of launching satellites (OECD, 2017[66]).

The resulting power savings and latency reductions of these innovations can significantly reduce satellite equipment costs on the user's premises, and allow for a much higher quality of experience associated with real-time services such as multi-player gaming services, Voice over Internet Protocol (VoIP) calls and video chat.

The improvements and innovations in the price/performance of LEO and MEO systems versus their legacy GEO counterparts might enable them to compete more effectively with terrestrial options. Satellite also has the potential to play a critical role as a middle-mile solution in conjunction with terrestrial options, as well as backhaul for terrestrial networks. However, the affordability, and therefore, the widespread viability of emerging LEO and MEO systems will depend on many factors, including the customer uptake to cover the costs of a global constellation (OECD, 2017[66]).

Other options

A number of other technological options have been proposed or attempted to extend broadband connectivity, some of which might ultimately prove to be important, particularly for rural and remote areas (OECD, 2018[51]).

A family of innovative approaches entails aerial vehicles, typically operating at high altitude. They might be expected to compete to some extent with satellite services. The high altitude enables a single vehicle to cover large swaths of territory, but without incurring the high latency associated with geosynchronous satellites. The platform could be an airplane (typically unmanned), a balloon or an airship.

The ITU refers to these *high-altitude platform stations* or *high-altitude pseudo-satellites* (*HAPS*) as stations "on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth" (ITU, 2019[68]). Commercial interest appears to focus on 17-22 km above the earth, a region that is well above commercial air travel, far lower than satellites, and where winds are moderate in most regions (i.e. it is above the jet stream). The cost and time required to deploy a HAPS platform is far less than that of a satellite; consequently, they may have military and disaster relief applications.

It can also be instructive to review technologies that were thought to be promising some years back, but that failed to evolve into large-scale commercial deployments. Especially noteworthy in this regard is *broadband over power lines* (*BPL*). Initially, it seemed that BPL had the potential to be an ideal solution – nearly every home in most countries already has a power line. BPL appeared to offer the opportunity not only to accelerate broadband deployment, but also a potential competitor to broadband services provided by communication operators.

There are many reasons why BPL has not been successful in widespread deployment. Neither the bandwidth nor the distance over which BPL can operate competes effectively with other currently available fixed broadband technologies. The power line acts as an antenna, making BPL both vulnerable to interference, and a source of interference for other services operating in the same frequency ranges. Despite these limitations, BPL continues to enjoy use within a building or a campus.

Annex B. The evolution of the broadband market

This annex reviews the evolution of the broadband market since the 2004 Recommendation.

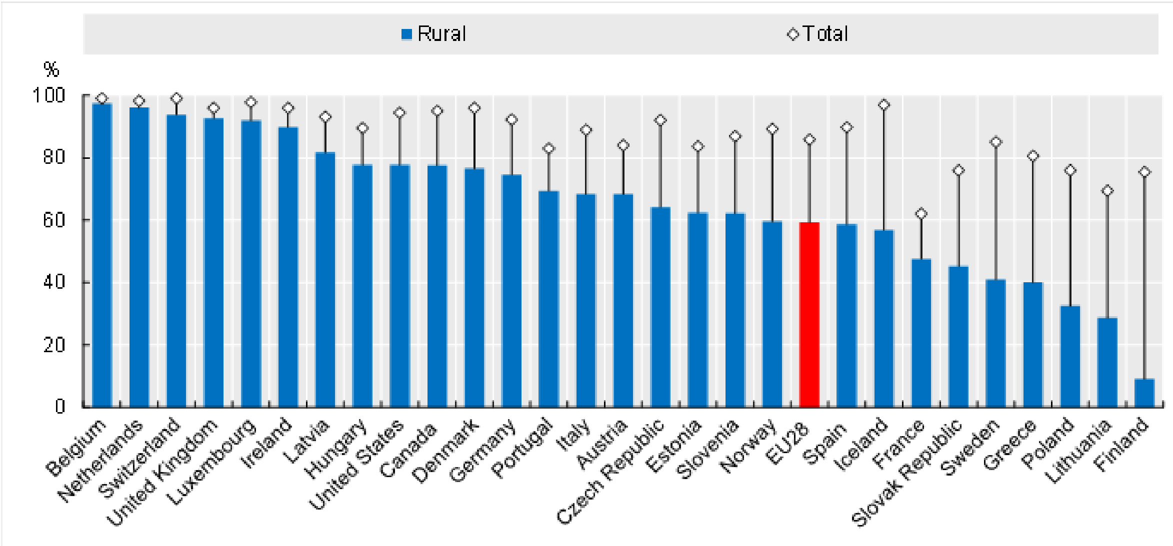
Indicators are crucial to understand the evolution of the communication sector over the many years since the Recommendation was adopted in 2004. This Annex summarises key results for fixed and mobile broadband markets, but does not attempt to present a comprehensive presentation of all the available statistics.

Broadband coverage

Broadband coverage indicators tend to rely on country-specific or region-specific measurement methodologies. Therefore, harmonised and cross- country comparable data across all OECD countries are not available at present. Nevertheless, the OECD Broadband Portal provides links to national broadband coverage maps for 31 countries. The latest available data on broadband coverage, as of 2021, included data from the European Union and communication monitoring reports from the CRTC in Canada and the FCC in the United States (Figure B.7).

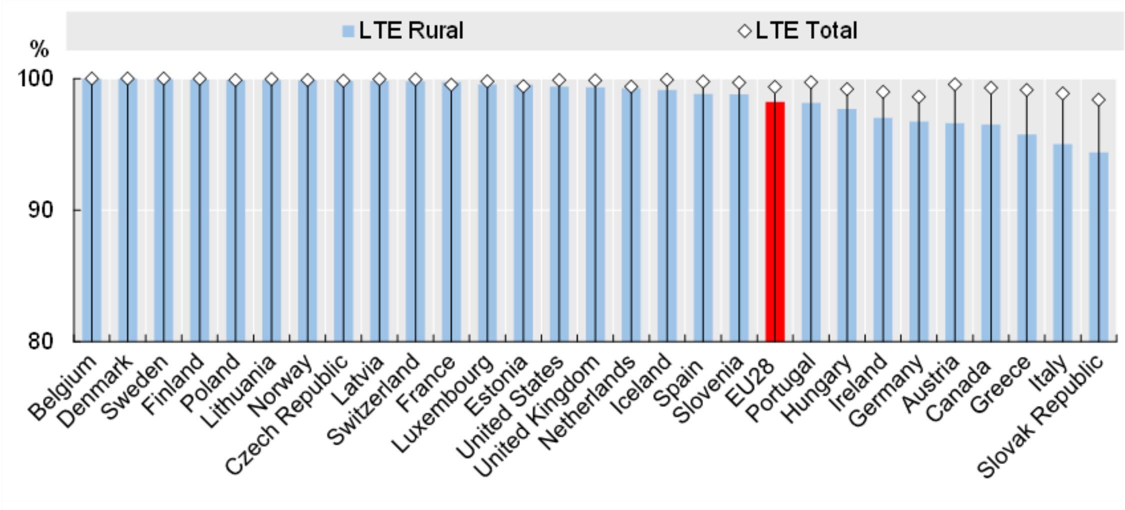
Broadband coverage varies by speed and technology, and differences among and within countries can be substantial. By 2019, 85.8% of European Union households lived in areas where 30 Mbps fixed broadband was offered, while only 59.3% of rural households had fixed broadband at this speed available. For Canada, coverage of fixed broadband of 25 Mbps and above was 77.6% in rural areas in 2019, versus 95% overall. For the United States, coverage of fixed broadband of 25 Mbps and above was 77.7% in rural areas in 2019, versus 94.4% overall (Figure B.7).

Figure B.7. Households with minimum 30 Mbps fixed broadband available, as a percentage of households in the total and rural categories, OECD (2019)



Note: (1) Rural areas: For European Union countries, rural areas are those with a population density less than 100 per square kilometre. For Canada, rural areas are those with a population density less than 400 per square kilometre. For the United States, rural areas are those with a population density less than 1 000 per square mile or 386 people per square kilometre. (2) Fixed broadband coverage: For European Union countries, coverage of NGA technologies (VDSL, FTTP, and DOCSIS 3.0) capable of delivering at least 30 Mbps download was used. For Canada and the United States, coverage of fixed terrestrial broadband capable of delivering 25 Mbps download and 3 Mbps upload services was used.
Source: OECD calculations based on CRTC, Communications Monitoring Report, 2020 (Canada); EC, Study on Broadband Coverage in Europe 2019 (European Union); FCC, 2020 Broadband Deployment Report (United States).LTE mobile coverage has been improving across the OECD area. For the European Union as a whole, coverage of LTE reached 99.4% households by 2019, and 98.2% of rural households. Rural LTE coverage for Canada and the United States amounted to 97.4% and 99.4%, respectively (Figure B.2).

Figure B.8. Percentage of households in total and rural areas LTE mobile coverage, OECD (2019)

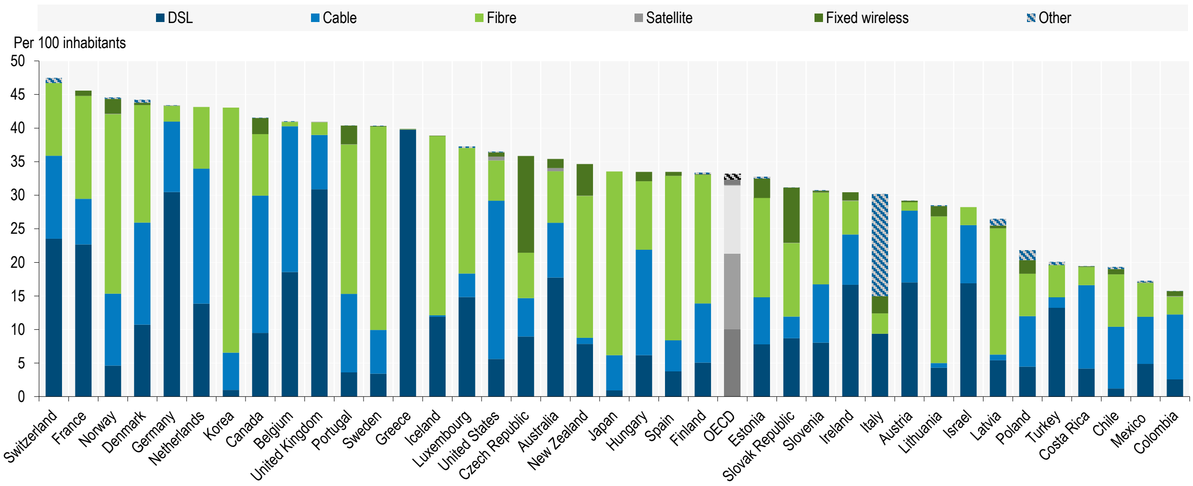


Note: Rural areas: For European Union countries, rural areas are those with a population density less than 100 per square kilometre. For Canada, rural areas are those with a population density less than 400 per square kilometre. For the United States, rural areas are those with a population density less than 1 000 per square mile or 386 people per square kilometre.
Source: OECD calculations based on CRTC, Communications Monitoring Report, 2020 (Canada); EC, Study on Broadband Coverage in Europe 2019 (European Union); FCC, 2020 Broadband Deployment Report (United States).

Broadband penetration

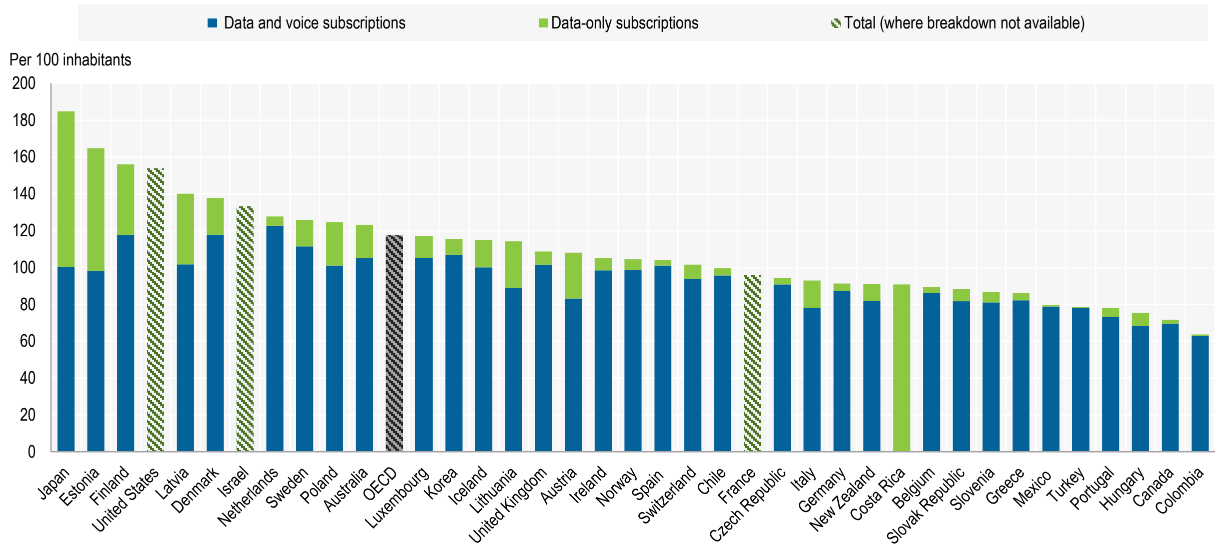
Data on fixed (Figure B.9) and mobile (Figure B.10) broadband subscriptions is available for OECD countries. As with coverage, the fixed broadband statistics demonstrate a wide variance among the technologies used. Since these figures are per 100 inhabitants, and average household size is generally greater than two, the household penetration will tend to be at least twice as high (i.e. the data are not directly comparable to the coverage data depicted in Figure B.7). Where mobile penetration is greater than 100%, the clear implication is that some consumers subscribe to more than one mobile service.

Figure B.9. Fixed broadband subscriptions per 100 inhabitants, by technology, OECD (December 2020)



Notes: Australia: Data reported for December 2018 and onwards is being collected by a new entity using a different methodology. Figures reported from December 2018 comprise a series break and are incomparable with previous data for any broadband measures Australia reports to the OECD. The OECD definition of fibre differs substantially from fibre classifications commonly used in Australian reporting. These figures treat connections known in Australia as 'Fibre-to-the-Node' and 'Fibre-to-the-Curb' as DSL connections, while 'Fibre-to-the-Premises' and 'Fibre-to-the-Basement' are treated as Fibre connections. Data on technology type prior to Q2-2016 should be treated as indicative until further notice. Canada: Fixed wireless includes Satellite. France: Cable data includes VDSL2 and fixed 4G solutions. Italy: Terrestrial fixed wireless data includes WiMax lines; *Other* includes vDSL services. Mexico and Switzerland: Data are preliminary.
Source: OECD (2021[65]), *OECD Broadband Portal*, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

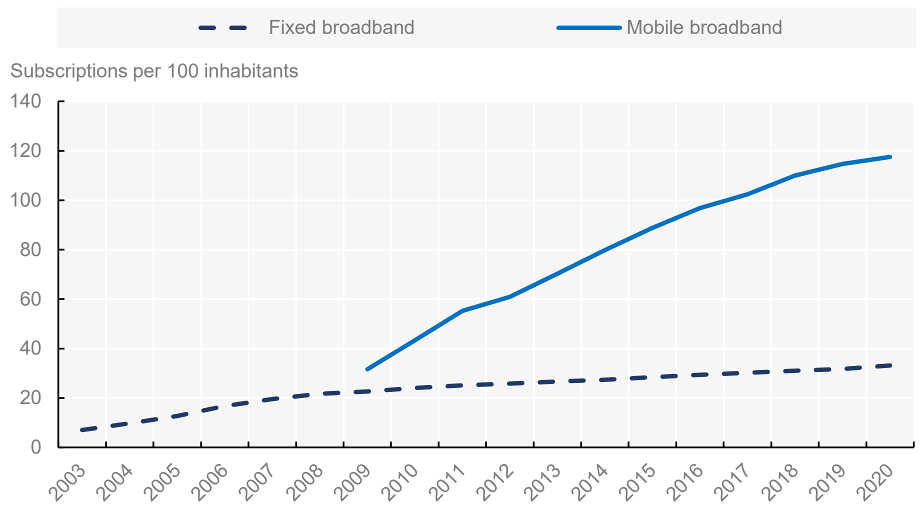
Figure B.10. Mobile broadband subscriptions per 100 inhabitants, by technology, OECD (December 2020)



Note: Australia: Data reported for December 2018 and onwards is being collected by a new entity using a different methodology. Figures reported from December 2018 comprise a series break and are incomparable with previous data for any broadband measures Australia reports to the OECD. Canada: A change in methodology occurred from 2020 Q2 onwards. Costa Rica: Only 'Data-only subscriptions' are available for the time being. France: Data for active subscriptions that have only made 4G connections in the last three months are not included. Switzerland: Data are preliminary. United States: Data are temporary estimates.
Source: OECD (2021[65]), *OECD Broadband Portal*, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

The overall trend for the OECD shows a rapid growth of fixed broadband penetration measured in subscription per 100 inhabitants, and an even more rapid growth of mobile broadband penetration.

Figure B.11. Historical fixed and mobile broadband penetration rates, OECD (2020)

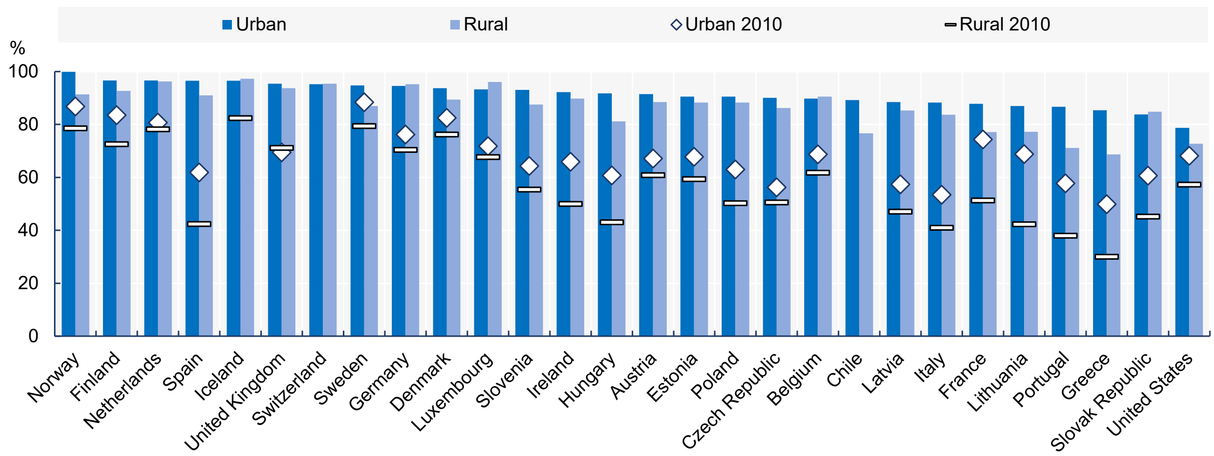


Source: OECD (2021[65]), *OECD Broadband Portal*, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

These data need to be understood in conjunction with survey data (TNS opinion & social, 2018[69]). Survey data are generally collected per household rather than per individual. Household penetration is much higher than penetration per individual, as expected (Figure B.12). The disparity in broadband Internet access (mostly fixed broadband) between urban and rural is visible, albeit less pronounced than the indicators on coverage of broadband services at speeds of minimum 30 Mbps.

While it is useful to know the number of subscriptions, for some purposes it is also important to know the number of individuals or households that lack Internet access (and to consider the reasons for the lack of adoption, as is done in this Annex).

Figure B.12. Households subscribing to broadband access (256 Kbps or greater), urban and rural, OECD (2010 and 2020)



Note: These data are collected through surveys, which ask if the respondent has undertaken the relevant activity within a specified recall period - within the three months prior to being surveyed is recommended, though some countries use different periods. According to the OECD Regional Typology a region is classified as rural if more than half of the population lives in local units with a population density below 150 inhabitants per square kilometre and urban if less than 15% live in such low-density local units (see https://doi.org/10.1787/5kg6z83tw7f4-en). For Chile, for the year 2012, large urban areas refer to a contiguous set of local areas, each of which has a density superior to 500 inhabitants per square kilometre, where the total population for the set is at least 50 000 inhabitants. Rural areas refer to a contiguous set of local areas belonging neither to a densely populated nor to an intermediate area. An intermediate area refer to a contiguous set of local areas, not belonging to a densely populated area, each of which has a density superior to 100 inhabitants per square kilometre, and either with a total population for the set of at least 50 000 inhabitants or adjacent to a densely populated area. For the United States, population density categories are approximated based on a household's location in a principal city, the balance of a metropolitan statistical area (MSA), or neither. To protect respondent confidentiality, the information has been redacted from some observations in the public use datasets. Beginning in 2017, the CPS Supplement no longer asks separately about mobile broadband use inside and outside the home. Instead, households are simply asked whether anyone uses a mobile data plan (irrespective of location). In order to approximate mobile broadband access at home, households were included if they reported mobile data plan use and home Internet use. In Japan and Korea the threshold is 500 inhabitants, as population density exceeds 300 inhabitants per square kilometre nationally.
Source: OECD (2021), *ICT Access and Usage by Households and Individuals Database*, http://oe.cd/hhind, December 2020.

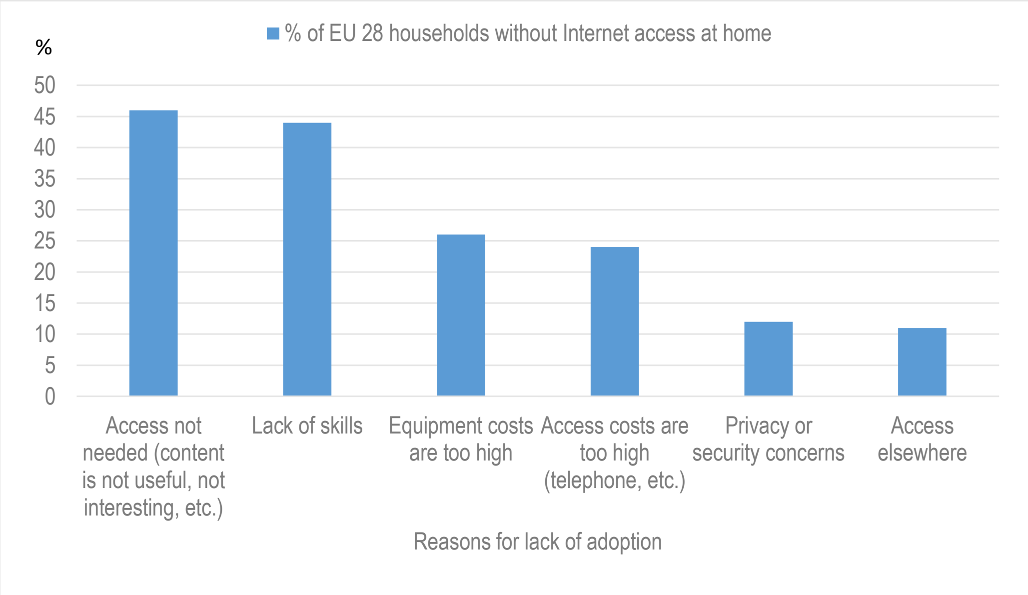
In the European Union, for example, for 19% of households, no one inside the household had a mobile Internet access in 2017. Of those who had mobile phone in April 2017, some 80% had a mobile subscription or pre-paid arrangement that included Internet access (IHS Markit and Point Topic, 2018[70]).

As with any survey, however, the data need to be interpreted with some care – it is not entirely clear that respondents interpreted the questions as might have been desired. "The fact that over one in ten respondents mentioned mobile Internet access, but no Internet access at home, may suggest that Internet access is perceived to be a household Internet access only once it is shared among household members, whereas mobile Internet access is associated with personal use" (IHS Markit and Point Topic, 2018[70]).

Reasons for lack of adoption

According to European Union Eurostat surveys, the main reasons for not having Internet access at home relate either to the perception that it is not of value (i.e. the content is not useful or not interesting), or due to lack of skills. These correspond to 46% and 44%, respectively, of respondents from European Union (EU 28) households with at least one member aged 16 to 74, and with no Internet access at home as of 2019. By contrast, cost factors for equipment or for access were cited by only 26% and 24%, respectively. Lack of availability of broadband access is not tabulated, presumably because more than 99% of European Union (EU 28) residents now have access to basic broadband.

Figure B.13. Reasons for not having Internet access at home, European Union (2019)



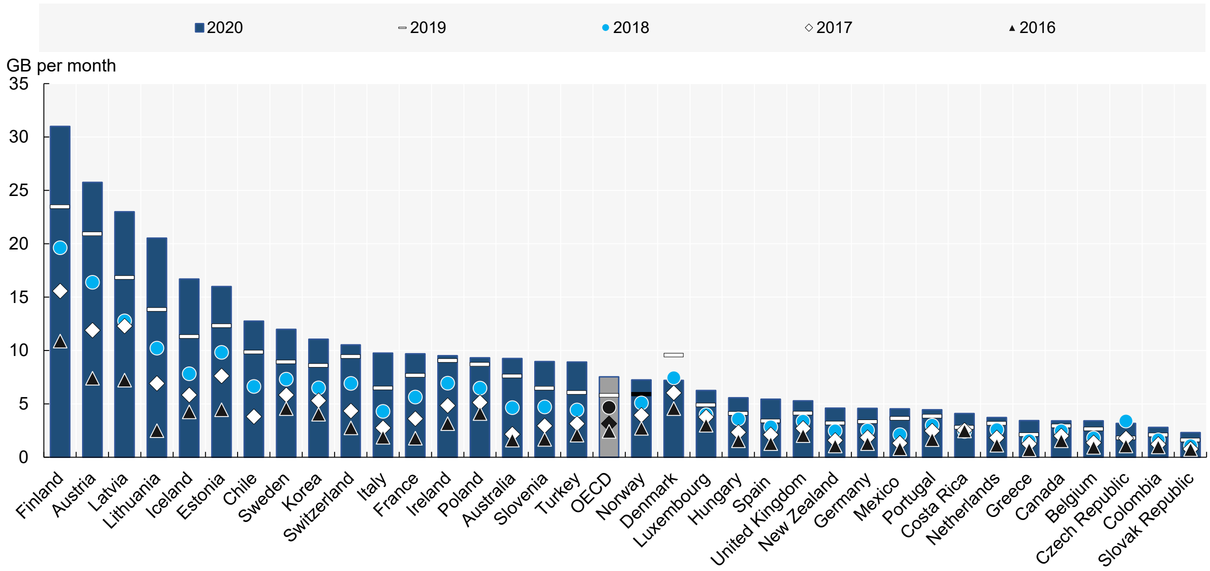
Source: Adapted from Eurostat (2021), "Reasons for not having Internet access at home", latest update May 2021, https://ec.europa.eu/eurostat/databrowser/view/ISOC_PIBI_RNI__custom_1120042/default/table?lang=en

Usage

In terms of generating societal benefits, it is important not only that people *have* broadband, but also that they *use* it. One simple measure of usage for mobile broadband subscriptions is mobile data usage measured by the amount of GB consumed per subscription per month.

For mobile subscriptions, OECD tracks this data (Figure B.14). Mobile broadband was barely visible at the time that the Broadband Recommendation was adopted in 2004, but it is clearly significant today. As of 2020, Finland took the lead among OECD countries, with a consumption of 31 GB per month per mobile data subscription, followed by Austria (25.8 GB) and Latvia (23 GB).

Figure B.14. Mobile data usage per mobile broadband subscription, OECD (2020)



Note: Australia: Data reported for December 2018 and onwards is being collected by a new entity using a different methodology. Figures reported from December 2018 comprise a series break and are incomparable with previous data for any broadband measures Australia reports to the OECD. Data for Switzerland are preliminary. Data for 2020 are not yet available for Japan and United States. OECD average includes estimates.
Source: OECD (2021[65]), *OECD Broadband Portal*, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

Quality of Service (QoS)

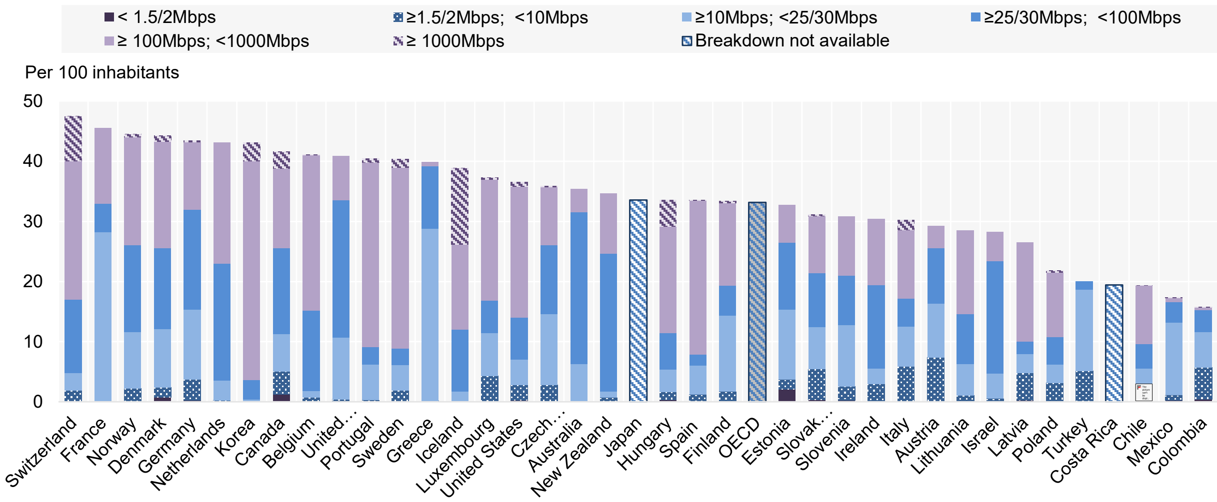
With the growing significance of broadband in everyday life, the quality of broadband increasingly matters. This aspect was not covered in the *Recommendation* as broadband development was still at a rather early stage.

Several broadband performance indicators can be considered. These include the speed of the broadband connection, end-to-end delay through the network (i.e. latency), the frequency of packet loss, and other factors that influence performance as perceived by the user. These QoS indicators influence the quality of experience (QoE) that the user perceives; however, some applications are far more sensitive to particular QoS parameters than are other applications. For example, e-mail is largely insensitive to delay, while two-directional real time voice works best with delay of less than roughly 150 milliseconds. As noted in the Section In the United States, the amount of public funding required was studied in depth as part of the NBP . Achieving full coverage is particularly challenging in the United States because there are many areas with low population density and challenging terrain (see Challenges in achieving full fixed broadband coverage). In related work, the FCC identified a coverage funding gap of USD 23.5 billion, assuming only one subsidised network in each unserved area . In order to close the funding gap in the United States, the NBP advocated a reform of universal service mechanisms so as to support deployment of broadband and voice in high-cost areas, and to ensure that low-income Americans could afford broadband. This has been implemented in four sub-programmes, all implemented as part of an overall universal programme overseen by the FCC and operationally run by the Universal Service Administrative Company, or USAC: (1) the Connect America Fund (CAF) for rural areas; (2) a sub-programme to support low-income consumers; (3) a sub-programme to support schools and libraries (E-rate); and (4) a sub-programme to support rural health care. Larger network operators that accept funds under CAF Phase II, the current incarnation of the CAF, are obliged to offer broadband services at speeds of at least 10 Mbps downstream and 1 Mbps upstream, with a round trip latency of not more than 100 milliseconds round trip, and consumer prices must be reasonably comparable to those in urban areas.

Quality of Service (QoS) standards, many OECD countries have implemented QoS measurement programmes in recent years.

The broadband download speeds have been growing rapidly over the years since 2004. It is important to distinguish between the nominal advertised speed and the speed that is actually delivered. The former can be measured by the fixed broadband subscription data per advertised speed tiers collected from OECD countries (Figure B.15).

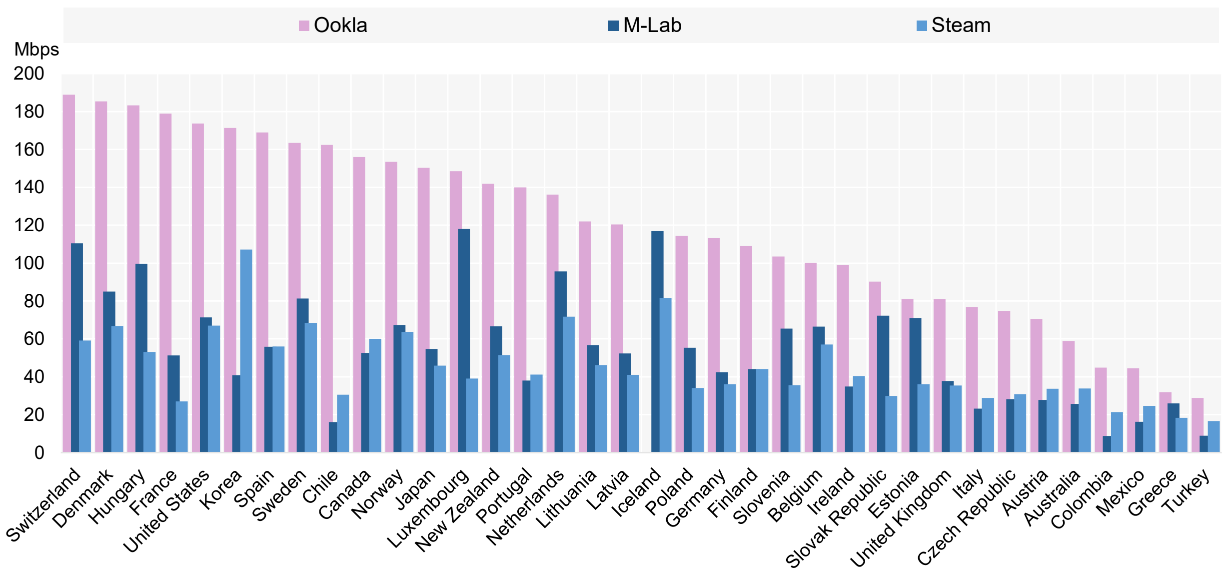
Figure B.15. Fixed broadband subscriptions per 100 inhabitants, per speed tiers, OECD (December 2020)



Notes: Based on 2019 speed tiers. Australia: Data reported for December 2018 and onwards is being collected by a new entity using a different methodology. Figures reported from December 2018 comprise a series break and are incomparable with previous data for any broadband measures Australia reports to the OECD. The OECD definition of fibre differs substantially from fibre classifications commonly used in Australian reporting. These figures treat connections known in Australia as 'Fibre-to-the-Node' and 'Fibre-to-the-Curb' as DSL connections, while 'Fibre-to-the-Premises' and 'Fibre-to-the-Basement' are treated as Fibre connections. Data on technology type prior to Q2-2016 should be treated as indicative until further notice. Mexico and Switzerland: Data are preliminary.
Source: OECD (2021[65]), *OECD Broadband Portal*, www.oecd.org/sti/broadband/oecdbroadbandportal.htm.

It is challenging to assess the actual speed of a broadband service, since many factors influence the speed the user experiences. Different entities measure the speed of Internet connections from their perspective. This is one reason multiple sources on speeds should be examined to provide a wider view of performance. Among the sources that attempt to measure actual broadband speeds and to provide statistics on a per-country basis are Ookla, M-Labs and Steam. This review shows all of them because they rely on different methodologies for measurement (Figure B.16). Ookla measurements are consistently higher than those of M-Labs and Steam. While Figure B.16 displays average broadband speeds experienced by users, this may not necessarily reflect the maximum (peak) speed that the network can deliver. The user may have chosen a less expensive, less performant service than the maximum that the network can deliver.

Figure B.16. Average experienced download speed of fixed broadband connections, OECD (2020*)



Notes: *Speedtest (Ookla) data are for January 2021; M-Lab (Worldwide Broadband Speed League) speeds were measured from 1 July 2019 to 30 June 2020; and Steam data are for March 2021.
Sources: Speedtest (Ookla) [https://www.speedtest.net/global-index], M-Lab (Worldwide broadband speed league) [https://www.cable.co.uk/broadband/speed/worldwide-speed-league/] and Steam [https://store.steampowered.com/stats/content].

The difference between advertised speeds and actual speeds has been a concern in many OECD countries. Some seek to publish actual delivered speeds so that the user is aware, but without imposing obligations on network operators, hoping that transparency and competition will provide incentives to upgrade networks. European Union legislation enacted in 2015, by contrast, empowers European Union regulators to sanction network operators who consistently fail to deliver the advertised speed to their customers.

Other QoS parameters relate to reliability and robustness. From the user's perspective, reliability can be viewed as an extremely important QoS parameter. A loss of access to the Internet today can represent a severe handicap in light of the increasingly central role that Internet plays in our lives. In the past, system reliability was often achieved by means of the use of very high quality hardware components. With Internet technology, it is often more cost-effective to achieve reliability by employing multiple components in parallel with one another (i.e. redundancy).

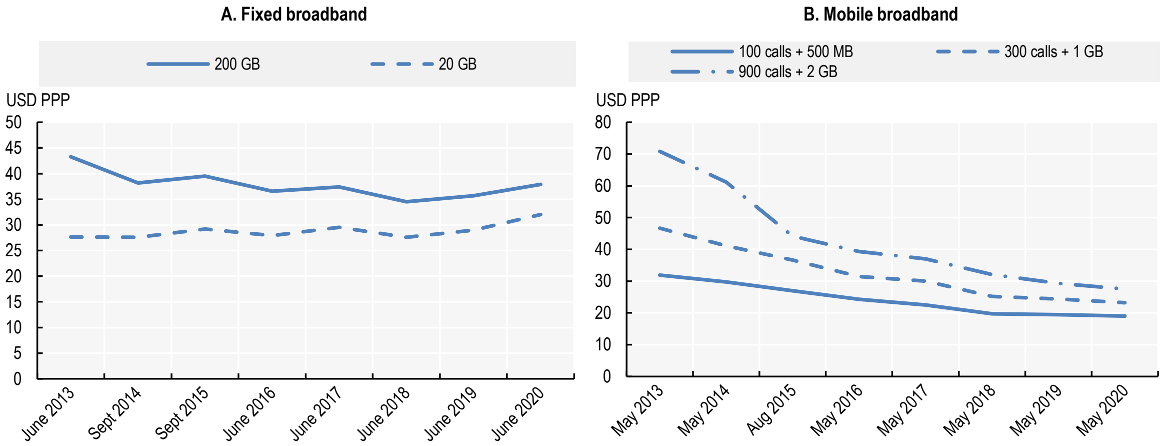
Robustness refers to the reliability of the network in the face of stress such as man-made or natural catastrophes. The need to guard against failure of the system is particularly important for critical information infrastructures (OECD, 2008[46]). As with reliability, it is often most cost-effective to achieve robustness by means of redundancy and by avoiding *single points of failure* (*SPOFs*). Today, software failures (and security vulnerabilities) can often pose a greater risk than hardware failures.

Prices

Communication prices are one indicator of the level of competition in a market and can influence the take up of services, especially in countries where there is unmet demand by low-income groups.

The OECD has defined price baskets for mobile and fixed communication services, measuring the prices for different patterns of usage across different countries and time. For fixed broadband, two baskets, one low-usage basket of 20 GB and one high-usage basket of 200 GB, are assessed in Figure B.17. For mobile broadband, three baskets are analysed: low-usage (100 calls + 500 MB), medium-usage (300 calls + 1 GB), and high- usage (900 calls + 2 GB). With the exception of prices in the fixed broadband low-usage basket, which have been more or less stable, prices for communication services have generally been trending downwards for many years. Over the period between 2013 and 2020, prices for the 200 GB fixed broadband basked declined by 12%, while prices for the low, medium and high usage mobile broadband baskets declined by 41%, 50%, and 60%, respectively (Figure B.17).

Figure B.17. Trends in fixed and mobile broadband prices, OECD (2013-20)



Note: PPP = purchasing power parity; GB = Gigabyte; MB = Megabyte.
Source: Strategy Analytics, “Teligen Tariff & Benchmarking Market data” using the OECD Methodology, https://www.strategyanalytics.com/

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End notes

[1] This observation is in line with the Recommendation, which calls for "[r]ecognition of the primary role of the private sector in the expansion of coverage and the use of broadband, with complementary government initiatives that take care not to distort the market".

[2] This was for point-to-point FTTH Ethernet, and assumes 70% penetration. Many would argue that these are overly optimistic assumptions; moreover, these were estimates from 2011. The detailed estimates would probably not apply today; nonetheless, the trade-offs that the study demonstrates are still directionally correct.

[3] The Unites States FCC confirms that these documents are their most recent publicly available estimate of the cost to achieve full broadband coverage of the United States.

[4] Per recital 152, "where undertakings are deprived of viable alternatives to non-replicable wiring, cables and associated facilities inside buildings or up to the first concentration or distribution point and in order to promote competitive outcomes in the interest of end-users, national regulatory authorities should be empowered to impose access obligations on all undertakings, irrespective of a designation as having significant market power".

[5] The Australian NBN is owned by the Government, but it is not operated by the government. It operates as a Government Business Enterprise overseen by an independent board.

[6] In Art. 77 and 78 EECC.

[7] Article 76 "offer commitments … to open the deployment of a new very high capacity network that consists of optical fibre elements up to the end-user premises or base station to co-investment, for example by offering co-ownership or long-term risk sharing through co-financing or through purchase agreements giving rise to specific rights of a structural character by other providers of electronic communications networks or services."

[8] If the cost of coverage obligations were to dissuade too many MNOs from bidding at all, however, that might be a more serious concern.

[9] For a discussion at some length, see (Pujol et al., 2019[71]).

[10] The description of universal service in Recital 212 reflects the fact that basic broadband is more or less universally available within the European Union. "Universal service is a safety net to ensure that a set of at least the minimum services is available to all end-users and at an affordable price to consumers, where a risk of social exclusion arising from the lack of such access prevents citizens from full social and economic participation in society"

[11] In the interest of brevity, the discussion on *Services of General Economic Interest* (*SGEI*), which are subject to slightly different rules, which however have similar effect, is omitted (European Commission, 2013[38]).

[12] As previously noted, the United States FCC confirms that this is their most recent publicly available estimate of the cost to achieve full broadband coverage of the United States.

[13] Recital 13 of the recently enacted European Electronic Communications Code (EECC) makes the same point. “The requirements concerning the capabilities of electronic communications networks are constantly increasing. While in the past the focus was mainly on growing bandwidth available overall and to each individual user, other parameters such as latency, availability and reliability are becoming increasingly important.”

[14] Privacy, security and consumer protection issues are addressed by the following OECD Recommendations: Recommendation of the Council concerning Guidelines Governing the Protection of Privacy and Transborder Flows of Personal Data [C(2013)79]; Recommendation of the Council on Cross-border Co-operation in the Enforcement of Laws Protecting Privacy [C(2007)67/FINAL]; Recommendation of the Council concerning Guidelines for Cryptography Policy [C(97)62]; Recommendation of the Council on Electronic Authentication [C(2007)68]. Recommendation of the Council on the Protection of Critical Information Infrastructures [C(2008)35]; Recommendation of the Council on Digital Security Risk Management for Economic and Social Prosperity [C(2015)115].